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(54) **METHOD FOR NEUROSTIMULATION ENHANCED TEAM PERFORMANCE**

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A61B 5/16	(2006.01)

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See application file for complete search history.

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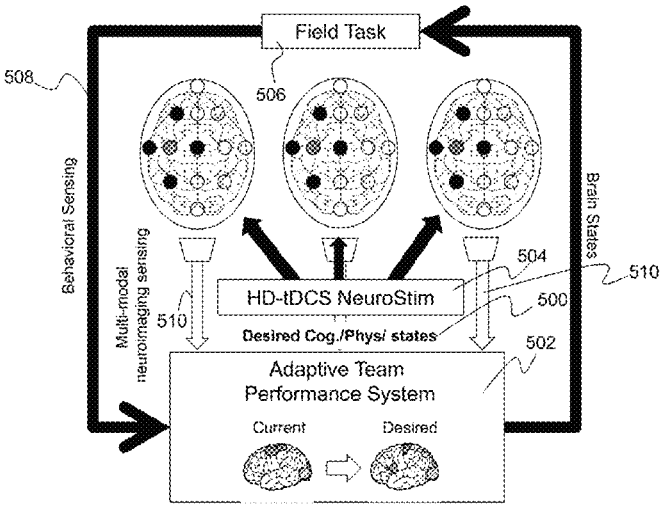
(57) **ABSTRACT**

Described is a system for augmenting team performance via individual neurostimulation. An assessment is generated for each team member of a team while the team member is performing a behavioral task using neuroimaging data. A target brain state is selected in team members for team performance enhancement. The target brain state is associated with specific brain regions, and the system determines a HD-tCS neurostimulation needed to reach the specific brain regions to induce the target brain state in the team members. The determined HD-tCS neurostimulation is applied to the team members while simultaneously sensing, via real-time neuroimaging, neural activity in each team member while the team member performs a behavioral task. Team performance is enhanced by adjusting the HD-tCS neurostimulation of each team member, based on the sensed neural activity, to direct each team member toward the target brain state.

24 Claims, 14 Drawing Sheets
(2 of 14 Drawing Sheet(s) Filed in Color)



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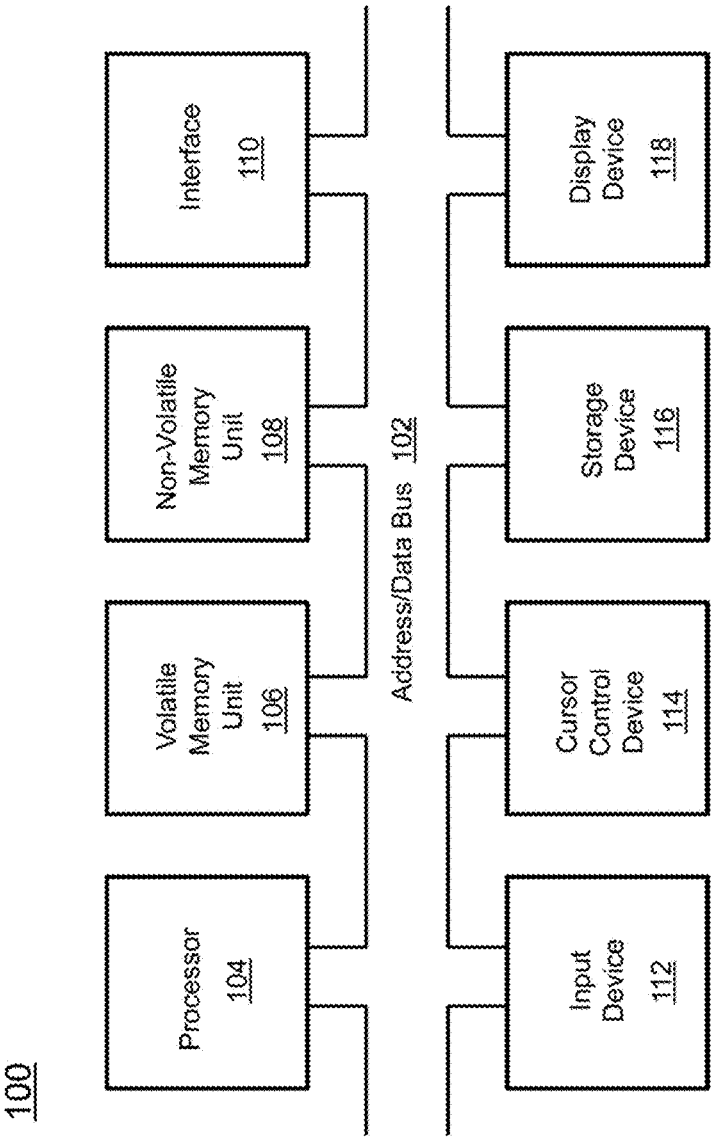

100
Processor 104
Volatile Memory Unit 106
Non-Volatile Memory Unit 108
Interface 110
Address/Data Bus 102
Input Device 112
Cursor Control Device 114
Storage Device 116
Display Device 118

FIG. 1

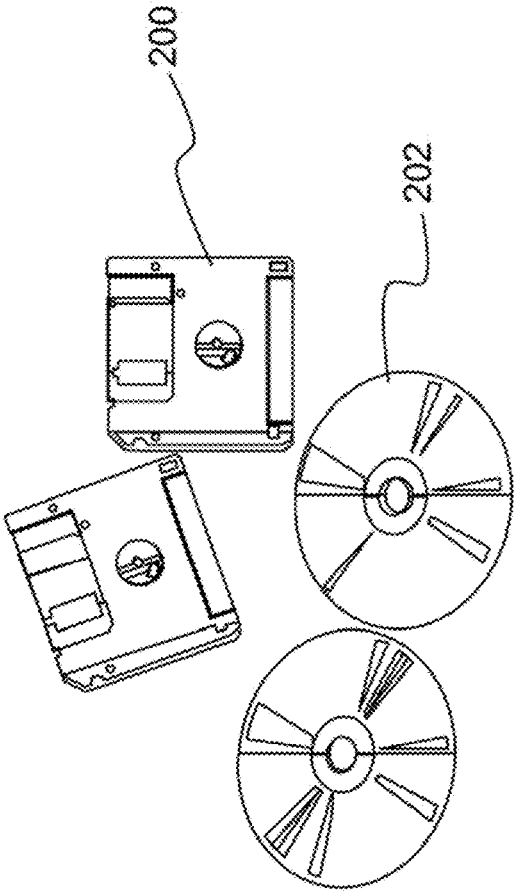


FIG. 2

	Behaviors/Process	Results
Individual Level: An Employee's Contribution to the Team	The employee: cooperates with team members, communicates ideas during meetings, participates in the team's decision-making processes.	The number of ideas contributed by the employee, the turn-around time for the individual's product, the accuracy of data supplied to the team.
Team Level: The Team's Performance	The team: runs effective meetings, communicates well as a group, allows all opinions to be heard, comes to consensus on decisions.	Customer satisfaction with the team product, the number of cases the team completed, the cycle time for the team's entire work process.

(Prior Art)

FIG. 3

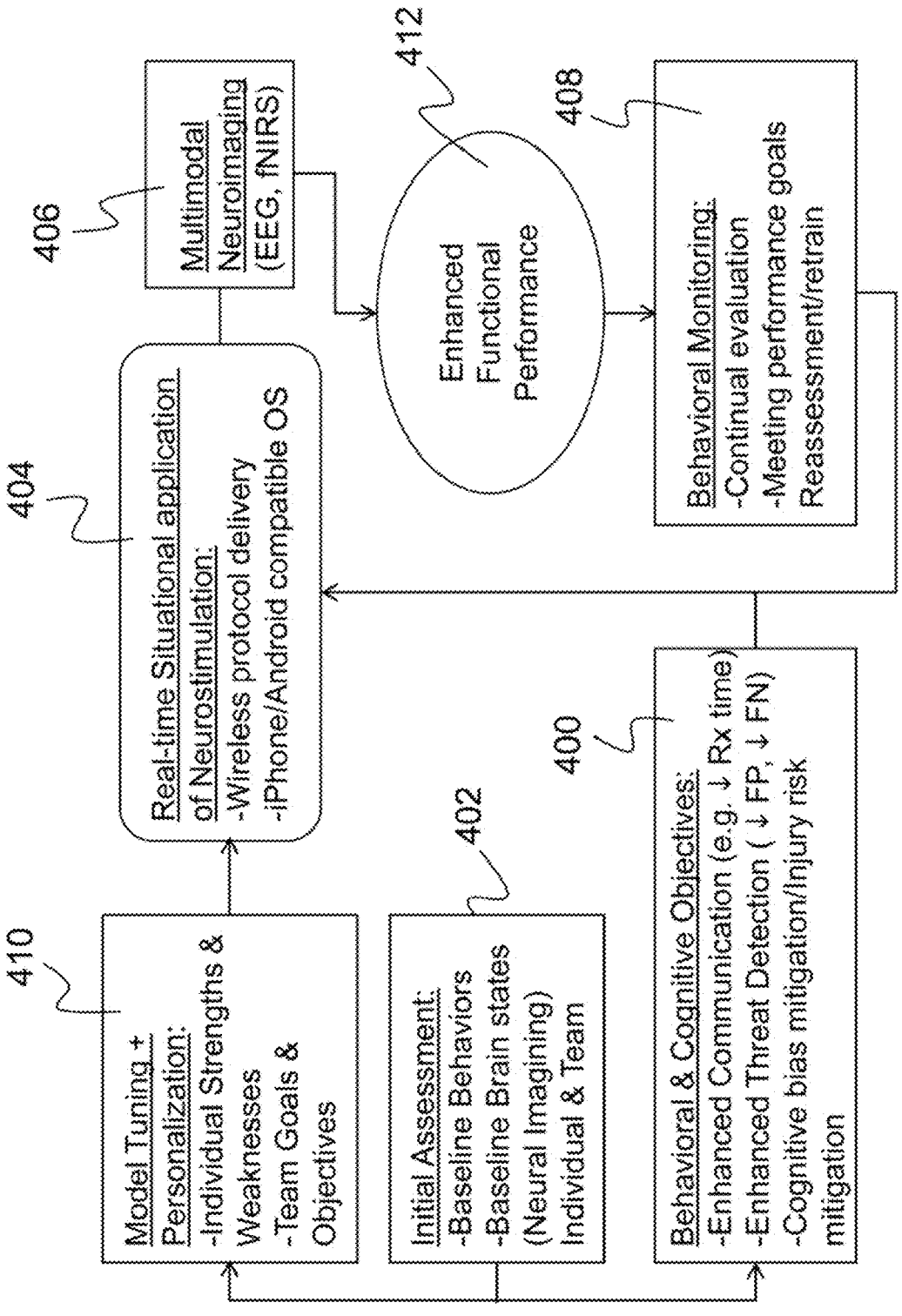

Model Tuning + Personalization:
-Individual Strengths & Weaknesses
-Team Goals & Objectives
410
Initial Assessment:
-Baseline Behaviors
-Baseline Brain states
(Neural Imagining)
Individual & Team
402
Behavioral & Cognitive Objectives:
-Enhanced Communication (e.g. ↓ Rx time)
-Enhanced Threat Detection (↓ FP, ↓ FN)
-Cognitive bias mitigation/Injury risk mitigation
400
Real-time Situational application of Neurostimulation:
-Wireless protocol delivery
-iPhone/Android compatible OS
404
Multimodal Neuroimaging (EEG, fNIRS)
406
Enhanced Functional Performance
412
Behavioral Monitoring:
-Continual evaluation
-Meeting performance goals
Reassessment/retrain
408

