US 20080287821A1

(19) United States
(12) Patent Application Publication
Jung et al.
(10) Pub. No.: US 2008/0287821 A1
(43) Pub. Date: Nov. 20, 2008

(54) **COMPUTATIONAL USER-HEALTH TESTING**

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(21) Appl. No.: **12/151,742**

(22) Filed: **May 7, 2008**

Related U.S. Application Data

(63) Continuation-in-part of application No. 11/731,745, filed on Mar. 30, 2007, Continuation-in-part of application No. 11/731,778, filed on Mar. 30, 2007, Continuation-in-part of application No. 11/731,801, filed on Mar. 30, 2007, Continuation-in-part of application No. 11/804,304, filed on May 15, 2007.

Publication Classification

(51) **Int. Cl.**

A61B 5/12	(2006.01)
A61B 5/00	(2006.01)
A61B 5/0476	(2006.01)
A61B 5/11	(2006.01)

(52) **U.S. Cl.** **600/544**; 600/300; 600/558; 600/559; 600/595

(57) **ABSTRACT**

Methods, apparatuses, computer program products, devices and systems are described that carry out accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application; accepting brain activity measurement data proximate to the interaction; associating the at least one user-health test function output with the brain activity measurement data; and presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data.

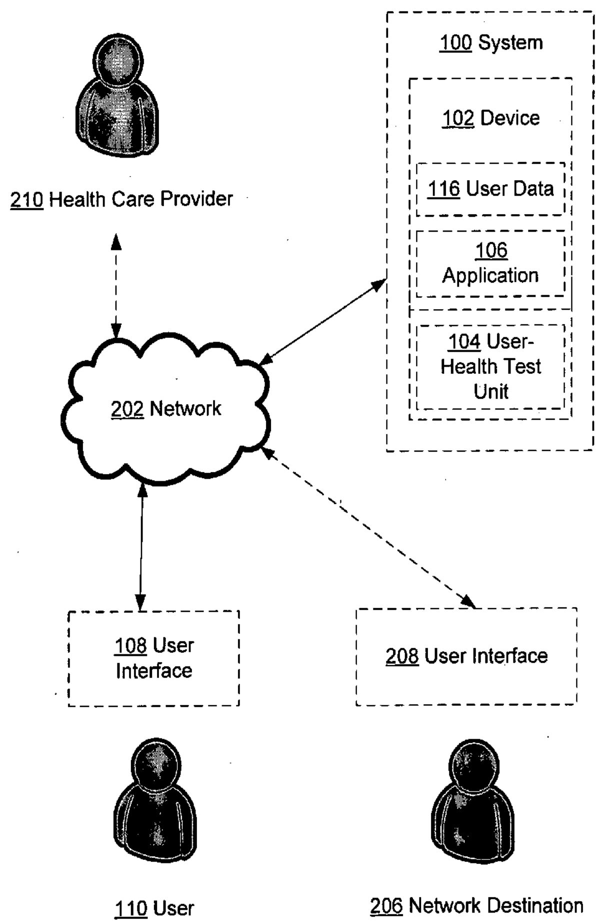


FIG. 1

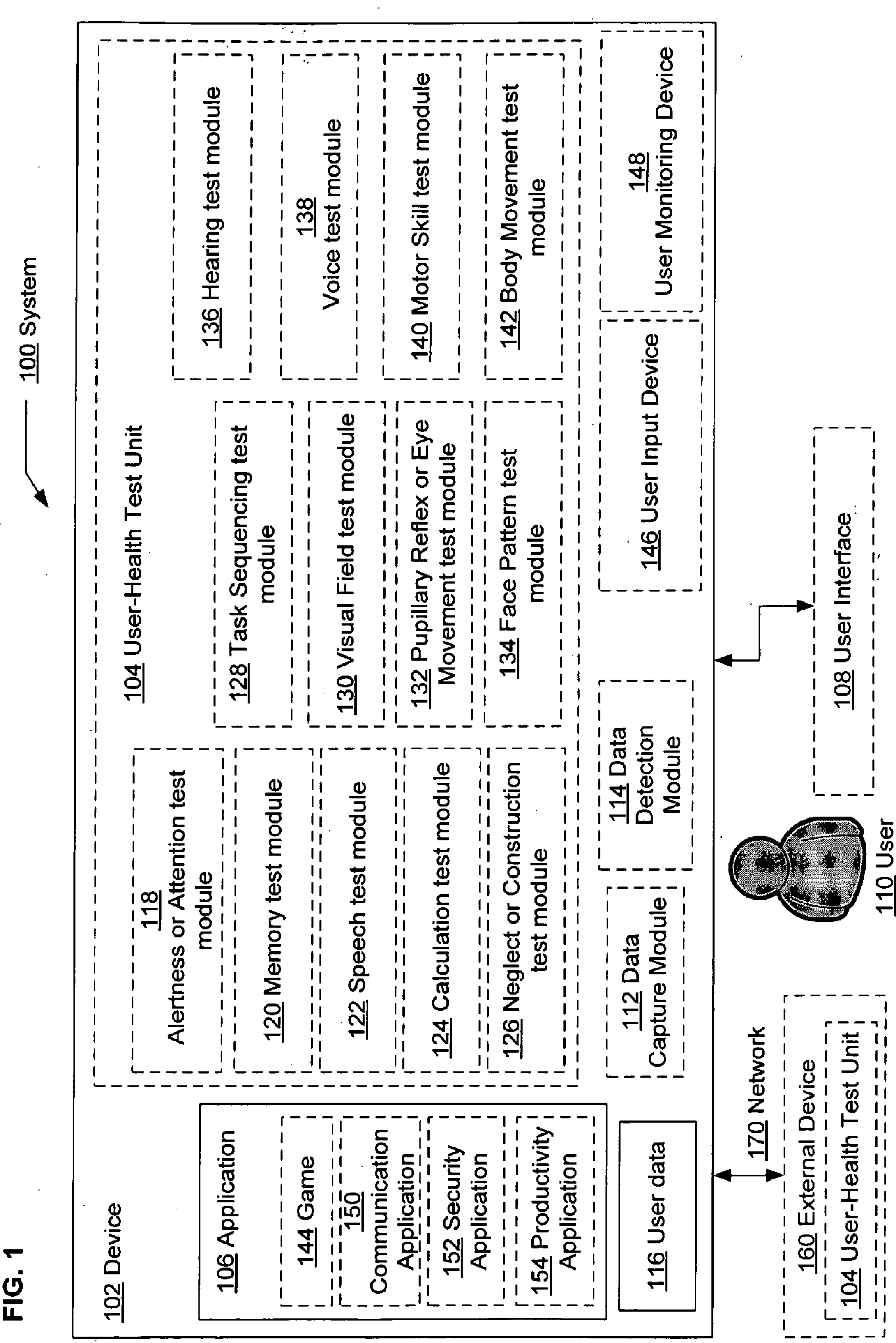

100 System
102 Device
106 Application
144 Game
150 Communication Application
152 Security Application
154 Productivity Application
116 User data
104 User-Health Test Unit
118 Alertness or Attention test module
120 Memory test module
122 Speech test module
124 Calculation test module
126 Neglect or Construction test module
128 Task Sequencing test module
130 Visual Field test module
132 Pupillary Reflex or Eye Movement test module
134 Face Pattern test module
136 Hearing test module
138 Voice test module
140 Motor Skill test module
142 Body Movement test module
112 Data Capture Module
114 Data Detection Module
146 User Input Device
148 User Monitoring Device
108 User Interface
110 User
170 Network
160 External Device
104 User-Health Test Unit

FIG. 2

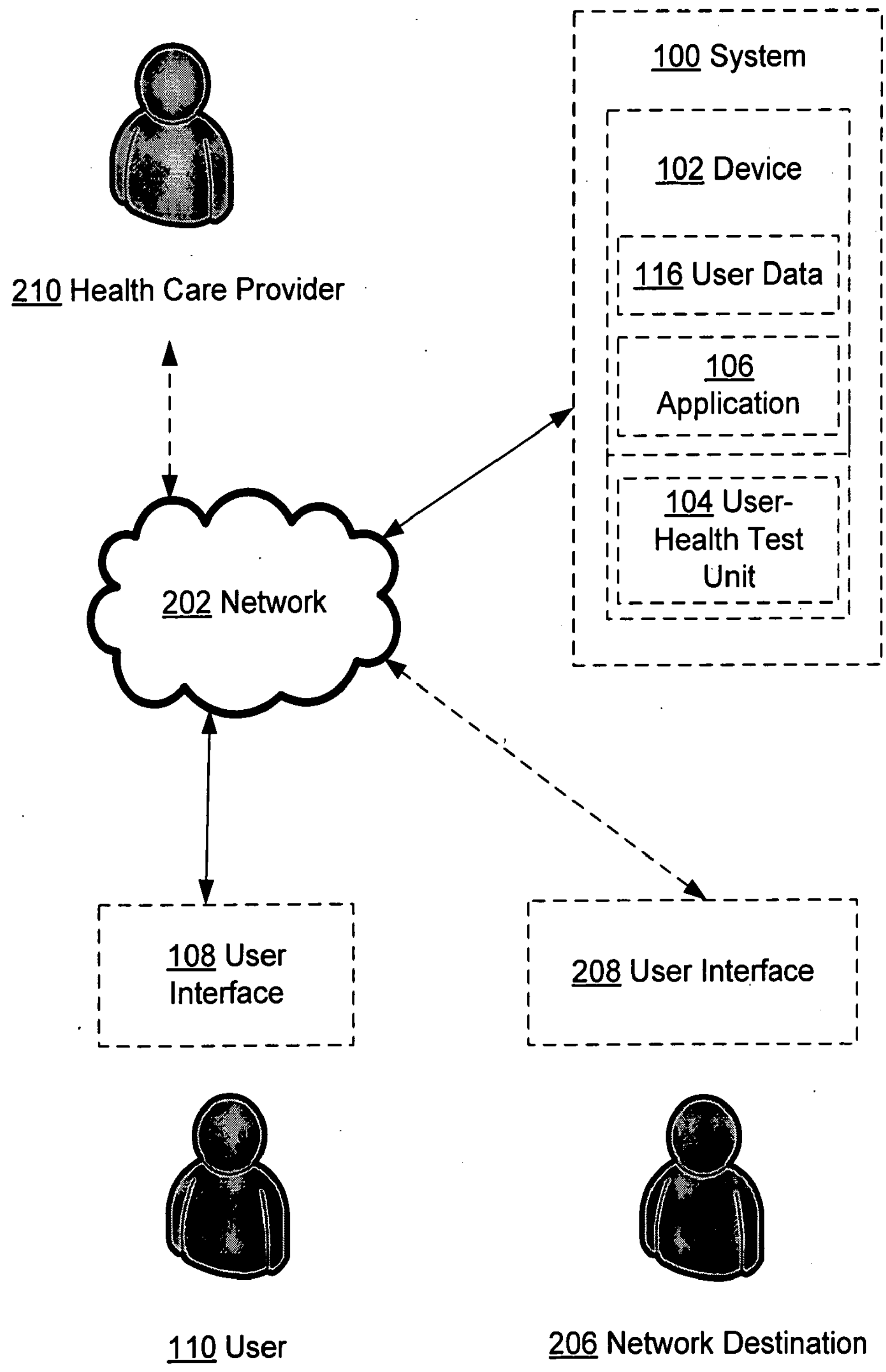

100 System
102 Device
116 User Data
106 Application
104 User-Health Test Unit
210 Health Care Provider
202 Network
108 User Interface
208 User Interface
110 User
206 Network Destination