FIG. 4

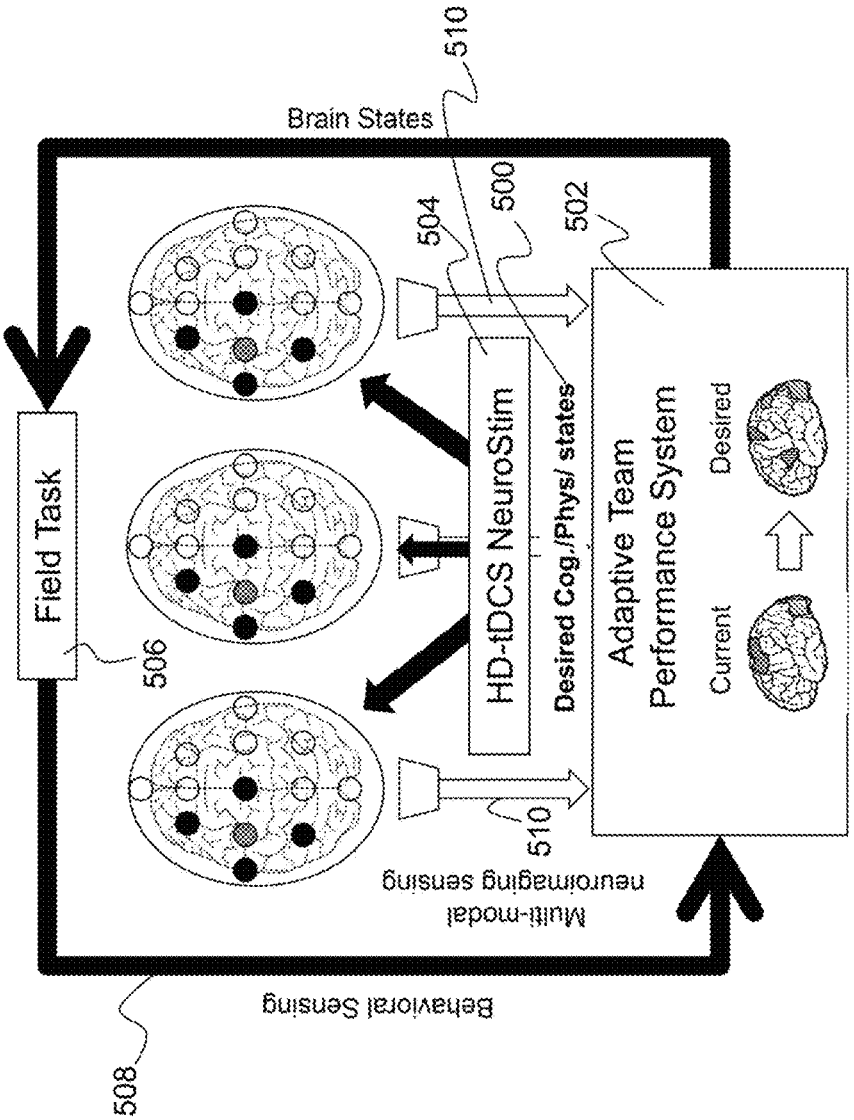

510
Brain States
504
500
502
Field Task
506
HD-tDCS NeuroStim
Desired Cog./Phys/ states
Adaptive Team
Performance System
Current
Desired
510
Multi-modal
neuroimaging sensing
Behavioral Sensing
508

FIG. 5

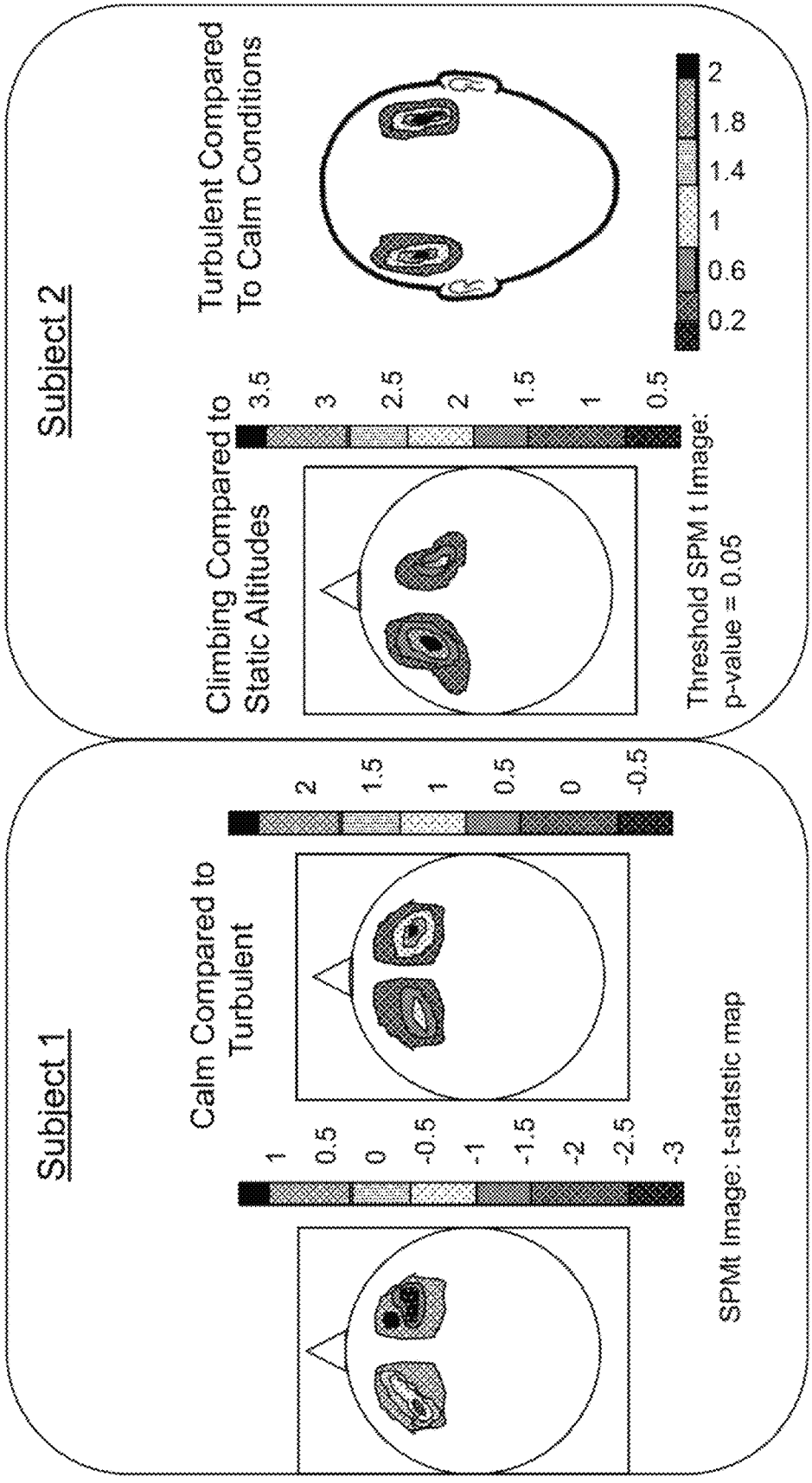

Subject 1
Calm Compared to Turbulent
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
2
1.5
1
0.5
0
-0.5
SPMt Image: t-statstic map
Subject 2
Turbulent Compared To Calm Conditions
2
1.8
1.4
1
0.6
0.2
Climbing Compared to Static Altitudes
3.5
3
2.5
2
1.5
1
0.5
Threshold SPM t Image: p-value = 0.05

FIG. 6A

FIG. 6B

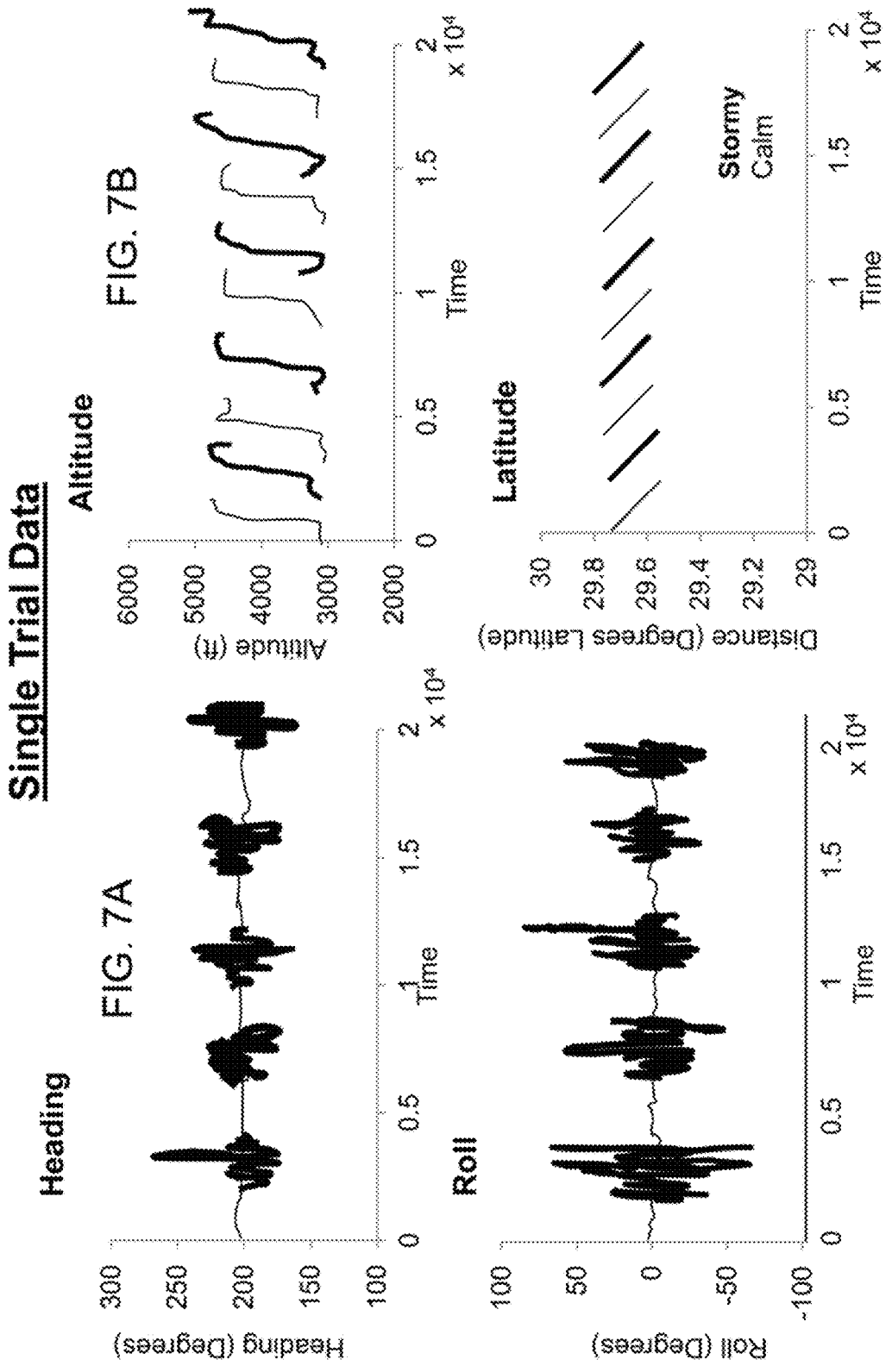


FIG. 7A

FIG. 7B

FIG. 7C

FIG. 7D

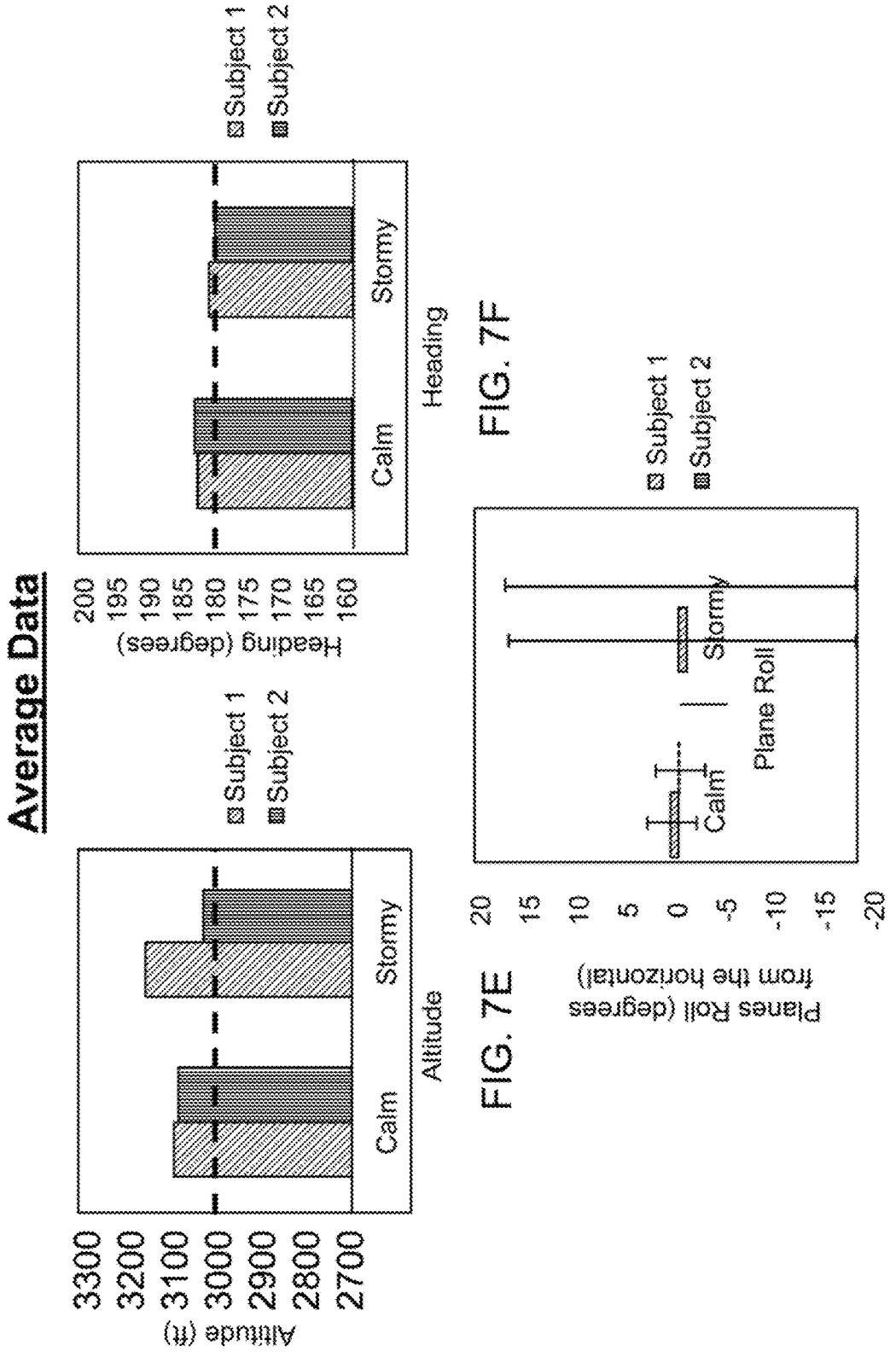


FIG. 7E

FIG. 7F

FIG. 7G

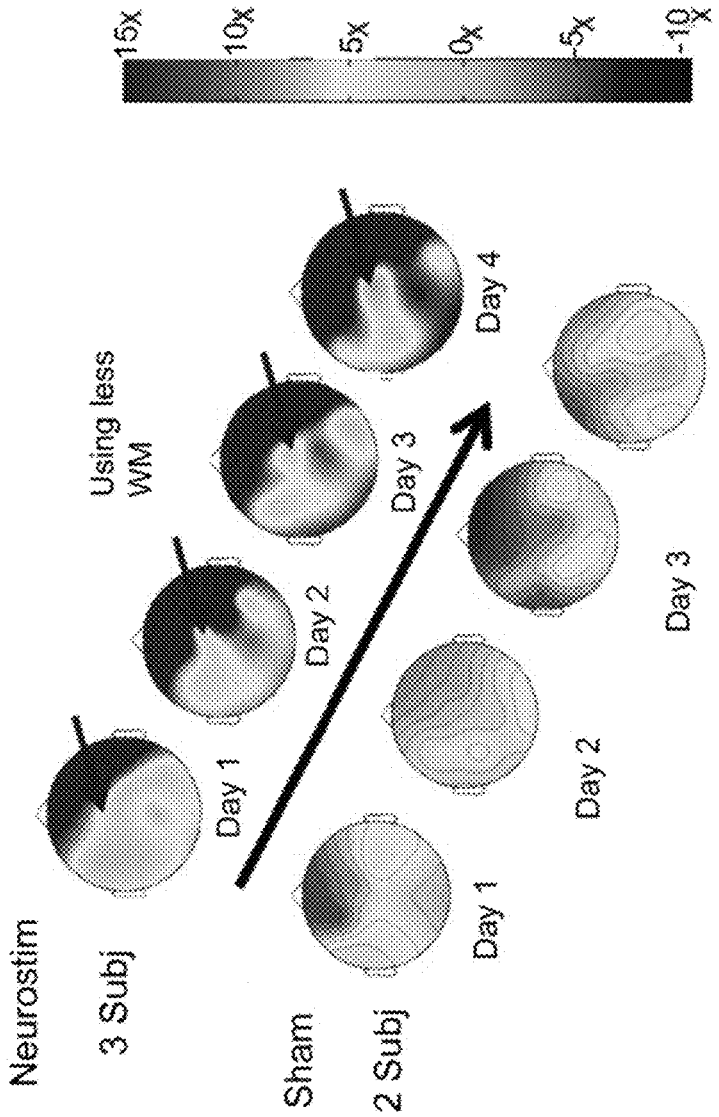

Landing Task
15x
10x
5x
0x
-5x
-10x
Neurostim
3 Subj
Sham
2 Subj
Day 1
Day 2
Day 3
Day 4
Using less WM

FIG. 8A

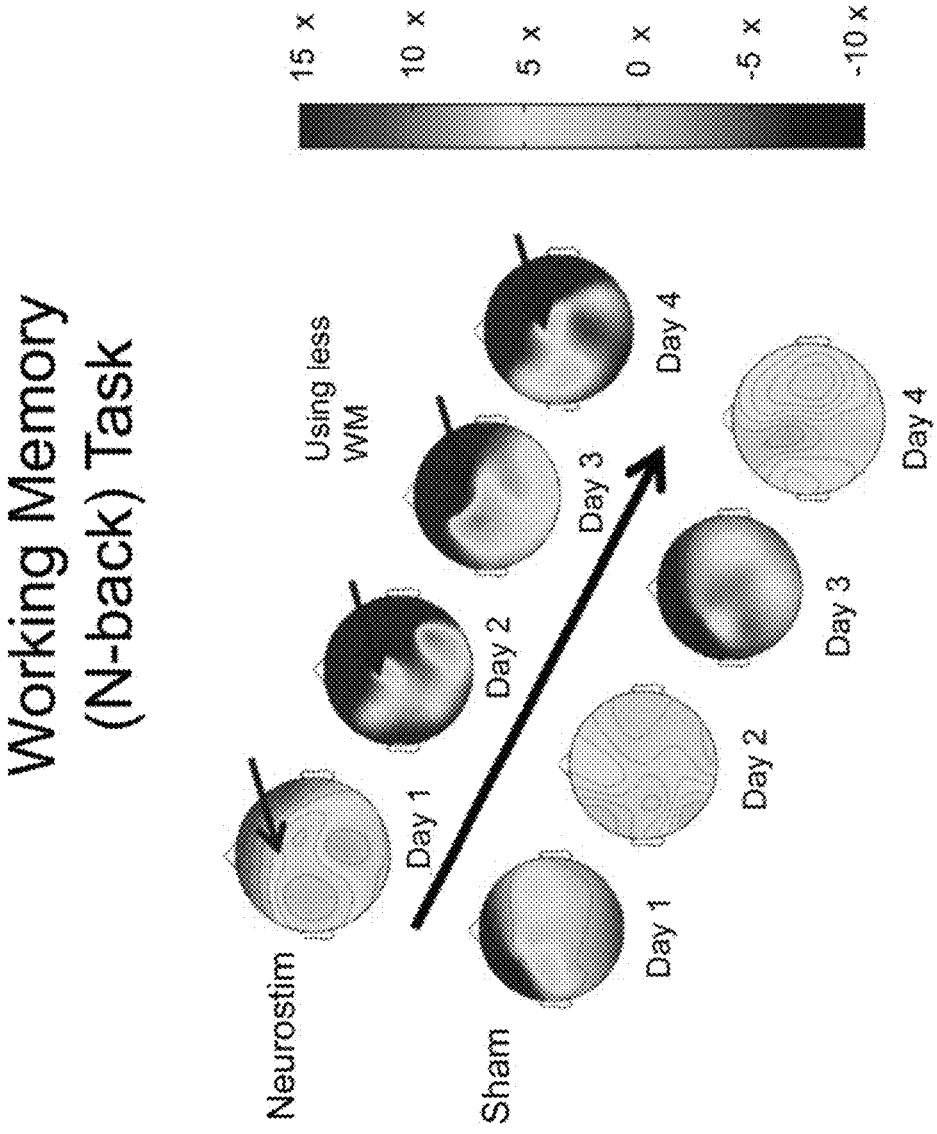

Working Memory
(N-back) Task
15 x
10 x
5 x
0 x
-5 x
-10 x
Using less WM
Neurostim
Sham
Day 1
Day 2
Day 3
Day 4