FIG. 3

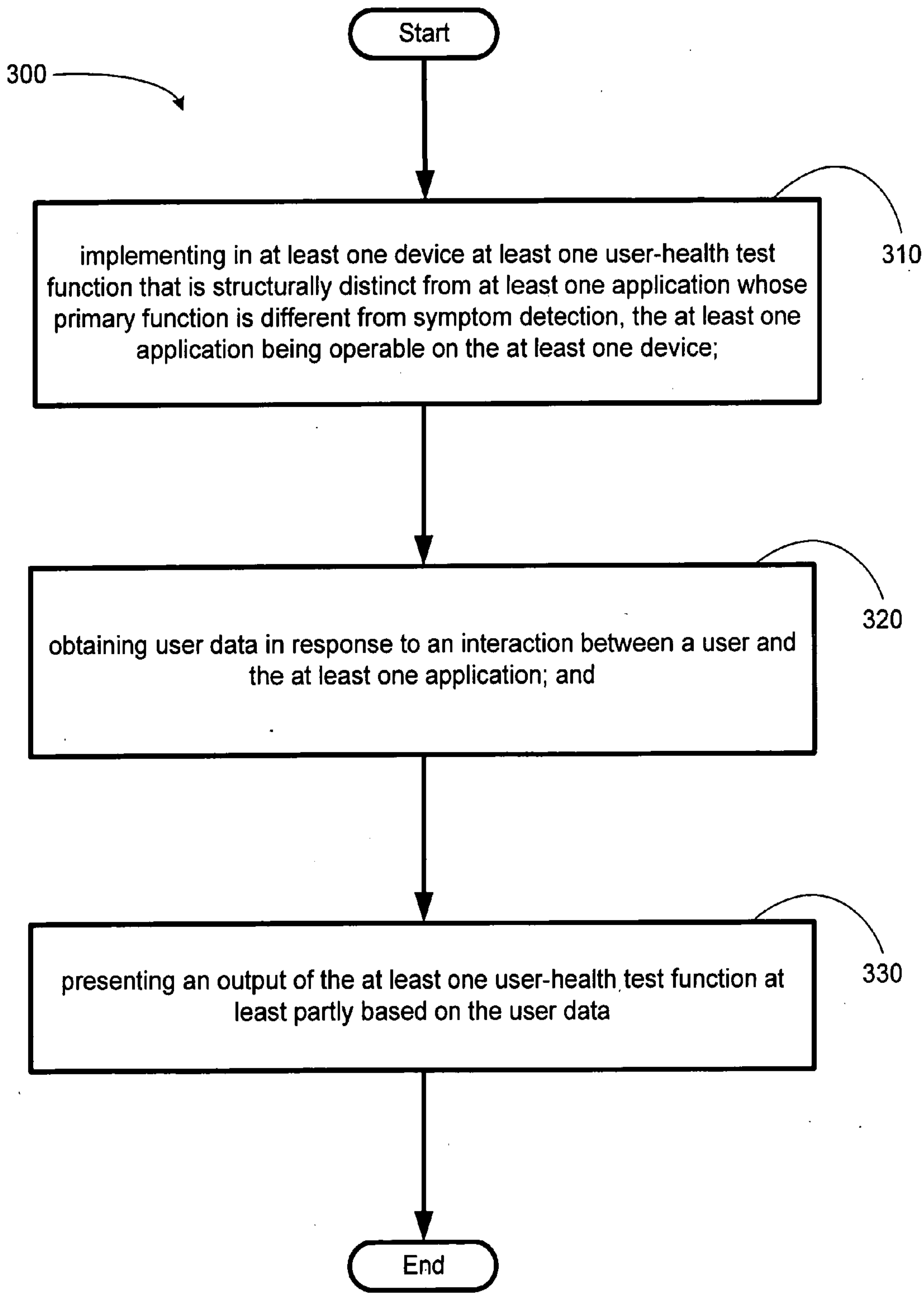
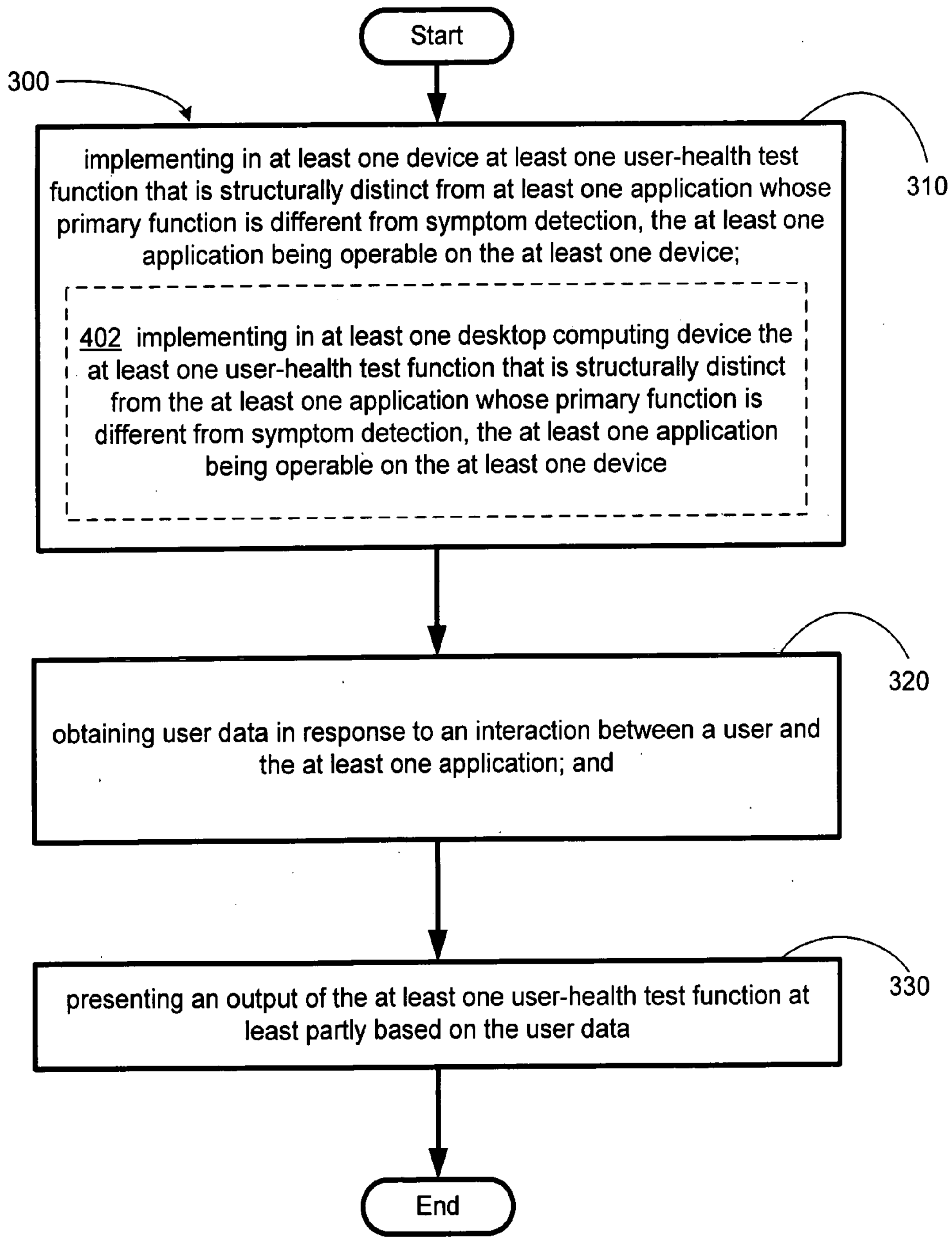

Start
300
implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
310
obtaining user data in response to an interaction between a user and the at least one application; and
320
presenting an output of the at least one user-health test function at least partly based on the user data
330
End

FIG. 4


Start
300
implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
310
402 implementing in at least one desktop computing device the at least one user-health test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device
obtaining user data in response to an interaction between a user and the at least one application; and
320
presenting an output of the at least one user-health test function at least partly based on the user data
330
End

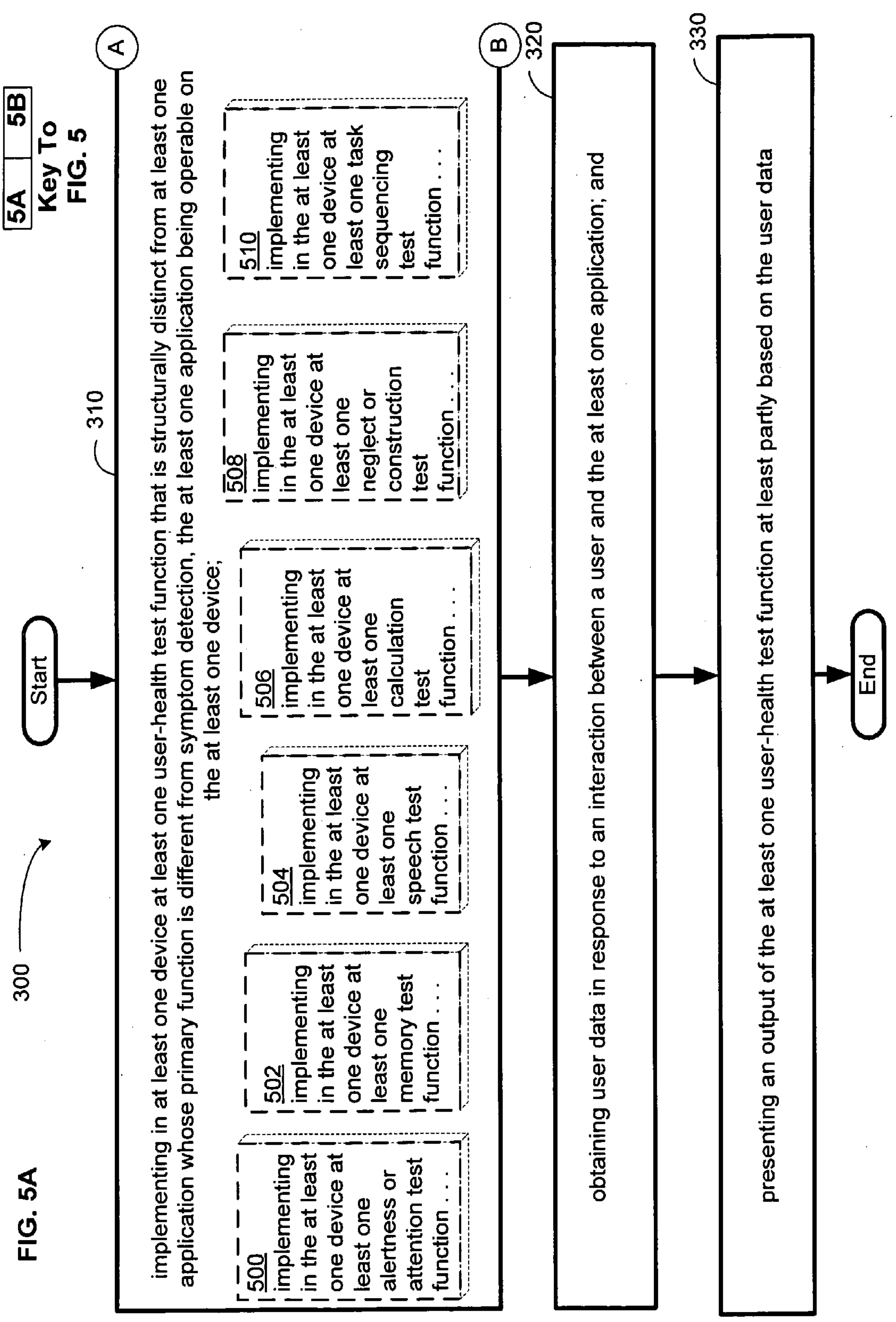

5A
5B
Key To
FIG. 5
300
Start
310
implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
A
500 implementing in the at least one device at least one alertness or attention test function . . .
502 implementing in the at least one device at least one memory test function . . .
504 implementing in the at least one device at least one speech test function . . .
506 implementing in the at least one device at least one calculation test function . . .
508 implementing in the at least one device at least one neglect or construction test function . . .
510 implementing in the at least one device at least one task sequencing test function . . .
B
320
obtaining user data in response to an interaction between a user and the at least one application; and
330
presenting an output of the at least one user-health test function at least partly based on the user data
End

FIG. 5A

FIG. 5B

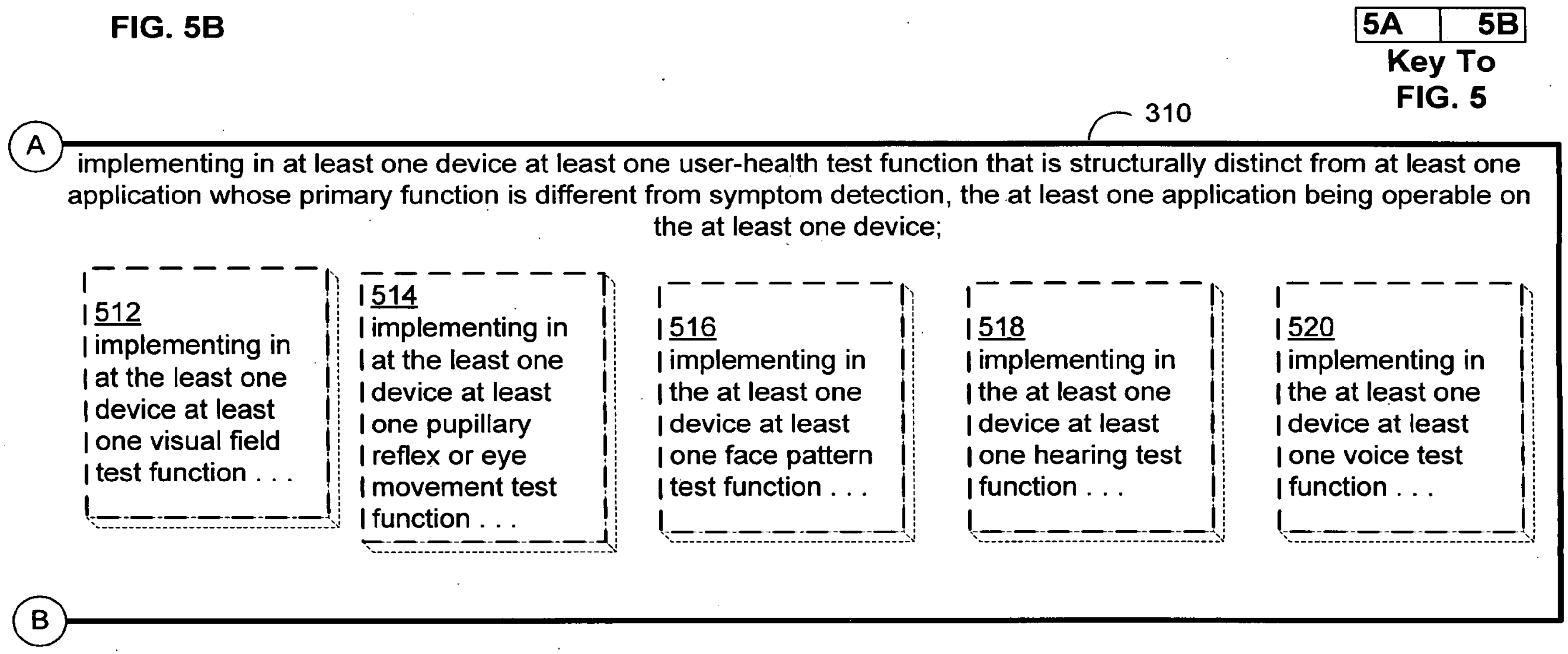
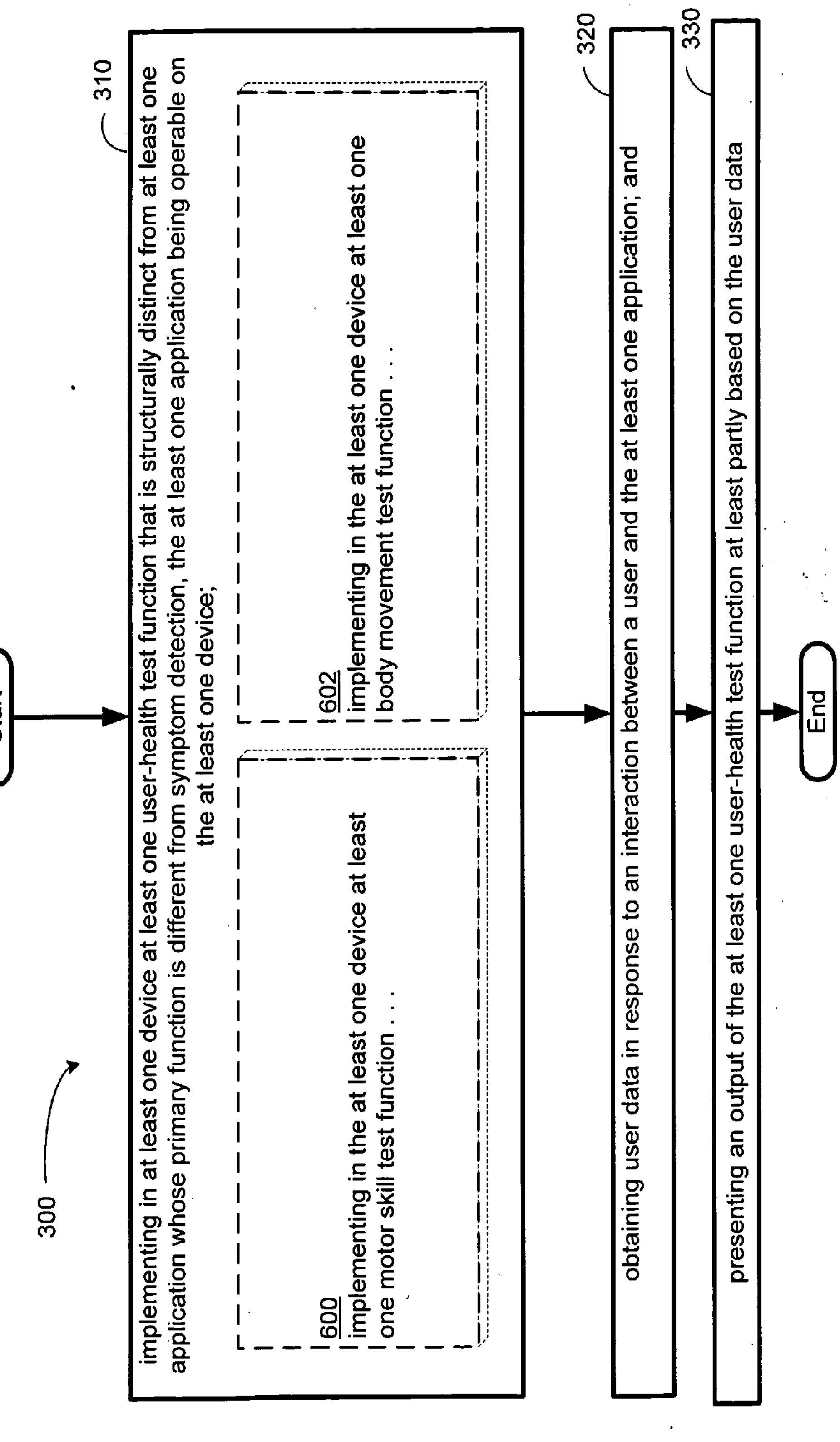

5A
5B
Key To
FIG. 5
310
A
implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
512
implementing in at the least one device at least one visual field test function . . .
514
implementing in at the least one device at least one pupillary reflex or eye movement test function . . .
516
implementing in the at least one device at least one face pattern test function . . .
518
implementing in the at least one device at least one hearing test function . . .
520
implementing in the at least one device at least one voice test function . . .
B

FIG. 6


300
Start
310
implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
600
implementing in the at least one device at least one motor skill test function . . .
602
implementing in the at least one device at least one body movement test function . . .
320
obtaining user data in response to an interaction between a user and the at least one application; and
330
presenting an output of the at least one user-health test function at least partly based on the user data
End

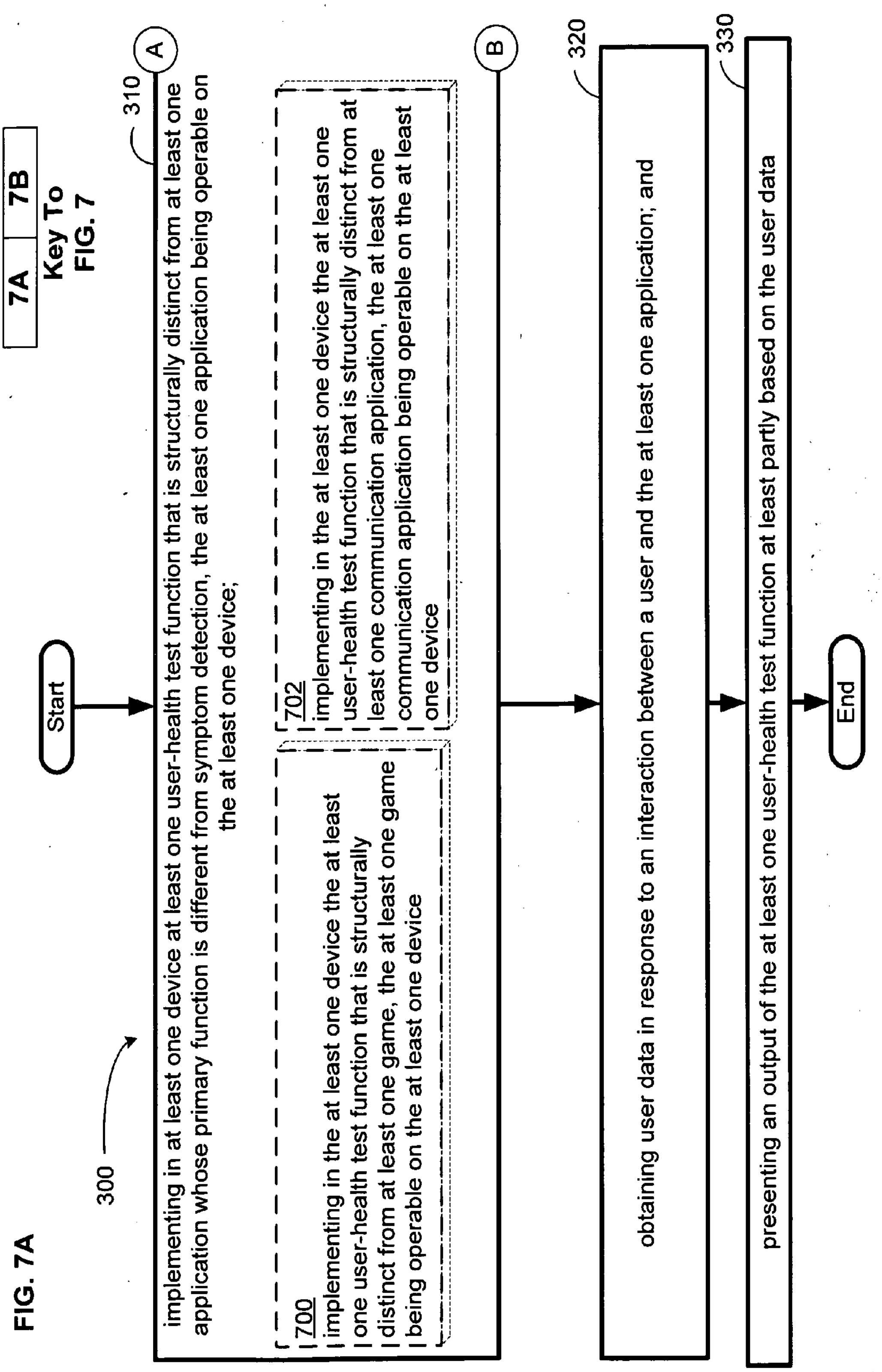
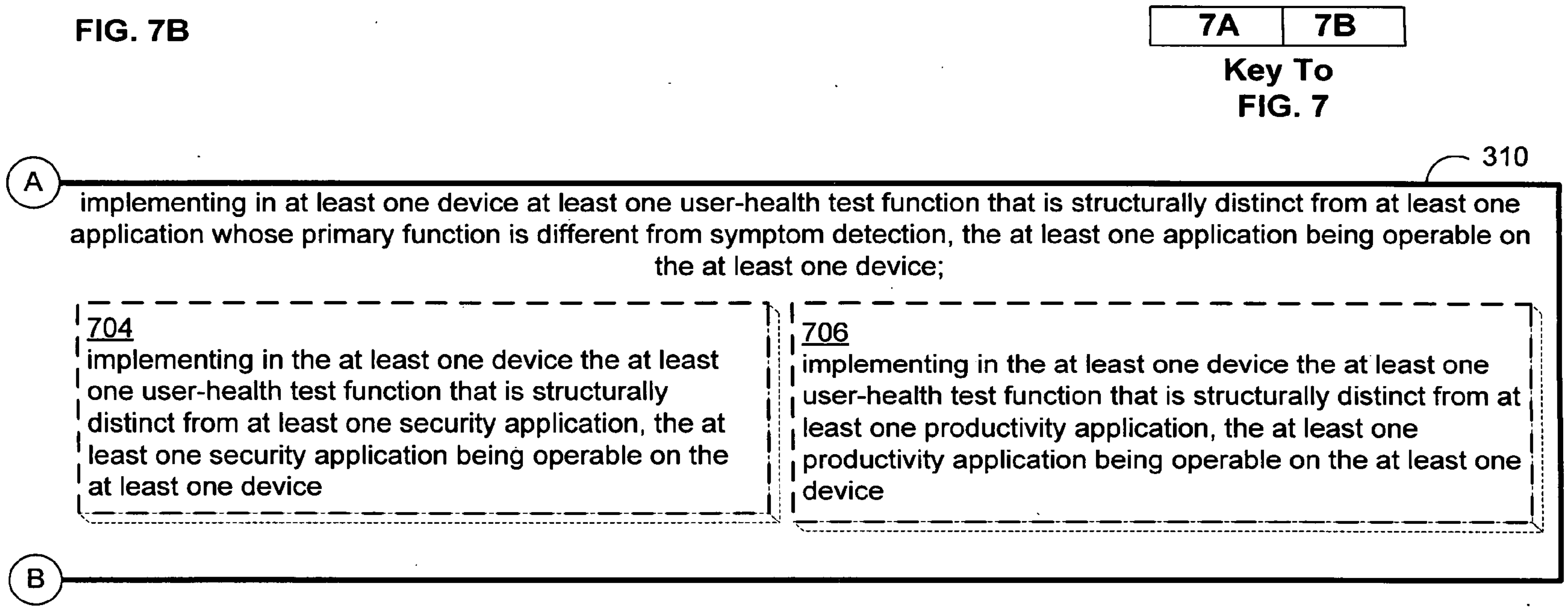