FIG. 8B

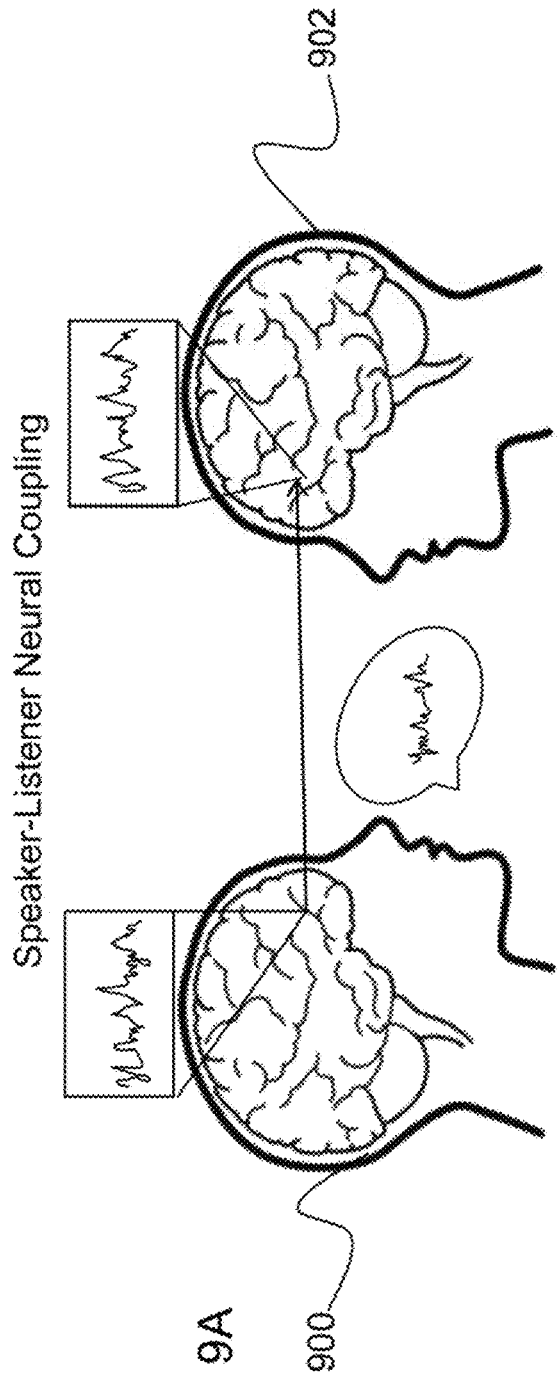

Speaker-Listener Neural Coupling
902
900

FIG. 9A

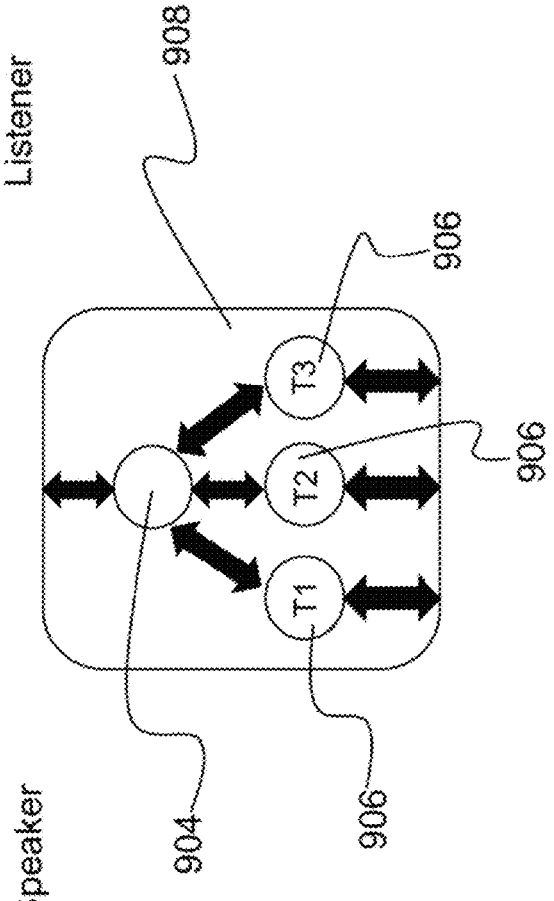
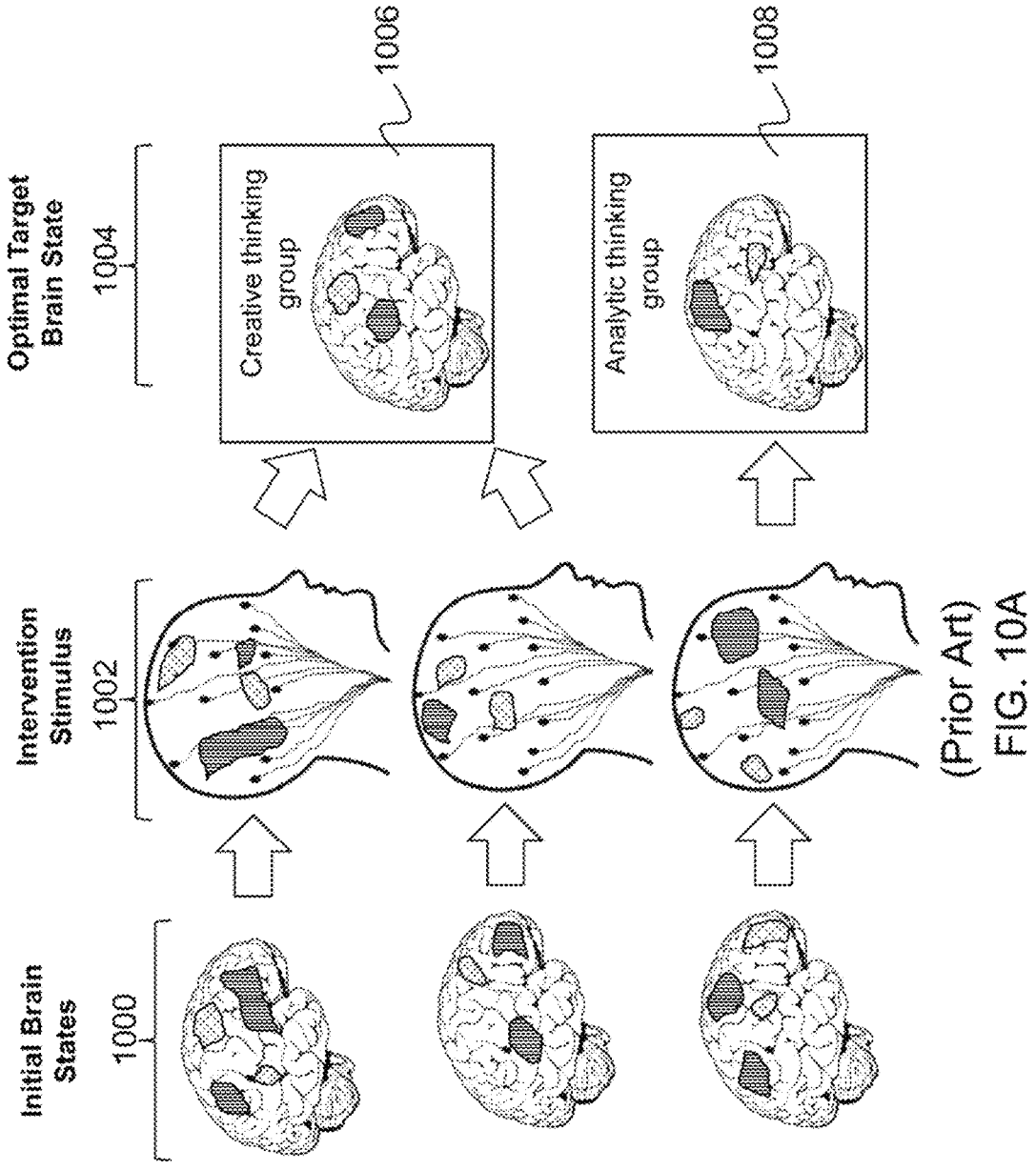
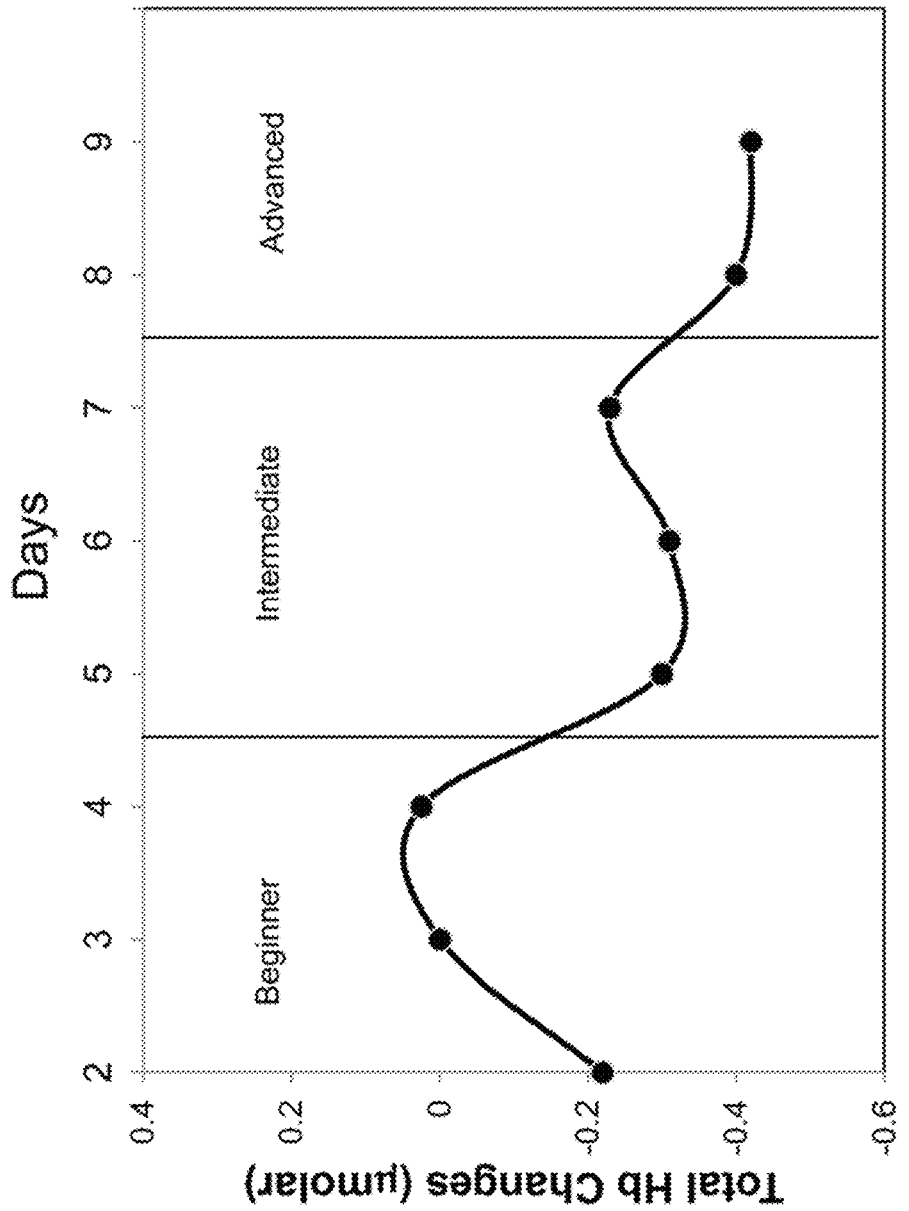

Listener
908
906
T3
T2
T1
906
Speaker
904
906

FIG. 9B



(Prior Art)
FIG. 10A



(Prior Art)

FIG. 10B

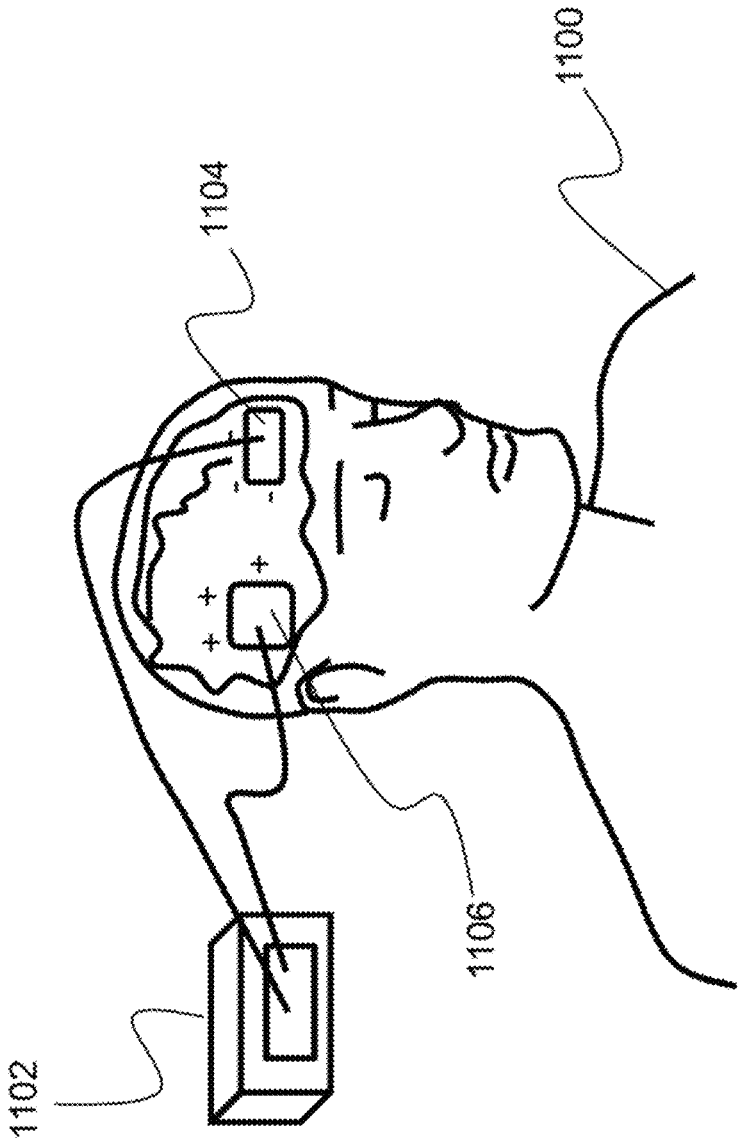


FIG. 11

METHOD FOR NEUROSTIMULATION ENHANCED TEAM PERFORMANCE

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a Continuation-in-Part Application of U.S. application Ser. No. 14/987,467, filed in the United States on Jan. 4, 2016, entitled, "The Thinking Cap: Combining Personalized, Model-Driven, and Adaptive High Definition Trans-Cranial Stimulation (HD-tCS) with Functional Near-Infrared Spectroscopy (fNIRS) and Electroencephalography (EEG) Brain State Measurement and Feedback," which is a Non-Provisional Application of U.S. Provisional Application No. 62/099,835, filed in the United States on Jan. 5, 2015, entitled, "The Thinking Cap: Combining Personalized, Model-Driven, and Adaptive HD-tCS with fNIRs and EEG Brain State Measurement and Feedback," the entirety of which are incorporated herein by reference.