7A
7B
Key To
FIG. 7
300
Start
310
implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
A
700
implementing in the at least one device the at least one user-health test function that is structurally distinct from at least one game, the at least one game being operable on the at least one device
702
implementing in the at least one device the at least one user-health test function that is structurally distinct from at least one communication application, the at least one communication application being operable on the at least one device
B
320
obtaining user data in response to an interaction between a user and the at least one application; and
330
presenting an output of the at least one user-health test function at least partly based on the user data
End

FIG. 7A

FIG. 7B


7A
7B
Key To
FIG. 7
A
310
implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
704
implementing in the at least one device the at least one user-health test function that is structurally distinct from at least one security application, the at least one security application being operable on the at least one device
706
implementing in the at least one device the at least one user-health test function that is structurally distinct from at least one productivity application, the at least one productivity application being operable on the at least one device
B

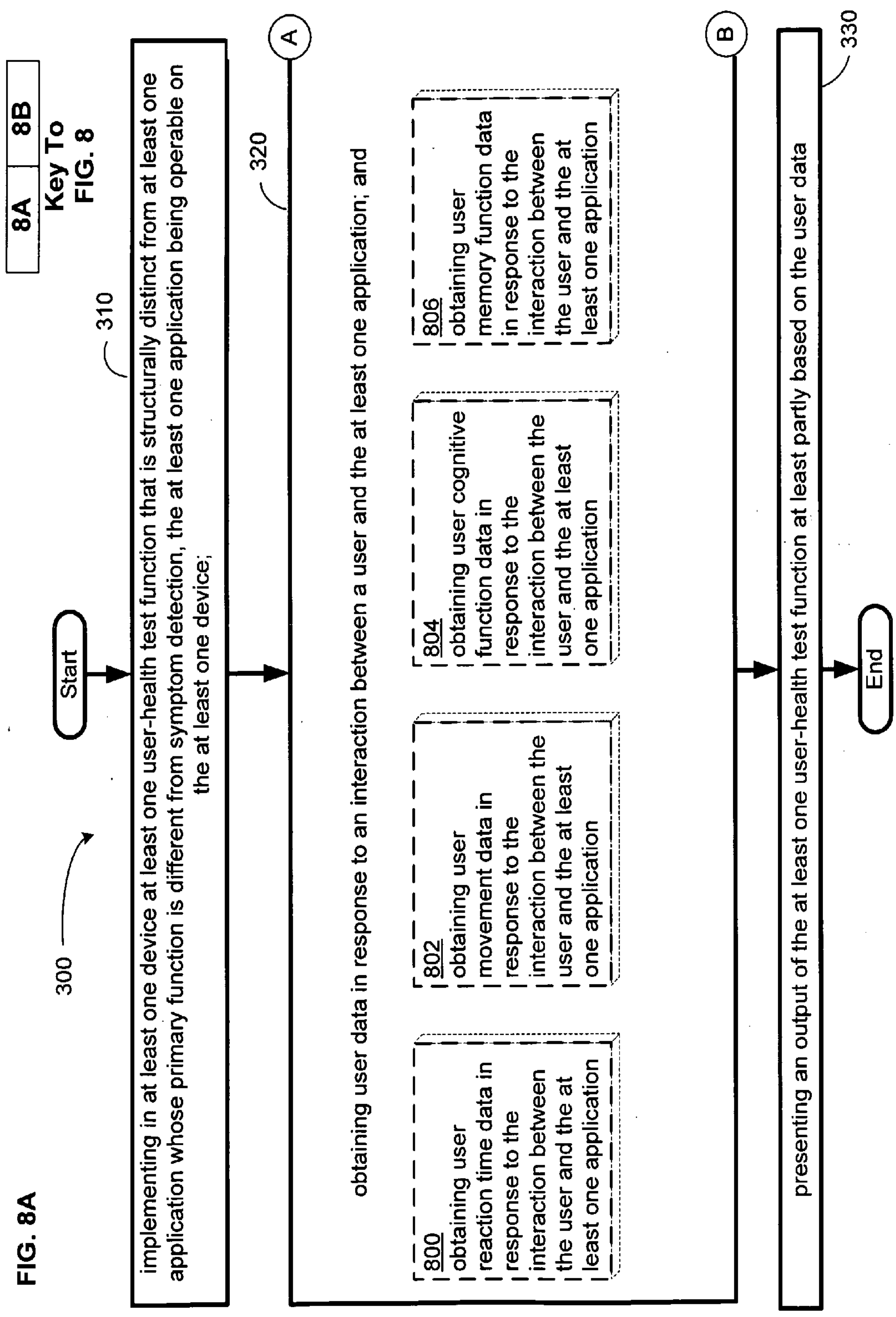

8A
8B
Key To FIG. 8
300
Start
310
implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
A
320
obtaining user data in response to an interaction between a user and the at least one application; and
800 obtaining user reaction time data in response to the interaction between the user and the at least one application
802 obtaining user movement data in response to the interaction between the user and the at least one application
804 obtaining user cognitive function data in response to the interaction between the user and the at least one application
806 obtaining user memory function data in response to the interaction between the user and the at least one application
B
330
presenting an output of the at least one user-health test function at least partly based on the user data
End

FIG. 8A

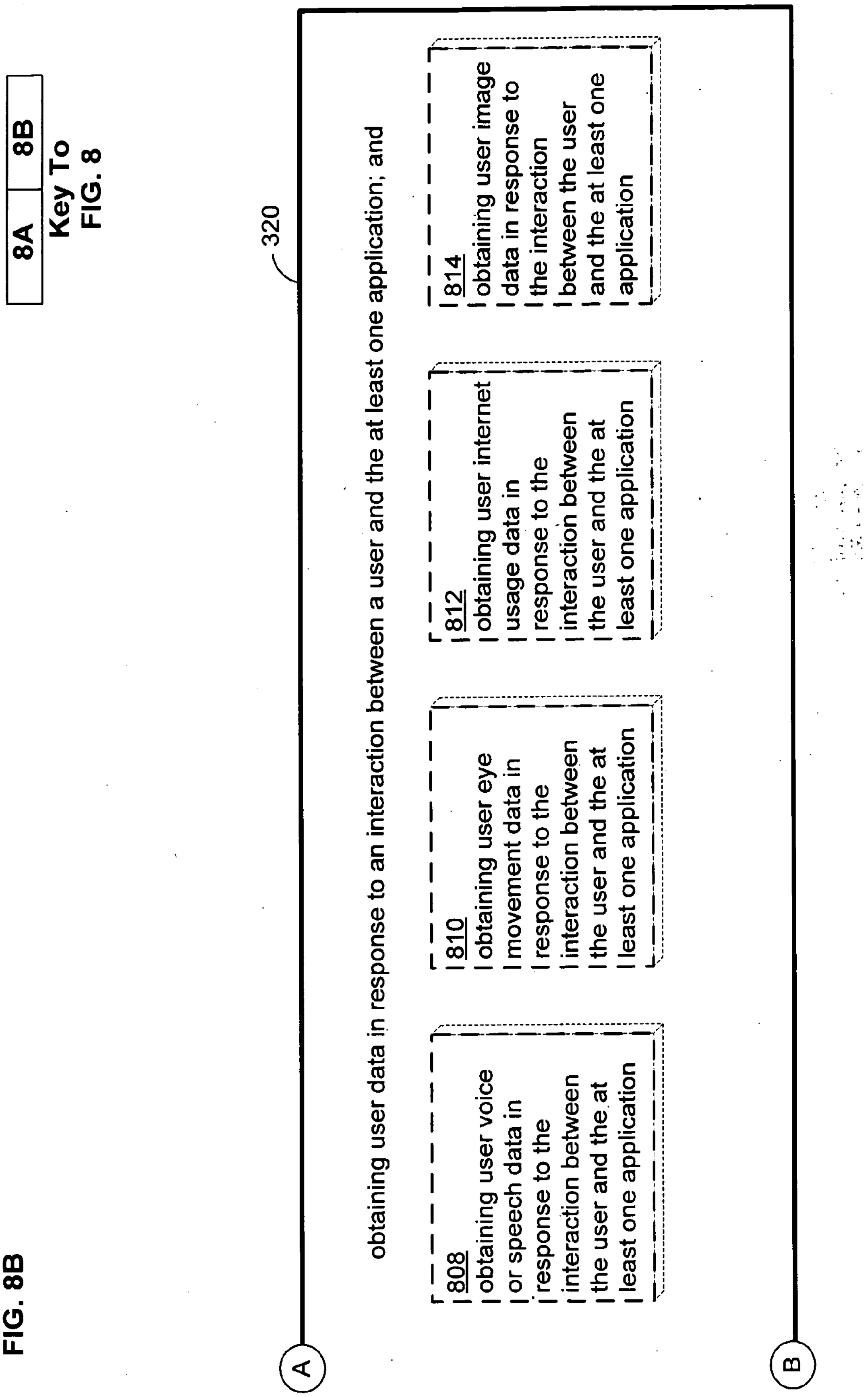

8A
8B
Key To FIG. 8
320
obtaining user data in response to an interaction between a user and the at least one application; and
808 obtaining user voice or speech data in response to the interaction between the user and the at least one application
810 obtaining user eye movement data in response to the interaction between the user and the at least one application
812 obtaining user internet usage data in response to the interaction between the user and the at least one application
814 obtaining user image data in response to the interaction between the user and the at least one application
A
B

FIG. 8B

FIG. 9

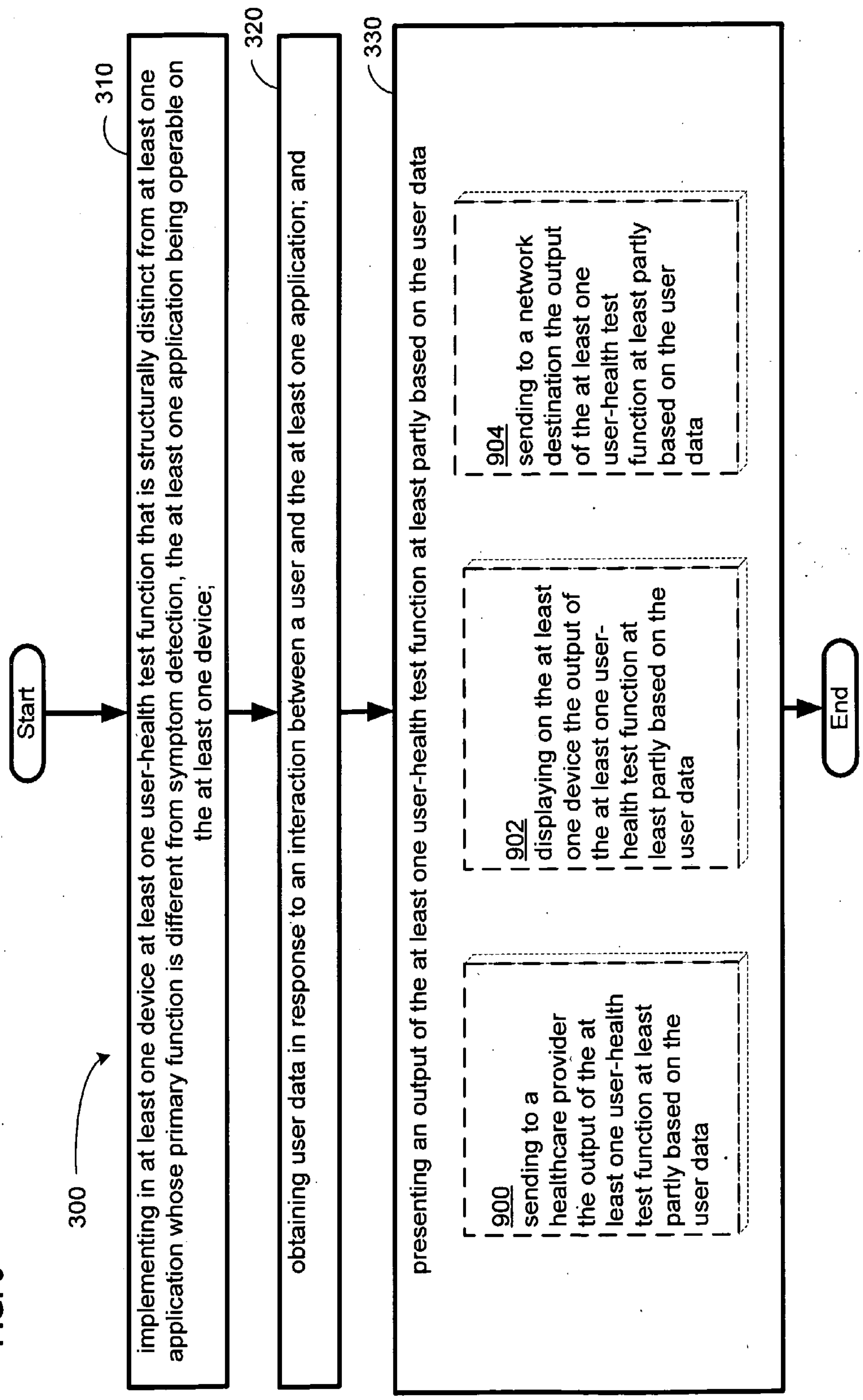

300
Start
310
implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
320
obtaining user data in response to an interaction between a user and the at least one application; and
330
presenting an output of the at least one user-health test function at least partly based on the user data
900
sending to a healthcare provider the output of the at least one user-health test function at least partly based on the user data
902
displaying on the at least one device the output of the at least one user-health test function at least partly based on the user data
904
sending to a network destination the output of the at least one user-health test function at least partly based on the user data
End

FIG. 10

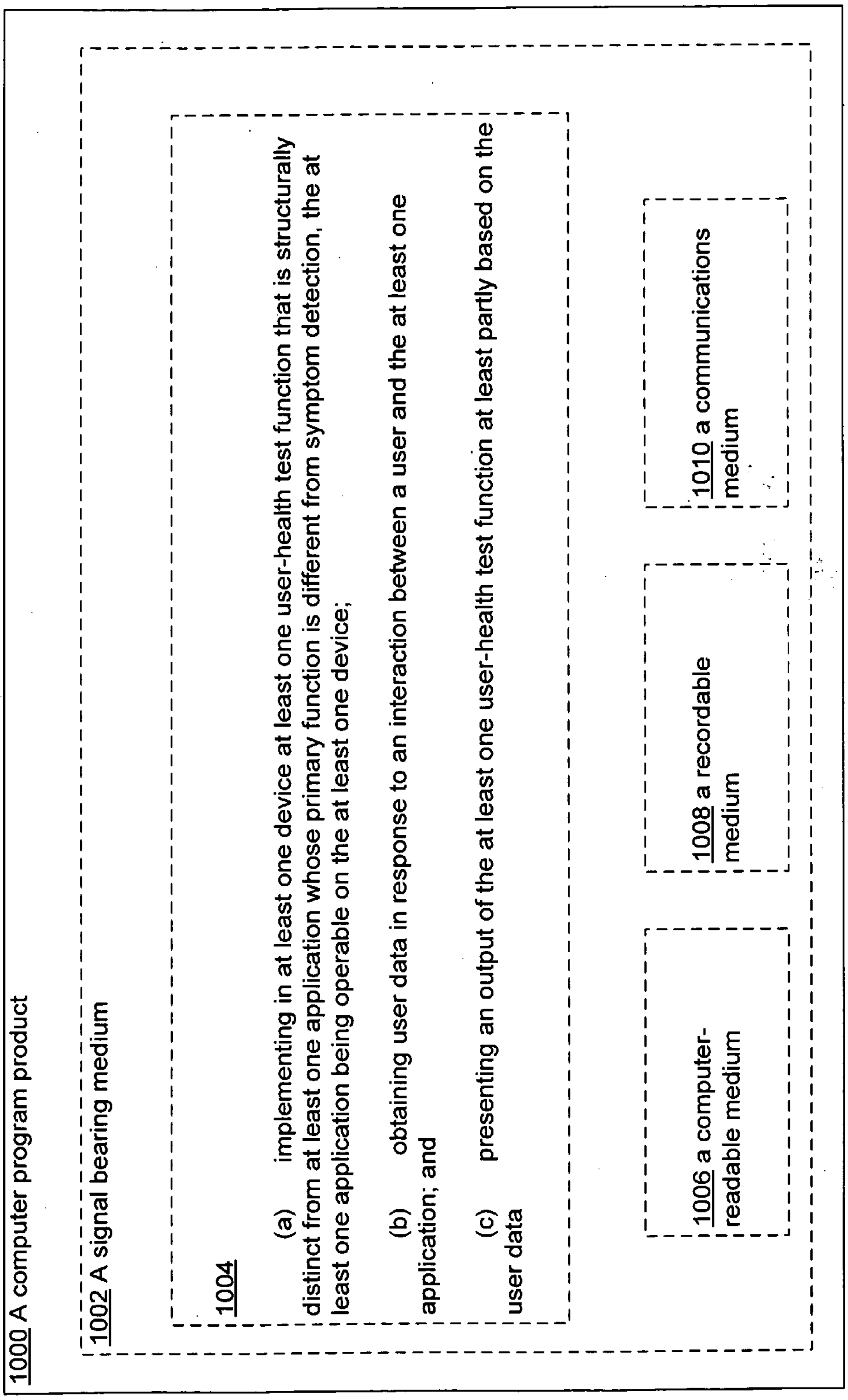

1000 A computer program product
1002 A signal bearing medium
1004
(a) implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
(b) obtaining user data in response to an interaction between a user and the at least one application; and
(c) presenting an output of the at least one user-health test function at least partly based on the user data
1006 a computer-readable medium
1008 a recordable medium
1010 a communications medium

FIG. 11

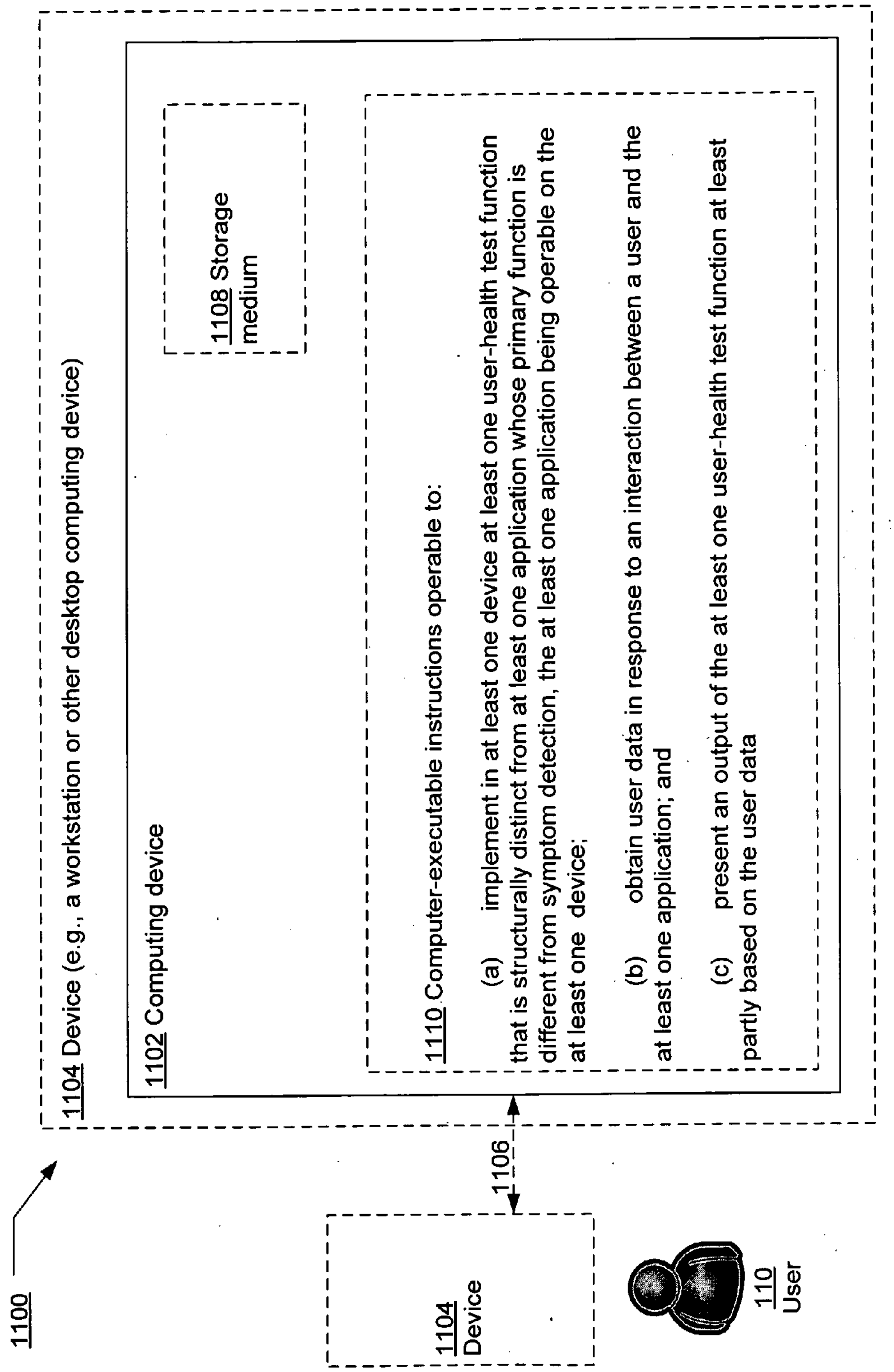

1100
1104 Device (e.g., a workstation or other desktop computing device)
1102 Computing device
1108 Storage medium
1110 Computer-executable instructions operable to:
(a) implement in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device;
(b) obtain user data in response to an interaction between a user and the at least one application; and
(c) present an output of the at least one user-health test function at least partly based on the user data
1106
1104 Device
110 User