This is ALSO a Continuation-in-Part Application of U.S. application Ser. No. 15/219,023, filed in the United States on Jul. 25, 2016, entitled, "System and Methods for Neuro-Playback," which is a Non-Provisional Application of U.S. Provisional Application No. 62/196,155, filed in the United States on Jul. 23, 2015, entitled, "Neuro-Playback," the entirety of which are incorporated herein by reference.

This is ALSO a Non-Provisional Patent Application of U.S. Provisional Application No. 62/210,976 entitled, "A Method for Neurostimulation Enhanced Team Performance" filed in the United States on Aug. 27, 2015, the entirety of which is incorporated herein by reference.

BACKGROUND OF INVENTION

(1) Field of Invention

The present invention relates to a system for enhancing team performance and, more particularly, to a system for enhancing team performance through individualized neurostimulation.

(2) Description of Related Art

Neurostimulation methods have been recently developed as a viable tool for cognitive training and enhancement, rapid recovery from brain injury including stroke, traumatic-brain-injuries, and as a teaching and learning assistance tool. However, while a number of experiments have demonstrated performance enhancement due to various forms of neurostimulation interventions, most studies show high variability and a tendency for some users to do worse even though the overall performance of the user pool improves (see Literature Reference No. 47 in the List of Incorporated Literature References).

Effective team performance depends on strong individual performance, dynamic communication, and adaptation from all members of the team. Research has shown that effective teams require defined and common individual and team goals, trust within the team, clarity in individual roles, open and effective communication, balance in the team's focus, and empowered leaders capable of rapid and effective team management (see Literature Reference Nos. 5, 64, and 65). If any one of these factors break down, poor team performance can result. Research has shown that this problem cannot be remedied with the addition of manpower, but requires well trained individuals capable of adapting their goals to suit the evolving needs of the team in dynamic, confusing and rapidly changing environments and missions (see Literature Reference Nos. 62-65).

Prior work has shown that if two subjects are in communication, common brain activity can be monitored using neuroimaging techniques, such as functional near-infrared spectroscopy (e.g. fNIRS). However, if the listener does not understand or is not paying attention, their measured neural activity does not match the speaker/leaders brain state. These methods are suited to detecting an imbalance in team understanding or communication, but do not take an active role in augmenting individual team member's neural states though feedback or modulation. Additionally, current individual and team training systems rely on live, virtual and constructive training to simulate mission-critical scenarios in order to develop the familiarity and experience of the team.

Current methods of cognitive enhancing neurostimulation have been limited by task specific improvements, a lack of personalization and adaptation, and a limited understanding of mechanistic changes. These methods have shown only limited applicability and transition potential to working environments, as shown in the table of FIG. 3 (from Literature Reference No 64).

Thus, a continuing need exists for a system and method that dynamically stimulates an individual team member's appropriate brain region, allowing the maximal opportunity for focus and understanding of a team leader and mitigation of fatigue.

SUMMARY OF INVENTION

The present invention relates to a system for enhancing team performance and, more particularly, to a system for enhancing team performance through individualized neurostimulation. The system comprises one or more processors and a memory having instructions such that when the instructions are executed, the one or more processors perform multiple operations. A target brain state is selected in a subject, and the target brain state is associated with specific brain regions. A HD-tCS neurostimulation needed to reach the specific brain regions is determined to induce the target brain state in the subject. The determined HD-tCS neurostimulation is applied to the subject while simultaneously sensing, via real-time neuroimaging from both electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS), neural activity of the subject while the subject performs a behavioral task. Based on the sensed neural activity, the neurostimulation of the subject is adjusted to move the subject into a target brain state.

In another aspect, an assessment of the subject is generated while the subject is performing a behavioral task using neuroimaging data. Any behavioral performance deficiencies in the subject are detected based on the assessment, and behavioral performance deficiencies are associated with activation states in specific brain regions.

In another aspect, a cognitive model for the subject is personalized by: estimating a set of cognitive capacities of the subject from a set of diagnostic tests; mapping the set of cognitive capacities onto a set of parameters; applying the set of parameters to the cognitive model; and predicting the subject's task performance and determining which tasks can be performed to improve the subject's task performance.

In another aspect, the subject's brain state is synchronized with one or more other subjects, allowing all subjects to act in unison when performing tasks.

In another aspect, if the sensed neural activity indicates a loss of focus in the subject, then the HD-tCS neurostimulation is adjusted to reach the specific brain regions needed to regain focus.

In another aspect, the system removes artifacts from a sensed EEG signal using a signal source separation method that uses parallel processing to separate maximally-independent sources of the sensed EEG signal by minimizing mutual information between source data channels.

In another aspect, timing between HD-tCS neurostimulation and sensing via real-time neuroimaging is alternated to avoid interference.

In another aspect, phenotypic subject categories of a target brain state comprise a creative thinking group and an analytic thinking group.

Finally, the present invention also includes a computer program product and a computer implemented method. The computer program product includes computer-readable instructions stored on a non-transitory computer-readable medium that are executable by a computer having one or more processors, such that upon execution of the instructions, the one or more processors perform the operations listed herein. Alternatively, the computer implemented method includes an act of causing a computer to execute such instructions and perform the resulting operations.

BRIEF DESCRIPTION OF THE DRAWINGS

The file of this patent or patent application publication contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

The objects, features and advantages of the present invention will be apparent from the following detailed descriptions of the various aspects of the invention in conjunction with reference to the following drawings, where:

FIG. **1** is a block diagram depicting the components of a system for enhancing team performance according to various embodiments of the present disclosure;

FIG. **2** is an illustration of a computer program product according to various embodiments of the present disclosure;

FIG. **3** is a table of team-related measures according to prior art;

FIG. **4** illustrates a system architecture diagram according to various embodiments of the present disclosure;

FIG. **5** illustrates model-driven high definition transcranial current stimulation (HD-tCS) for adaptive team performance according to embodiments of the present disclosure;

FIG. **6**A illustrates hemoglobin concentration differences in subject 1 during climbing compared to level flight, and calm compared to turbulent flight conditions in a simulator according to embodiments of the present disclosure;

FIG. **6**B illustrates hemoglobin concentration differences in subject 2 during climbing compared to level flight, and calm compared to turbulent flight conditions in a simulator according to embodiments of the present disclosure;

FIG. **7**A illustrates changes in heading during stormy and calm simulated flight conditions according to embodiments of the present disclosure;

FIG. **7**B illustrates changes in altitude during stormy and calm simulated flight conditions according to embodiments of the present disclosure;

FIG. **7**C illustrates changes in plane roll during stormy and calm simulated flight conditions according to embodiments of the present disclosure;

FIG. **7**D illustrates changes in latitude during stormy and calm simulated flight conditions according to embodiments of the present disclosure;

FIG. **7**E illustrates a comparison of altitude changes for two subjects experiencing calm and stormy flight simulation conditions according to embodiments of the present disclosure;

FIG. **7**F illustrates a comparison of heading changes for two subjects experience calm and stormy flight simulation conditions according to embodiments of the present disclosure;

FIG. **7**G illustrates a comparison of plane roll changes for two subjects experience calm and stormy flight simulation conditions according to embodiments of the present disclosure;

FIG. **8**A illustrates changes in electroencephalogram (EEG) patterns across four consecutive days of flight training according to embodiments of the present disclosure;

FIG. **8**B illustrates changes in EEG patterns across four consecutive days of flight training during a working memory task according to embodiments of the present disclosure;

FIG. **9**A illustrates speaker-listener neural coupling according to embodiments of the present disclosure;

FIG. **9**B illustrates how a team leader defers tasks to subordinate members in a hierarchical team structure according to embodiments of the present disclosure;

FIG. **10**A illustrates optimal brain state induction for phenotypic subject categories according to prior art;

FIG. **10**B illustrates that prefrontal cortex activity generally reduces over the course of behavioral training after an initial increase according to prior art; and

FIG. **11** illustrates a human subject receiving neurostimulation according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

The present invention relates to a system for enhancing team performance and, more particularly, to a system for enhancing team performance through individualized neurostimulation. The following description is presented to enable one of ordinary skill in the art to make and use the invention and to incorporate it in the context of particular applications. Various modifications, as well as a variety of uses in different applications will be readily apparent to those skilled in the art, and the general principles defined herein may be applied to a wide range of aspects. Thus, the present invention is not intended to be limited to the aspects presented, but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

In the following detailed description, numerous specific details are set forth in order to provide a more thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced without necessarily being limited to these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring the present invention.

The reader's attention is directed to all papers and documents which are filed concurrently with this specification and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference. All the features disclosed in this specification, (including any accompanying claims, abstract, and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly

stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

) Furthermore, any element in a claim that does not explicitly state "means for" performing a specified function, or "step for" performing a specific function, is not to be interpreted as a "means" or "step" clause as specified in 35 U.S.C. Section 112, Paragraph 6. In particular, the use of "step of" or "act of" in the claims herein is not intended to invoke the provisions of 35 U.S.C. 112, Paragraph 6.

Before describing the invention in detail, first a list of cited references is provided. Next, a description of the various principal aspects of the present invention is provided. Following that is an introduction that provides an overview of the present invention. Finally, specific details of the present invention are provided to give an understanding of the specific aspects.

(1) List of Incorporated Literature References

The following references are incorporated and cited throughout this application. For clarity and convenience, the references are listed herein as a central resource for the reader. The following references are hereby incorporated by reference as though fully set forth herein. The references are cited in the application by referring to the corresponding literature reference number, as follows:

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(2) Principal Aspects

The present invention has three "principal" aspects. The first is a system for enhancing team performance. The system is typically in the form of a computer system operating software or in the form of a "hard-coded" instruction set. This system may be incorporated into a wide variety of devices that provide different functionalities. The second principal aspect is a method, typically in the form of software, operated using a data processing system (computer). The third principal aspect is a computer program product. The computer program product generally represents computer-readable instructions stored on a non-transitory computer-readable medium such as an optical storage device, e.g., a compact disc (CD) or digital versatile disc (DVD), or a magnetic storage device such as a floppy disk or magnetic tape. Other, non-limiting examples of computer-readable media include hard disks, read-only memory (ROM), and flash-type memories. These aspects will be described in more detail below.

A block diagram depicting an example of a system (i.e., computer system **100**) of the present invention is provided in FIG. **1**. The computer system **100** is configured to perform calculations, processes, operations, and/or functions associated with a program or algorithm. In one aspect, certain processes and steps discussed herein are realized as a series of instructions (e.g., software program) that reside within computer readable memory units and are executed by one or more processors of the computer system **100**. When executed, the instructions cause the computer system **100** to perform specific actions and exhibit specific behavior, such as described herein.