FIG. 12

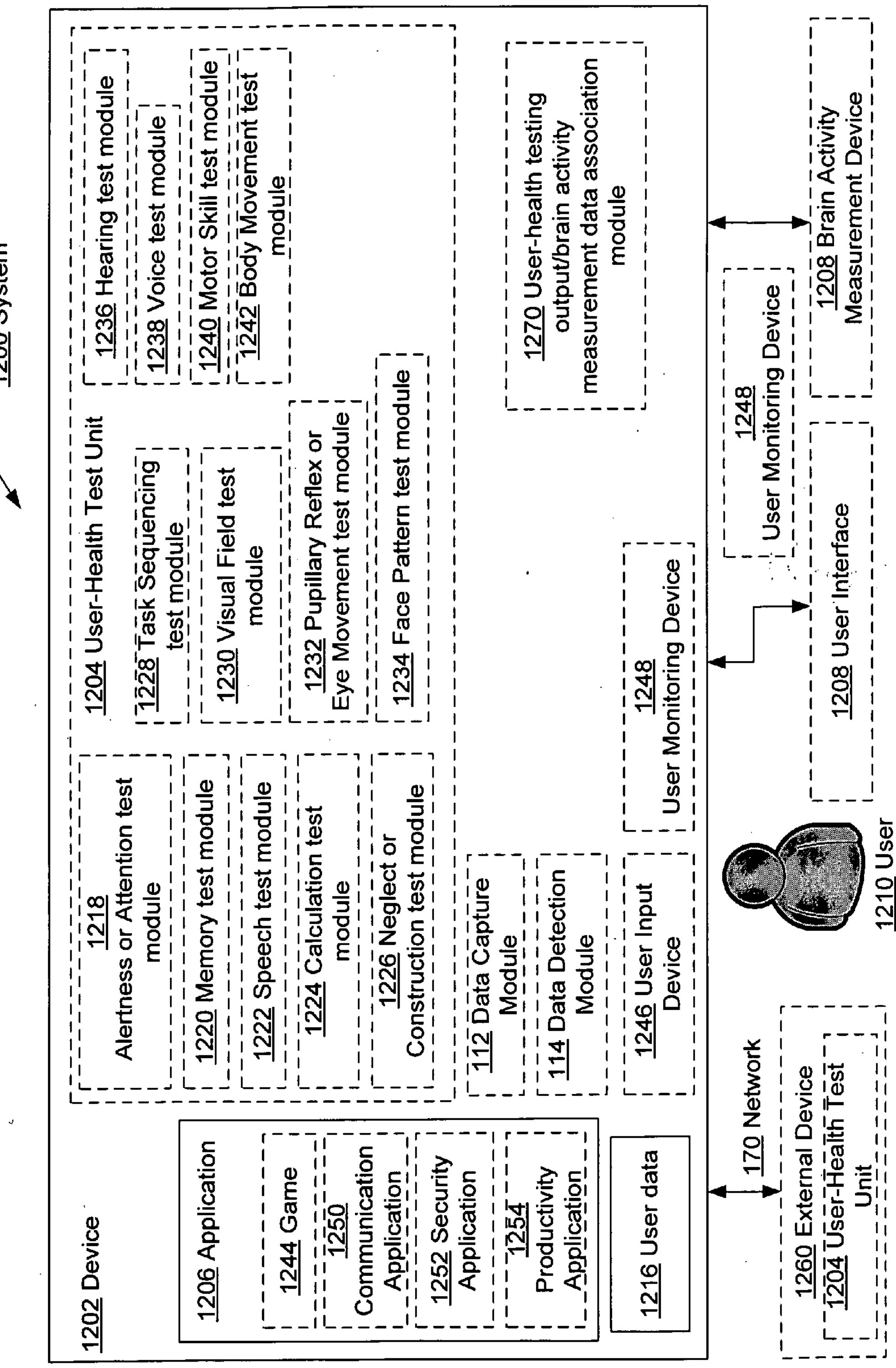

1200 System
1202 Device
1206 Application
1244 Game
1250 Communication Application
1252 Security Application
1254 Productivity Application
1216 User data
1204 User-Health Test Unit
1218 Alertness or Attention test module
1220 Memory test module
1222 Speech test module
1224 Calculation test module
1226 Neglect or Construction test module
1228 Task Sequencing test module
1230 Visual Field test module
1232 Pupillary Reflex or Eye Movement test module
1234 Face Pattern test module
1236 Hearing test module
1238 Voice test module
1240 Motor Skill test module
1242 Body Movement test module
1270 User-health testing output/brain activity measurement data association module
112 Data Capture Module
114 Data Detection Module
1246 User Input Device
1248 User Monitoring Device
1248 User Monitoring Device
170 Network
1260 External Device
1204 User-Health Test Unit
1210 User
1208 User Interface
1208 Brain Activity Measurement Device

FIG. 13

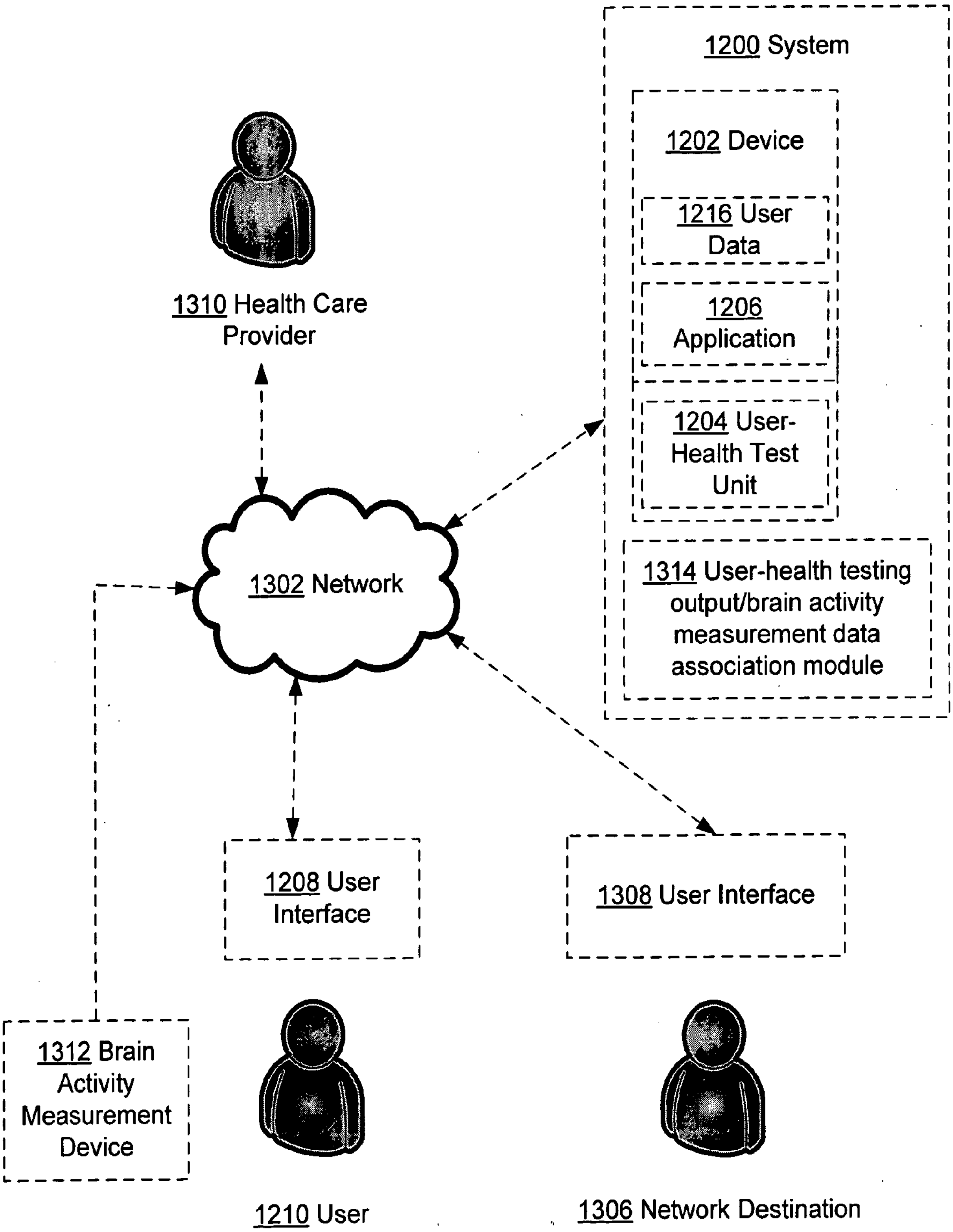
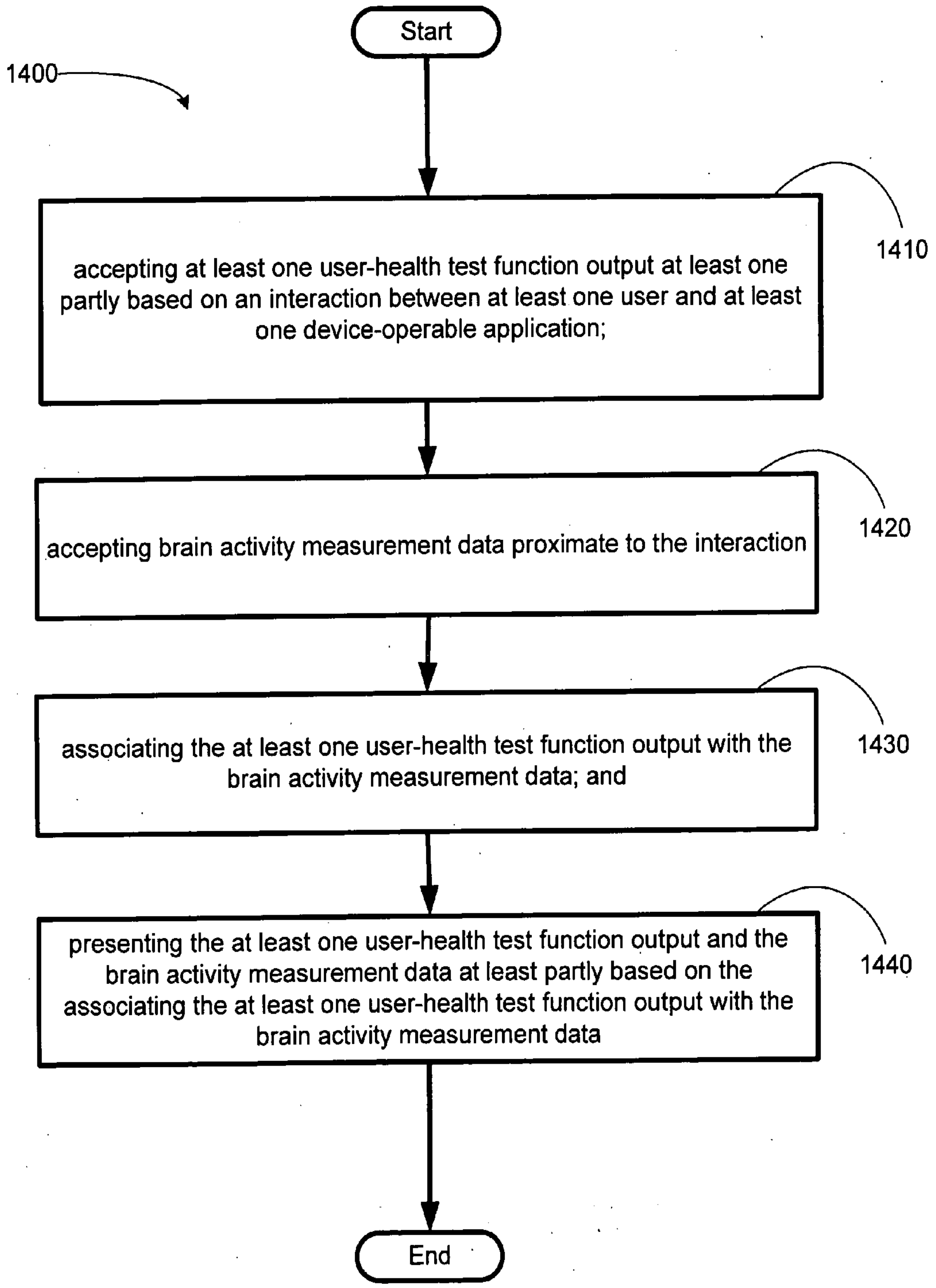