The computer system **100** may include an address/data bus **102** that is configured to communicate information. Additionally, one or more data processing units, such as a processor **104** (or processors), are coupled with the address/data bus **102**. The processor **104** is configured to process information and instructions. In an aspect, the processor **104** is a microprocessor. Alternatively, the processor **104** may be a different type of processor such as a parallel processor, or a field programmable gate array.

The computer system **100** is configured to utilize one or more data storage units. The computer system **100** may include a volatile memory unit **106** (e.g., random access memory ("RAM"), static RAM, dynamic RAM, etc.) coupled with the address/data bus **102**, wherein a volatile memory unit **106** is configured to store information and instructions for the processor **104**. The computer system **100** further may include a non-volatile memory unit **108** (e.g., read-only memory ("ROM"), programmable ROM ("PROM"), erasable programmable ROM ("EPROM"), electrically erasable programmable ROM "EEPROM"), flash memory, etc.) coupled with the address/data bus **102**, wherein the non-volatile memory unit **108** is configured to store static information and instructions for the processor **104**. Alternatively, the computer system **100** may execute instructions retrieved from an online data storage unit such as in "Cloud" computing. In an aspect, the computer system **100** also may include one or more interfaces, such as an interface **110**, coupled with the address/data bus **102**. The one or more interfaces are configured to enable the computer system **100** to interface with other electronic devices and computer systems. The communication interfaces implemented by the one or more interfaces may include wireline (e.g., serial cables, modems, network adaptors, etc.) and/or wireless (e.g., wireless modems, wireless network adaptors, etc.) communication technology.

In one aspect, the computer system **100** may include an input device **112** coupled with the address/data bus **102**, wherein the input device **112** is configured to communicate information and command selections to the processor **100**. In accordance with one aspect, the input device **112** is an alphanumeric input device, such as a keyboard, that may include alphanumeric and/or function keys. Alternatively, the input device **112** may be an input device other than an alphanumeric input device. For example, the input device **112** may include one or more sensors, such as a camera for video or still images, a microphone, or a neural sensor. Other example input devices **112** may include an accelerometer, a GPS sensor, or a gyroscope.

In an aspect, the computer system **100** may include a cursor control device **114** coupled with the address/data bus **102**, wherein the cursor control device **114** is configured to communicate user input information and/or command selections to the processor **100**. In an aspect, the cursor control device **114** is implemented using a device such as a mouse, a track-ball, a track-pad, an optical tracking device, or a touch screen. The foregoing notwithstanding, in an aspect, the cursor control device **114** is directed and/or activated via input from the input device **112**, such as in response to the

use of special keys and key sequence commands associated with the input device **112**. In an alternative aspect, the cursor control device **114** is configured to be directed or guided by voice commands.

In an aspect, the computer system **100** further may include one or more optional computer usable data storage devices, such as a storage device **116**, coupled with the address/data bus **102**. The storage device **116** is configured to store information and/or computer executable instructions. In one aspect, the storage device **116** is a storage device such as a magnetic or optical disk drive (e.g., hard disk drive ("HDD"), floppy diskette, compact disk read only memory ("CD-ROM"), digital versatile disk ("DVD")). Pursuant to one aspect, a display device **118** is coupled with the address/data bus **102**, wherein the display device **118** is configured to display video and/or graphics. In an aspect, the display device **118** may include a cathode ray tube ("CRT"), liquid crystal display ("LCD"), field emission display ("FED"), plasma display, or any other display device suitable for displaying video and/or graphic images and alphanumeric characters recognizable to a user.

The computer system **100** presented herein is an example computing environment in accordance with an aspect. However, the non-limiting example of the computer system **100** is not strictly limited to being a computer system. For example, an aspect provides that the computer system **100** represents a type of data processing analysis that may be used in accordance with various aspects described herein. Moreover, other computing systems may also be implemented. Indeed, the spirit and scope of the present technology is not limited to any single data processing environment. Thus, in an aspect, one or more operations of various aspects of the present technology are controlled or implemented using computer-executable instructions, such as program modules, being executed by a computer. In one implementation, such program modules include routines, programs, objects, components and/or data structures that are configured to perform particular tasks or implement particular abstract data types. In addition, an aspect provides that one or more aspects of the present technology are implemented by utilizing one or more distributed computing environments, such as where tasks are performed by remote processing devices that are linked through a communications network, or such as where various program modules are located in both local and remote computer-storage media including memory-storage devices.

An illustrative diagram of a computer program product (i.e., storage device) embodying the present invention is depicted in FIG. **2**. The computer program product is depicted as floppy disk **200** or an optical disk **202** such as a CD or DVD. However, as mentioned previously, the computer program product generally represents computer-readable instructions stored on any compatible non-transitory computer-readable medium. The term "instructions" as used with respect to this invention generally indicates a set of operations to be performed on a computer, and may represent pieces of a whole program or individual, separable, software modules. Non-limiting examples of "instruction" include computer program code (source or object code) and "hard-coded" electronics (i.e. computer operations coded into a computer chip). The "instruction" is stored on any non-transitory computer-readable medium, such as in the memory of a computer or on a floppy disk, a CD-ROM, and a flash drive. In either event, the instructions are encoded on a non-transitory computer-readable medium.

(3) Introduction

Effective team performance depends on strong individual performance, dynamic communication, and adaptation from all members of the team. Current individual and team training systems rely on live, virtual and constructive training to simulate mission-critical scenarios in order to develop the familiarity and experience of the team.

The method described in detail below dynamically stimulates the individual team member's appropriate brain region, allowing the maximal opportunity for focus and understanding of the team leaders and the mitigation of fatigue. By monitoring the brain and using individualized neural models to predict the correct team member/leader neural patterns this method can increase the unison within the team leading to greater effectiveness and collaboration between team members.

The system according to embodiments of the present disclosure personalizes and adapts neurostimulation to each team member (FIG. **4**) to pinpoint the phenotypic neurobiological mechanisms across a large population with a variety of neural imaging methods. In addition, using the model-driven adaptive performance team system (see, for example, FIG. **5**) provides a comprehensive map from team to user to behaviors to brain regions of interest for neurostimulation patterns to enable rapid and specific enhancement of directed cognitive faculties in teams. Other, methods use generic anatomical models (see Literature Reference Nos. 2 and 3) to direct neurostimulation, and cannot make predictions of team or individual behaviors based on neurobiological mechanisms. The present invention provides an elegant system-level solution to several problems in adapting and personalizing neurostimulation for team performance and training.

The system and method described herein addresses these needs by increasing the effectiveness of team performance though model-driven neurostimulation in both operational and training settings though the application of real-time model-driven neurostimulation. Specifically, the system and method described herein allow for the advantageous enhancement of: team communication, objective and goal understanding, increases in goal-directed behavior and adaptability and overall performance. This method not only benefits team performance in mission relevant metrics (i.e., a team may obtained mission objectives faster with less risk to team members and utilizing fewer resources), but it can also mitigate potential accident and injury risks by decreasing fatigue and assisting team members to maintain focus on goals and mission objectives in confusing and challenging real-world scenarios.

Specifically, the method according to various embodiments of the present disclosure has the following advantages over prior work. A combined multimodal neuroimaging and neurostimulation system allows individual team members to act in unison when conducting missions in a controlled environment by synchronizing team members brain states (e.g., amplitude and phase of functional measures of brain states (e.g., EEG frontal synchrony) for mission-critical cognitive functions (i.e., cognitive control allows an individual to ignore distractions and focus on a goal objective).

Additionally, the present invention performs behavioral and neuroimaging monitoring and classification of individual decision making (e.g., with respect to a reference flight path in the pilot training task). Real-time mitigation of fatigue/boredom states via neurostimulation of attentional centers in the brain is used to ultimately decrease an individual's fatigue and improve performance. Behavioral and/or neuroimaging measures show decreased alertness and fatigue, so the system described herein excites the prefrontal cortex to increase arousal in the subject. Continual monitoring of each team member is utilized to ensure focus

is kept on the individual objectives, and ensure that team leader and mission instructions and goals are understood and executed to the best of the individual's ability.

Finally, when neuromonitoring signals indicate a loss of focus or understanding, neurostimulation is applied to the correct region of the brain to aid the individual in regaining focus. Increased activity in the neural regions depicted in FIGS. **6**A and **6**B correspond to focus, attention, and workload. If these appear in the calm condition and behavioral metrics begin to decline (see FIGS. **7**A-**7**G), then the system can infer that the subject is losing focus.

The invention described herein compensates for individual differences using a combination of three innovations that, together, revolutionize the field of neurostimulation. First, the unique high definition (HD) neurostimulation system offers unprecedented specificity and control over the neural activity induced in the brain. Second, a functional-anatomical model, such as The Virtual Brain (see Literature Reference No. 40 for a description of The Virtual Brain), coupled with a cognitive-behavioral model, such as ACT-R (see Literature Reference No. 5 for a description of ACT-R) are adapted to subject performance and brain states. This gives the needed predictive power to personalize both neural stimulation patterns as well as behavioral tasks for maximum adaptive reasoning and problem solving (ARP) enhancement. Third, monitoring brain states during neurostimulation (in addition to before and after) using a combination of neural recordings, including functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG) offers a deeper understanding of the neural basis for intervention effects, allowing within-trial adaptation of stimuli for improved cognitive flexibility. These innovations ensure that no users degrade in performance. Each of these aspects will be described in further detail below.

(4) Specific Details of the Invention

(4.1) Basic Concept of Operation

The basic concept of operation, shown in FIG. **4**, is a multi-step process of choosing the correct behavior and cognitive objectives **400**, stimulation location, and parameters for the team member (based on an initial assessment module **402**); stimulating the correct brain areas in individual team members (using a real-time situational application of neurostimulation module **404**); measuring the changing brain states and behavior (using a multimodal imaging module **406** and a behavioral monitoring module **408**); and adapting the team's neurostimulations (using the real-time situational application of neurostimulation module **404**). Each team member must be linked to their functional role and goal state requiring specific cognitive faculties (via a model tuning and personalization module **410**).

As depicted in FIG. **5**, once the desired cognitive and physical states **500** have been chosen, the adaptive team performance system **502** (comprising a functional-anatomical model and a cognitive-behavior model) will determine what HD-tCS (high definition transcranial current stimulation) neurostimulation **504** will best improve each team member's performance on the specific field task **506**.

FIG. **5** illustrates model-driven HD-tCS according to embodiments of the present disclosure which precisely targets each team member's specific brain regions, networks, and dynamic states, with the ability to excite, suppress and synchronize brain regions across team members accurately and adapt in real-time based on behavioral sensing **508** and multi-modal neuroimaging sensing **510**.

The functional anatomical model of the adaptive team performance system **502** then determines what stimulation (HD-tCS **504**) protocol to use for the given task **506**. The first time stimulation occurs, the stimulation will be a general task specific stimulation. The models of the adaptive team performance system **502** will adapt to the personal behavioral responses to the task. As the team member performs tasks, the brain state is measured by multiple neural imaging modalities (e.g., functional near-infrared spectroscopy (fNIRS), electroencephalogram (EEG) and/or functional magnetic resonance imaging (fMRI)), represented by element **510** in FIG. **5** and element **406** in FIG. **4**). The behavioral-monitoring module **408** assesses (i.e., behavioral sensing **508**) the enhanced functional performance **412** relative to the behavioral and cognitive objectives **400** and recommends modified neurostimulations (elements **404** and **504**). Additionally, the behavioral-monitoring module **408** identifies regions of interest to be stimulated which are personalized for the current user based on their target brain state and team performance goal (i.e., model tuning and personalization **410**).