1200 System
1202 Device
1216 User Data
1206 Application
1204 User-Health Test Unit
1314 User-health testing output/brain activity measurement data association module
1310 Health Care Provider
1302 Network
1208 User Interface
1308 User Interface
1312 Brain Activity Measurement Device
1210 User
1306 Network Destination

FIG. 14



Start
1400
accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
1410
accepting brain activity measurement data proximate to the interaction
1420
associating the at least one user-health test function output with the brain activity measurement data; and
1430
presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
1440
End

FIG. 15

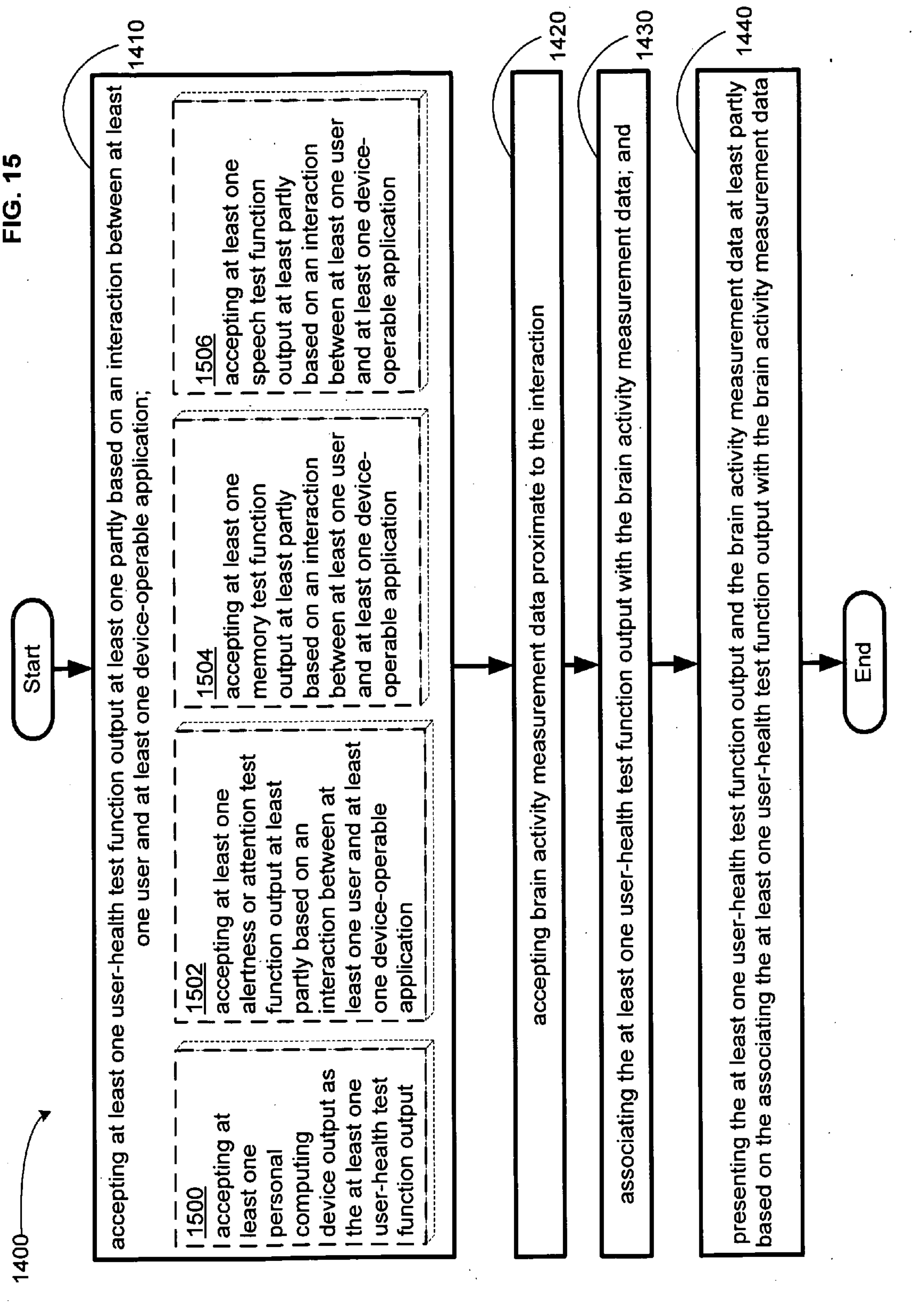

1400
Start
1410
accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
1500
accepting at least one personal computing device output as the at least one user-health test function output
1502
accepting at least one alertness or attention test function output at least partly based on an interaction between at least one user and at least one device-operable application
1504
accepting at least one memory test function output at least partly based on an interaction between at least one user and at least one device-operable application
1506
accepting at least one speech test function output at least partly based on an interaction between at least one user and at least one device-operable application
1420
accepting brain activity measurement data proximate to the interaction
1430
associating the at least one user-health test function output with the brain activity measurement data; and
1440
presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
End

FIG. 16

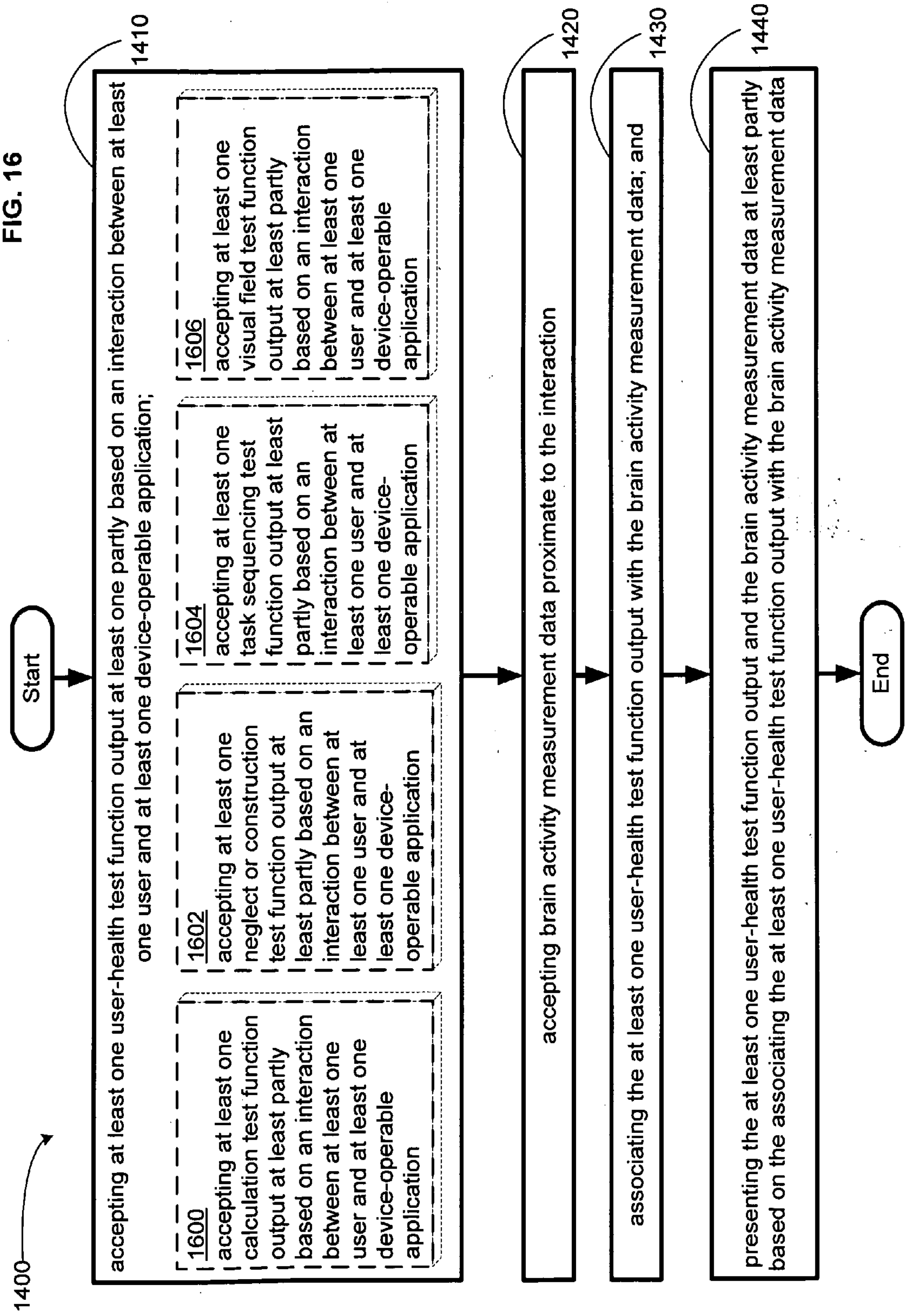

1400
Start
1410
accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
1600
accepting at least one calculation test function output at least partly based on an interaction between at least one user and at least one device-operable application
1602
accepting at least one neglect or construction test function output at least partly based on an interaction between at least one user and at least one device-operable application
1604
accepting at least one task sequencing test function output at least partly based on an interaction between at least one user and at least one device-operable application
1606
accepting at least one visual field test function output at least partly based on an interaction between at least one user and at least one device-operable application
1420
accepting brain activity measurement data proximate to the interaction
1430
associating the at least one user-health test function output with the brain activity measurement data; and
1440
presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
End