(4.2) Multi-Modal Adaptive Mixture Independent Component Analysis (ICA)

The adaptive stimulation approach according to embodiments of the present disclosure incorporates two modes of brain monitoring to facilitate feedback and neurostimulation adaptation for each team member as the intervention takes place. A unique advance was developed to allow both EEG and fNIRS data to be collected during the stimulation intervention. For example, high definition transcranial current stimulation (HD-tCS) electrodes are the same form factor as EEG electrodes and can be placed on the same electrode cap. Interference is avoided between electrical stimulation currents and EEG by alternating the timing of the stimulation and EEG data capture switching up to 250 Hertz (Hz). In this way, snippets of EEG data can be collected throughout the stimulation period without interference.

In multi-modal adaptive mixture independent component analysis the Infomax ICA algorithm achieves minimization of (y) based on the information maximization principle (see Literature Reference No. 66). Extended Infomax is similar to Infomax, with the additional ability to separate mixed non-Gaussian signal distributions. This is done by a learning rule which adaptively changes the sign of the 4th-order moment of the probability density function (PDF) to fit sub- and super-Gaussian distributions. Adaptive Mixture ICA (AMICA) goes a step farther and models adaptive mixtures of Gaussian PDFs fit to individual component time courses and spatial projections in entropy maximization, rather than a selecting single Gaussian or non-Gaussian PDFs.

In the present invention, a multi-modal adaptive-mixture ICA was developed to remove residual artifacts from the EEG signal using a signal source separation method that uses massively parallel processing to separate maximally-independent sources of the EEG signal, by minimizing mutual information between N components, where N is the number of source data channels. The multi-modal adaptive-mixture ICA method was developed to remove 60 Hz line artifacts, eye-blinks, vertical and horizontal eye movements, and cardiac signals (when these signals are present in the data).

The algorithm is a natural gradient descent ICA algorithm (such as Infomax, extended Infomax, and AMICA). This algorithm is an iterative procedure where multiple solutions

are examined until a stopping criterion is reached. Entropy (or information content) of the output vectors h(y) is maximized by minimizing the mutual information I(y) shared between them. Entropy h within vector x of random data (e.g., from an EEG sensor) is given by: $h(x)=E\{-\log p(x)\}$. Entropy h of the vector x is the expected value of the log-transformed PDF for the vector/sensor p(x), which ranges from 0 to 1. In other words, entropy of an EEG channel is the area under the curve of the probability distribution function. Sensor x and component y have a linear relationship by the factor W (y=Wx), and for a linear transformation Y=BX, entropy of the vector Y can be calculated with $h(Y)=\log|\det B|+h(X)$, so entropy of component y can be calculated with $h(y)=\log|\det W|+h(x)$. Pairwise, mutual information I between two vectors X1 and X2 (e.g., two EEG sensors or ICA components) can be defined as $I(X\_1,2)=h(X\_1)+h(X\_2)-h(X\_1,2)$, or for N components derived from Y sensors $I(Y)=h(Y\_)+\ldots+h(Y\_N)-h(Y)$. Therefore, mutual information I(y) among component time courses $y\_(1\ldots n)$ is given by: $I(y)=h(y\_1)+\ldots+h(y\_n)-\log|\det W|-h(x)$.

The system according to various embodiments of the present disclosure uses EEG to monitor dynamic brainwave power in the alpha and gamma frequency bands over the dorsal-lateral pre-frontal cortex (dlPFC) region. This signal is utilized to classify cognitive workload in pilots with one-show classification accuracy of 90%. Functional near-infrared spectroscopy (fNIRS) measures regional activity levels and is used to complement the EEG-based brain state sensing with a mode that has different noise and artifact characteristics, resulting in improved classifier performance when combined with the EEG based sensing. For instance, FIGS. **6**A and **6**B show fNIRS results of workload classification signals in a calm versus turbulent condition task, which can be used to assess operator vigilance and workload. Prefrontal cortex activity is measured in total hemoglobin (Hb) changes. Thus, FIG. **6**A illustrates hemoglobin concentration differences in subject 1 during climbing compared to level flight, and calm compared to turbulent flight conditions. FIG. **6**B illustrates hemoglobin concentration differences in subject 2 during climbing compared to level flight, and calm compared to turbulent flight conditions.

The HD-tCS system according to embodiments of the present disclosure supports 9 DC/AC (direct current/alternating current) stimulation channels and 32 EEG channels for concurrent data collection (interleaved up to 250 Hz). The stimulation channels support any combination of three different types of HD-tCS. Direct Current Stimulation (HD-tDCS) is used to inhibit or excite targeted functional brain regions. Alternating Current Stimulation (HD-tACS) induces oscillatory patterns of neural activity with target amplitudes, frequencies, and phases. Random Noise Stimulation (HD-tRNS) will promote neural plasticity. Additional details regarding the different types of HD-tCS can be found in Literature References No. 19, 42, 48, and 49.

(4.3) Behavioral Monitoring and Initial Assessment (Represented by Elements **408** and **402**, Respectively)

Behavioral tasks have been developed to rapidly assess cognitive workload and operator performance in a variety of contexts. The present invention uses performance measures, such as aircraft heading, altitude, roll, pitch, airspeed, and latitude/longitude position to calibrate a pilot's behavioral performance relative to a database of subjects (including commercial and military pilots). These performance metrics are used to calibrate the training and the initial neurostimulation patterns for those subjects, in the team system, these are user-task measures nested into a team performance model. For example, in a simplified navigation and piloting team task, the team's performance metric could be: nav*pilot/(nav+pilot) if nav and pilot scores are 0-1 performance measures.

FIGS. **7**A-**7**G illustrate pilot behavioral data from two subjects showing behavioral classification of high and low workload conditions during simulated flight. Specifically, FIG. **7**A illustrates changes in heading during stormy (high workload, represented by bolded lines) and calm (low workload, represented by unbolded lines) flying conditions. FIG. **7**B illustrates changes in altitude during stormy (high workload, represented by bolded lines) and calm (low workload, represented by unbolded lines) flying conditions. FIG. **7**C illustrates changes in roll during stormy (high workload, represented by bolded lines) and calm (low workload, represented by unbolded lines) flying conditions. FIG. **7**D illustrates changes in latitude during stormy (high workload, represented by bolded lines) and calm (low workload, represented by unbolded lines) flying conditions. FIG. **7**E illustrates changes in altitude during stormy and calm flying conditions, comparing two subjects. FIG. **7**F illustrates a change in heading during stormy and calm flying conditions, comparing two subjects. FIG. **7**G illustrates a change in plane roll during stormy and calm flying conditions, comparing two subjects.

(4.4) Model Tuning and Personalization (Represented by Element **410**)

Individual team-member task strategies and brain states may vary from one person to the next during problem-solving. The system according to various embodiments of the present disclosure has the ability to precisely apply neurostimulation with high resolution to induce personalized brain states for team performance. A generic neurostimulation is inappropriate; therefore, the present invention is model-based, and the models adapt during training from subject-specific fMRI, fNIRS, and EEG data. The behavioral assessment and objectives models (elements **408** and **508**) account for individual differences from behavioral and cognitive perspectives and recommend anatomical targets for neurostimulation. These models link to an anatomical model (element **402**) to determine a combination of electrode currents to produce on a subject's scalp so as to modulate target brain regions.

The first stage of modeling assesses behavioral performance deficiencies in individual team members and associates them with activation states in various brain regions. To initialize the model, the subject is engaged in a battery of cognitive tasks while scanning with fNIRS and EEG, and the performance is used to parameterize the model. The resulting model can be implemented in a cognitive simulator (such as ACT-R (Adaptive Control of Thought-Rational)). Once parameterized, the model predicts the subject's and team's performance over the full spectrum of related tasks. Using these identified weaknesses, the model will then be used to assemble a set of training tasks. For each task, the model searches for the desired "target" brain states (i.e., the state measured during peak behavioral performance during personalization) that will yield the greatest estimated improvement in overall performance of the team.

The second stage of modeling selects the target brain state in individuals for team performance enhancement. Three-dimensional (3D) Functional-Anatomical models (such as

Soterix HDTargets (produced by Soterix Medical, Inc. located at 237 W 35 St., New York, N.Y. 10001) or the Virtual Brain (described in Literature Reference No. 41)) capture both shape and conductance of tissues above and beneath the skull. These models associate functional brain regions for the target brain state to specific physical locations within the skull and provide a means to determine the HD-tCS electrode currents needed to reach these regions effectively. The functional-anatomical model must be initialized from a user's fMRI scan, but during the training regimen it is adapted based on fNIRS sensing, providing a lower-cost rough approximation to fMRI data.

Given a set of brain regions designated for intervention and the desired activations of these regions, the system model (element **502**) can derive the needed electrode currents and polarities to induce the target brain state (see Literature Reference No. 40. The stimulation is applied while the subject is engaged in the selected task. Finally, the HD-tCS currents guide subjects' neural activity during the tasks into states that assist subjects in realizing peak team performance. These target brain states promote neural plasticity essential for improvement and persistence, while also enhancing the generalizability and retention of the cognitive skills developed during the training (described in Literature Reference Nos. 23, 25, and 37.

(4.4.1) Model Personalization

Personalization consists of two main approaches: setting architectural parameters (described in Literature Reference No. 15) and defining knowledge and skill structures (described in Literature Reference No. 57). In the first approach, cognitive capacities of each team member are estimated from diagnostic tests (e.g., working memory capacity, set-shifting ability, reaction times, recall accuracy) and are then mapped onto architectural parameters based on the range of skill within a population (e.g., 1-poor, 10-best). These parameters are then applied to the cognitive model to predict an individual's task performance and determine which tasks (and stimulations) will show the most generalized improvements of the individual and the team. The latter approach to personalization is to estimate the state of an individual's knowledge from the subject's performance (e.g., intelligent tutoring) and to determine which knowledge structures (e.g., hippocampal system for memory performance, pre-frontal cortex working memory capacity, executive function) the participant has available and which new structures (e.g., skills) would maximize the team's task performance. Intelligent tutoring systems, such as ACT-R, can estimate the state of an individual's skill or knowledge based on their behavior.

(4.5) Real-Time Neurostimulation Application (Represented by Element **404**)

Another element of the method according to some embodiments of the present disclosure is to dynamically alter the stimulus currents based on sensor feedback of the team's brain states both before and during engagement in behavioral tasks. Some embodiments may be utilized to manipulate the oscillatory dynamics present in neural activity of specific brain regions in order to train and assist team members in flexibly switching between operational modes (e.g., synchronized (dissemination of knowledge/tasks to subordinates as in FIG. **9**B), and unsynchronized (each team member is performing independently on their separate tasks). The method described herein functions by incorporating alternating current stimulation (HD-tACS), at gamma-band frequencies (~40 Hz), for activation and alpha-band frequencies (~10 Hz) for suppression into a feedback loop that involves real-time sensing from both EEG and fNIRS. Data from both modalities is used during the course of transcranial team stimulation.

In order to solve complex real-world problems, teams need to be adaptive and use a combination of problem-solving strategies, as described in Literature Reference No. 32. However, most team members tend to have a natural predilection toward using one strategy or the other (described in Literature Reference No. 33), and they have difficulty switching between them. Recent neuroimaging research has identified differences in brain states associated with analysis and insight (see Literature Reference No. 32). For example, insight solving involves a burst of activity in the right temporal lobe (see Literature Reference No. 29). Immediately prior to the presentation of an expected problem, subsequent insight solving is associated with elevated activity in the anterior cingulate and bilateral temporal lobes (see Literature Reference No. 34).

The real-time, closed-loop, multi-modal sensing and adaptive-mixture ICA according to embodiments of the present disclosure informs the behavioral and functional models for guided, adaptive and personalized team neurostimulation to steer each member toward their desired brain states. There are two key benefits of this capability. First, it increases the efficiency and efficacy of traditional neurostimulation and neurofeedback training in which a team member will learn to "mentally steer" his or her brain state towards one of two target states. Second, it allows the induction of the desired target brain states while a user is actively engaged in behavior, a capability that is infeasible during traditional neurofeedback training.

The unique method of adaptive stimulation described herein facilitates a more flexible switching between modes of problem solving. For example, the method according to embodiments of the present disclosure can induce the analytic brain state in subjects by stimulating their anterior cingulate region with alpha frequencies to decrease activity (see Literature Reference No. 50 for a description of inducing the analytic brain state). This reduces the brain's monitoring of competing solution possibilities, resulting in a focused analytic strategy that follows the dominant, obvious, path to solution (see Literature Reference Nos. 34 and 54). As cognitive workload increases, presumably because the user is stuck and can't make further progress, the system guides the user to enter the insight brain state and then resume the task. This involves the cognitive-behavioral and functional-anatomical models stimulating the anterior cingulate region with gamma frequencies to increase activity. This operation sensitizes users to competing, nonobvious solution possibilities, or "long shot" ideas. When the anterior cingulate detects weak, unconscious ideas, it can signal dorsolateral PFC to switch to one (as described in Literature Reference No. 45), resulting in an insight, as described in Literature Reference No. 29. Weak, unconscious ideas are detected based on a comparison between the current and a salient template to signal the PFC.

FIGS. **8**A and **8**B show the changes in EEG patterns of groups (neurostimulation and sham/control) across four consecutive days of flight training (FIG. **8**A) and during a work memory task (FIG. **8**B). FIG. **9**A depicts the neural synchrony between speaker **900** and listener **902** teams. FIG. **9**B illustrates how a team leader **904** defers tasks to subordinate members (T**1**-T**3**) **906** in a hierarchical team structure **908**.

FIGS. **10**A and **10**B illustrate phenotypic personalization and expertise training according to prior art. FIG. **10**A depicts how the personalized adaptive method according to some embodiments of the present disclosure results in improved brain state induction for phenotypic subject categories. Initial brain states **1000** undergo an intervention stimulus **1002** to reach an optimal target brain state **1004**. As non-limiting examples, the phenotypic subject categories of an optimal target brain state **1004** include a creative thinking group **1006** and an analytic thinking group **1008**.

FIG. **10**B iillustrates fNIRS pilot data showing that prefrontal cortex activity (indicative of mental effort on task) generally reduces over the course of 9 days of behavioral training, after an initial increase. This is interpreted as increasing efficiency with expertise (see Literature Reference No. 8). Prefrontal cortex activity is measured in total hemoglobin (Hb) changes.

FIG. **11** illustrates a human subject **1100** receiving neurostimulation according to some embodiments of the present disclosure. A device **1102** able to generate an electrical current delivers neurostimulation by applying a current through one electrode **1104** (e.g., anode), and it flows through the brain to another electrode **1106** (e.g., cathode).

In the domain of unmanned aerial vehicles (UAV) teams, the discrepancy between added man-hours and higher accident rates has been partly attributed to individual operator fatigue, due to long operation shifts (e.g., typically 8+ hours), and operator boredom. The increased need for unmanned aerial vehicles in reconnaissance and combat operations has rapidly increased the demands, workloads, and hourly requirements of UAV pilots, operators, and support crew.

For example, the RQ-7 Shadow UAV requires 22 soldiers to operate effectively in the field. However, despite the added human effort, studies have shown that UAVs have three times the accident rate, and twice the cost of similar manned aircraft (see Literature Reference No. 61). UAV pilots often cite boredom and the required extended hours as reasons for quitting (see Literature Reference No. 63).

A second set of factors for the higher accident rates and increased demand on UAV teams can be attributed to inefficient team organization and performance. The effects of individual operator fatigue and boredom will compound and negatively influence team performance when an individual's state (especially a team leader) influences the team's states by decreasing performance through reduced team communication, role clarification, and objective/goal focus. Thus, there is an immediate and pressing need to increase UAV team performance by decreasing operator fatigue, enhancing team communication and understanding, and maintaining goal-oriented and adaptable team roles to focus individuals on the team's objective.

Neurostimulation enhancement of team performance according to the present disclosure has numerous domains of expected value and commercial applications, as well as military domains. For instance, UAV and pilot team enhancement training can be used to enhance operators' communication between individuals (in training, or as an operational system). Further, the present invention can be used to produce more effective UAV aircraft and systems requiring less man power and providing improved mission outcomes over current systems. Similarly, decreasing operator fatigue and enhancing team communication will facilitate leadership development and operability of those individuals.

Additionally, the present invention has applications in drive/operator/factory team training for enhanced human-human and human-machine/computer collaborations as well as worker injury preventions and avoidance. Furthermore, the method described herein has expected value for use in aircraft and operator team systems mentioned above. In addition, the present invention can facilitate combat team training and team performance, and reduce causalities/fatalities in combat situations with improved mission outcomes.

Finally, while this invention has been described in terms of several embodiments, one of ordinary skill in the art will readily recognize that the invention may have other applications in other environments. It should be noted that many embodiments and implementations are possible. Further, the following claims are in no way intended to limit the scope of the present invention to the specific embodiments described above. In addition, any recitation of "means for" is intended to evoke a means-plus-function reading of an element and a claim, whereas, any elements that do not specifically use the recitation "means for", are not intended to be read as means-plus-function elements, even if the claim otherwise includes the word "means". Further, while particular method steps have been recited in a particular order, the method steps may occur in any desired order and fall within the scope of the present invention.

What is claimed is:

1. A system for augmenting team performance via neurostimulation, the system comprising:

one or more processors and a non-transitory memory having instructions encoded thereon such that when the instructions are executed, the one or more processors perform operations of:

selecting a target brain state in a subject;

associating the target brain state with specific brain regions;

determining a HD-tCS neurostimulation needed to reach the specific brain regions to induce the target brain state in the subject;

applying the determined HD-tCS neurostimulation to the subject and sensing, via real-time neuroimaging from both electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS), neural activity of the subject while the subject performs a behavioral task;

based on the sensed neural activity, adjusting the neurostimulation of the subject to move the subject into a target brain state; and

personalizing a cognitive model for the subject by mapping a set of estimated cognitive capacities of the subject onto a set of parameters, and applying the set of parameters to the cognitive model.

2. The system as set forth in claim **1**, wherein the one or more processors further perform operations of:

generating an assessment of the subject while the subject is performing a behavioral task using neuroimaging data;

detecting any behavioral performance deficiencies in the subject based on the assessment; and

associating behavioral performance deficiencies with activation states in specific brain regions.

3. The system as set forth in claim **1**, wherein the one or more processors further perform an operation of personalizing the cognitive model for the subject by:

estimating the set of cognitive capacities of the subject from a set of diagnostic tests;

predicting the subject's task performance and determining which tasks can be performed to improve the subject's task performance.

4. The system as set forth in claim 1, wherein the subject's brain state is synchronized with one or more other subjects, allowing all subjects to act in unison when performing tasks.

5. The system as set forth in claim 1, wherein if the sensed neural activity indicates a loss of focus in the subject, then the HD-tCS neurostimulation is adjusted to reach the specific brain regions needed to regain focus.

6. The system as set forth in claim 1, wherein the one or more processors further perform an operation of removing artifacts from a sensed EEG signal using a signal source separation method that uses parallel processing to separate maximally-independent sources of the sensed EEG signal by minimizing mutual information between source data channels.

7. The system as set forth in claim 1, wherein timing between HD-tCS neurostimulation and sensing via real-time neuroimaging is alternated to avoid interference.

8. The system as set forth in claim 1, wherein phenotypic subject categories of a target brain state comprise a creative thinking group and an analytic thinking group.

9. A computer-implemented method for augmenting team performance via neurostimulation, comprising:

an act of causing one or more processors to execute instructions stored on a non-transitory memory such that upon execution, the one or more processors perform operations of:

selecting a target brain state in a subject;

associating the target brain state with specific brain regions;

determining a HD-tCS neurostimulation needed to reach the specific brain regions to induce the target brain state in the subject;

applying the determined HD-tCS neurostimulation to the subject and sensing, via real-time neuroimaging from both electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS), neural activity of the subject while the subject performs a behavioral task;

based on the sensed neural activity, adjusting the neurostimulation of the subject to move the subject into a target brain state; and

personalizing a cognitive model for the subject by mapping a set of estimated cognitive capacities of the subject onto a set of parameters, and applying the set of parameters to the cognitive model.

10. The method as set forth in claim 9, wherein the one or more processors further perform operations of:

generating an assessment of the subject while the subject is performing a behavioral task using neuroimaging data;

detecting any behavioral performance deficiencies in the subject based on the assessment; and

associating behavioral performance deficiencies with activation states in specific brain regions.

11. The method as set forth in claim 9, wherein the one or more processors further perform an operation of personalizing the cognitive model for a subject by:

estimating the set of cognitive capacities of the subject from a set of diagnostic tests;

predicting the subject's task performance and determining which tasks can be performed to improve the subject's task performance.

12. The method as set forth in claim 9, wherein the subject's brain state is synchronized with one or more other subjects, allowing all subjects to act in unison when performing tasks.

13. The method as set forth in claim 9, wherein if the sensed neural activity indicates a loss of focus in the subject, then the HD-tCS neurostimulation is adjusted to reach the specific brain regions needed to regain focus.

14. The method as set forth in claim 9, wherein the one or more processors further perform an operation of removing artifacts from a sensed EEG signal using a signal source separation method that uses parallel processing to separate maximally-independent sources of the sensed EEG signal by minimizing mutual information between source data channels.

15. The method as set forth in claim 9, wherein timing between HD-tCS neurostimulation and sensing via real-time neuroimaging is alternated to avoid interference.

16. The method as set forth in claim 9, wherein phenotypic subject categories of a target brain state comprise a creative thinking group and an analytic thinking group.

17. A computer program product for augmenting team performance via neurostimulation, the computer program product comprising:

computer-readable instructions stored on a non-transitory computer-readable medium that are executable by a computer having one or more processors for causing the processor to perform operations of:

selecting a target brain state in a subject;

associating the target brain state with specific brain regions;

determining a HD-tCS neurostimulation needed to reach the specific brain regions to induce the target brain state in the subject;

applying the determined HD-tCS neurostimulation to the subject and sensing, via real-time neuroimaging from both electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS), neural activity of the subject while the subject performs a behavioral task;

based on the sensed neural activity, adjusting the neurostimulation of the subject to move the subject into a target brain state; and

personalizing a cognitive model for the subject by mapping a set of estimated cognitive capacities of the subject onto a set of parameters, and applying the set of parameters to the cognitive model.

18. The computer program product as set forth in claim 17, further comprising instructions for causing the one or more processors to perform operations of:

generating an assessment of the subject while the subject is performing a behavioral task using neuroimaging data;

detecting any behavioral performance deficiencies in the subject based on the assessment; and

associating behavioral performance deficiencies with activation states in specific brain regions.

19. The computer program product as set forth in claim 17, further comprising instructions for causing the one or more processors to perform an operation of personalizing the cognitive model for the subject by:

estimating the set of cognitive capacities of the subject from a set of diagnostic tests;

predicting the subject's task performance and determining which tasks can be performed to improve the subject's task performance.

20. The computer program product as set forth in claim 17, wherein the subject's brain state is synchronized with one or more other subjects, allowing all subjects to act in unison when performing tasks.

21. The computer program product as set forth in claim 17, wherein if the sensed neural activity indicates a loss of focus in the subject, then the HD-tCS neurostimulation is adjusted to reach the specific brain regions needed to regain focus.

22. The computer program product as set forth in claim 17, further comprising instructions for causing the one or more processors to further perform an operation of removing artifacts from a sensed EEG signal using a signal source separation method that uses parallel processing to separate maximally-independent sources of the sensed EEG signal by minimizing mutual information between source data channels.

23. The computer program product as set forth in claim 17, wherein timing between HD-tCS neurostimulation and sensing via real-time neuroimaging is alternated to avoid interference.

24. The computer program product as set forth in claim 17, wherein phenotypic subject categories of a target brain state comprise a creative thinking group and an analytic thinking group.

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