FIG. 17

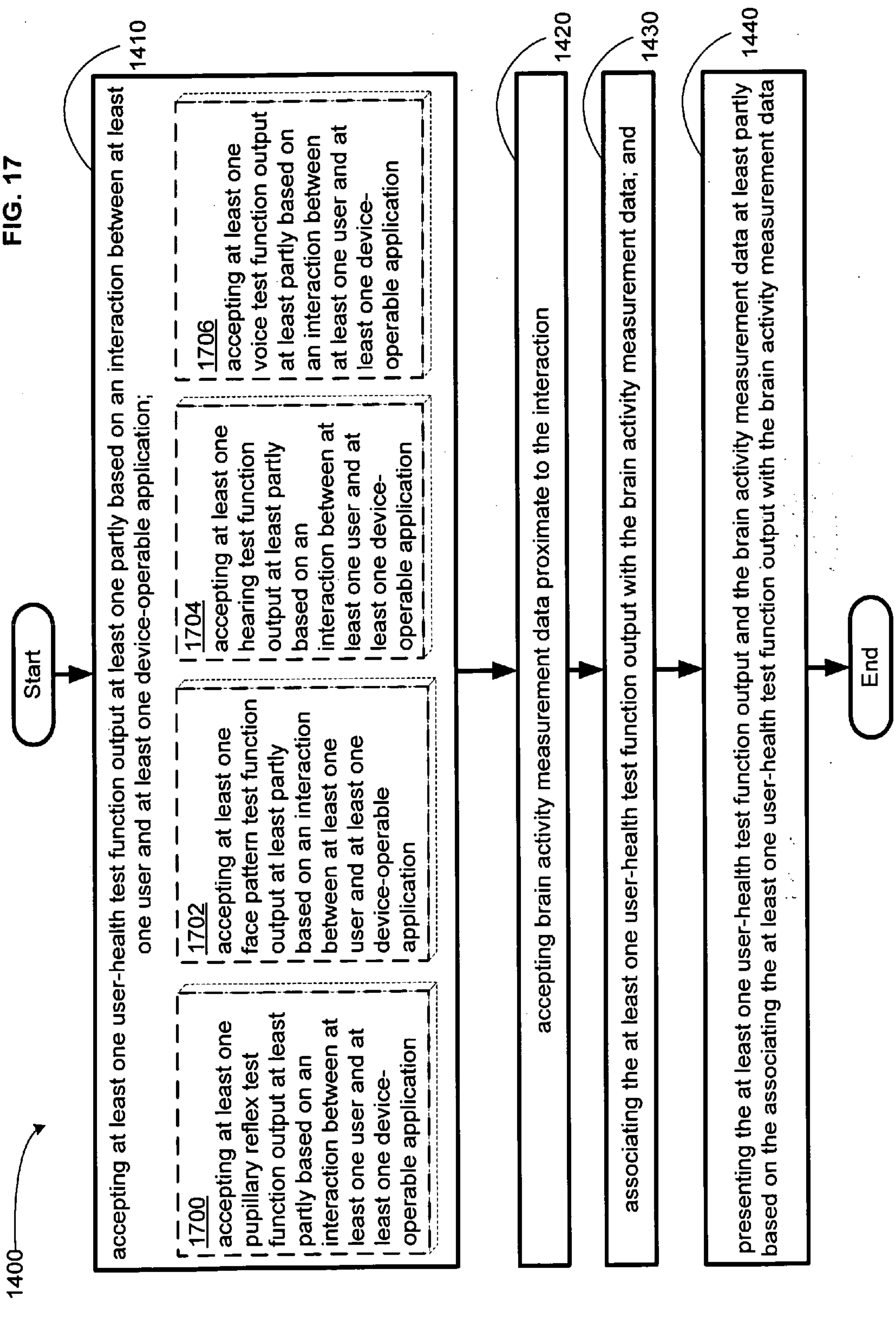
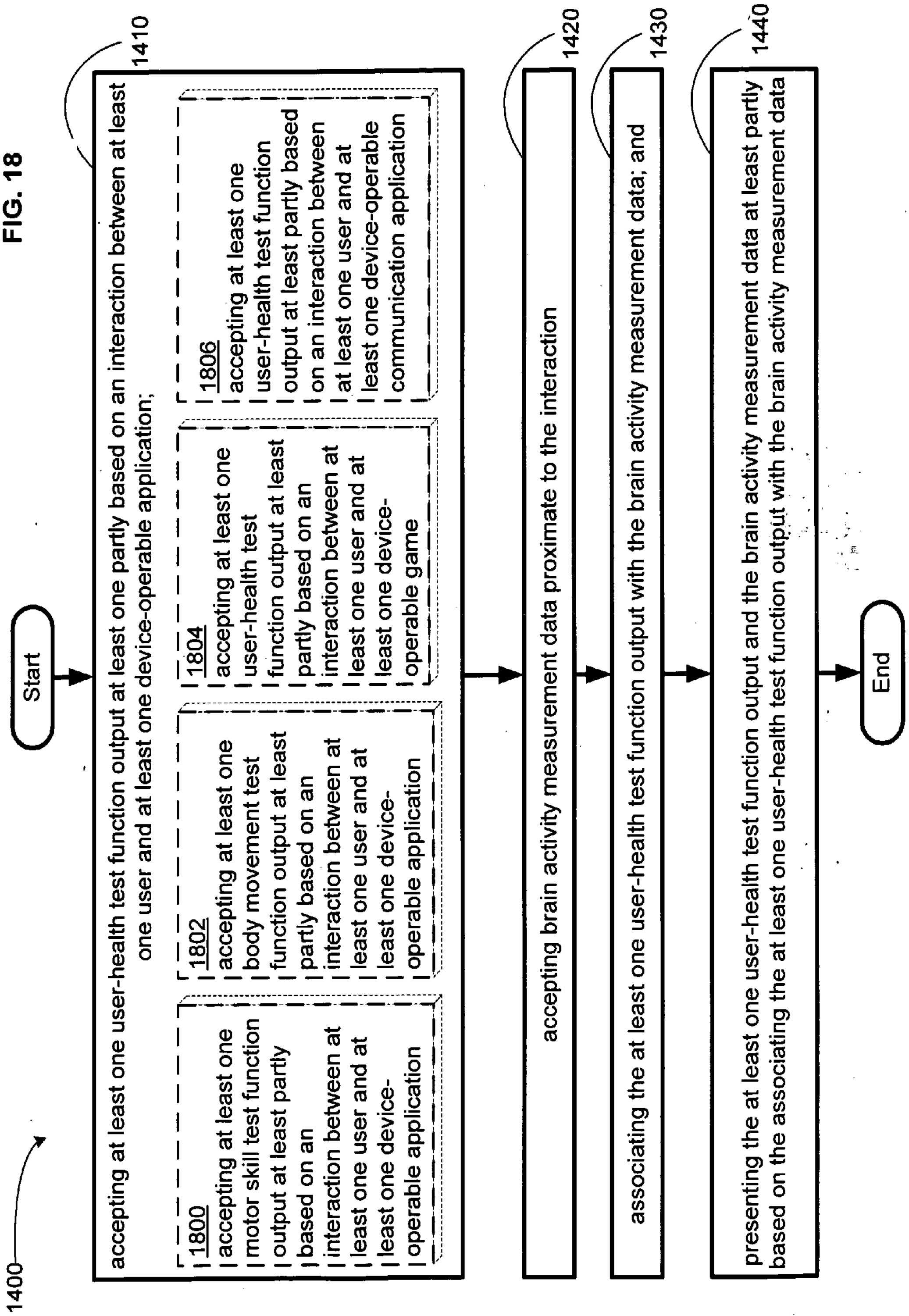

1400
Start
1410
accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
1700
accepting at least one pupillary reflex test function output at least partly based on an interaction between at least one user and at least one device-operable application
1702
accepting at least one face pattern test function output at least partly based on an interaction between at least one user and at least one device-operable application
1704
accepting at least one hearing test function output at least partly based on an interaction between at least one user and at least one device-operable application
1706
accepting at least one voice test function output at least partly based on an interaction between at least one user and at least one device-operable application
1420
accepting brain activity measurement data proximate to the interaction
1430
associating the at least one user-health test function output with the brain activity measurement data; and
1440
presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
End

FIG. 18


1400
Start
1410
accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
1800
accepting at least one motor skill test function output at least partly based on an interaction between at least one user and at least one device-operable application
1802
accepting at least one body movement test function output at least partly based on an interaction between at least one user and at least one device-operable application
1804
accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable game
1806
accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable communication application
1420
accepting brain activity measurement data proximate to the interaction
1430
associating the at least one user-health test function output with the brain activity measurement data; and
1440
presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
End

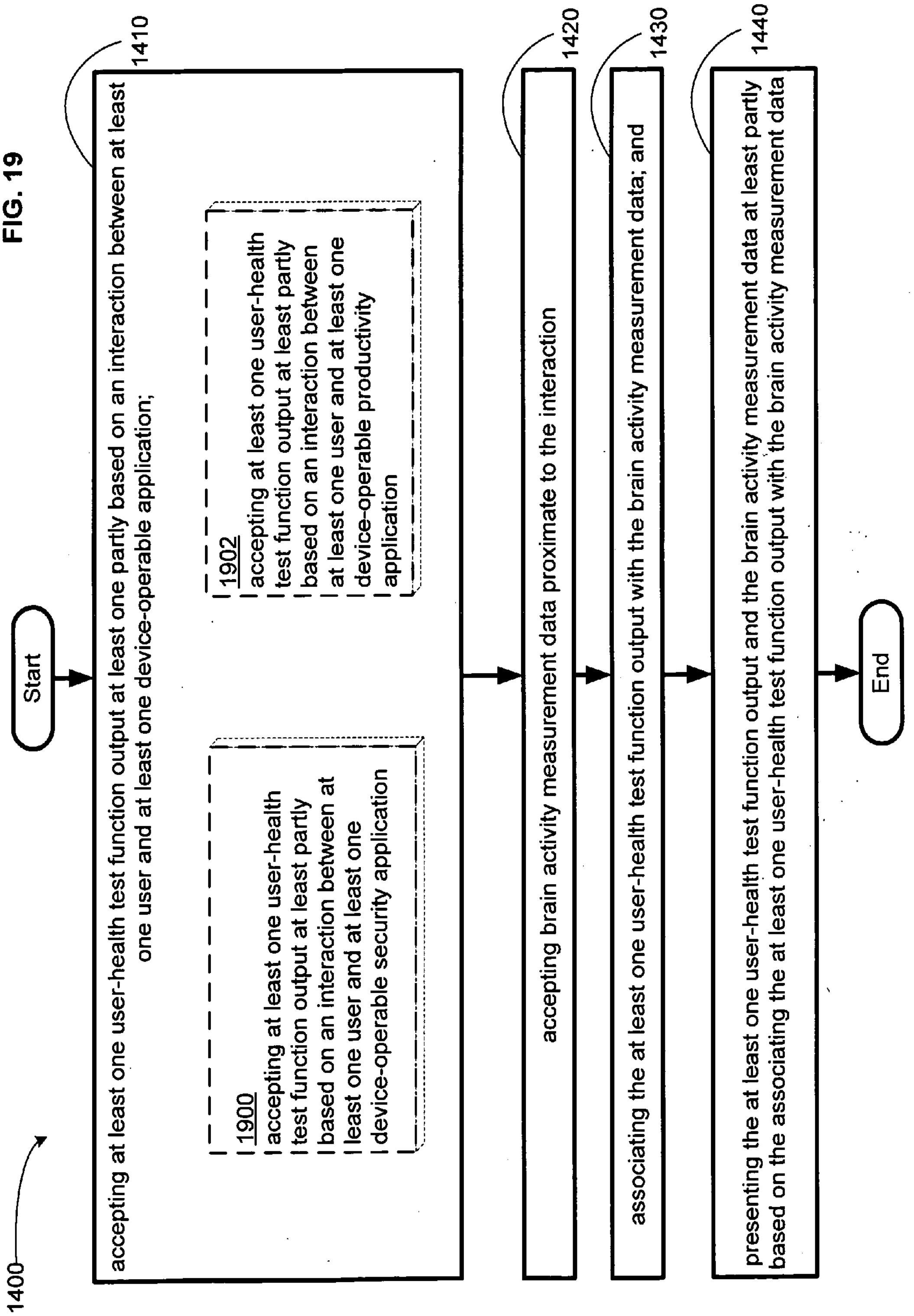

1400
Start
accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
1410
1900
accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable security application
1902
accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable productivity application
accepting brain activity measurement data proximate to the interaction
1420
associating the at least one user-health test function output with the brain activity measurement data; and
1430
presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
1440
End

FIG. 19

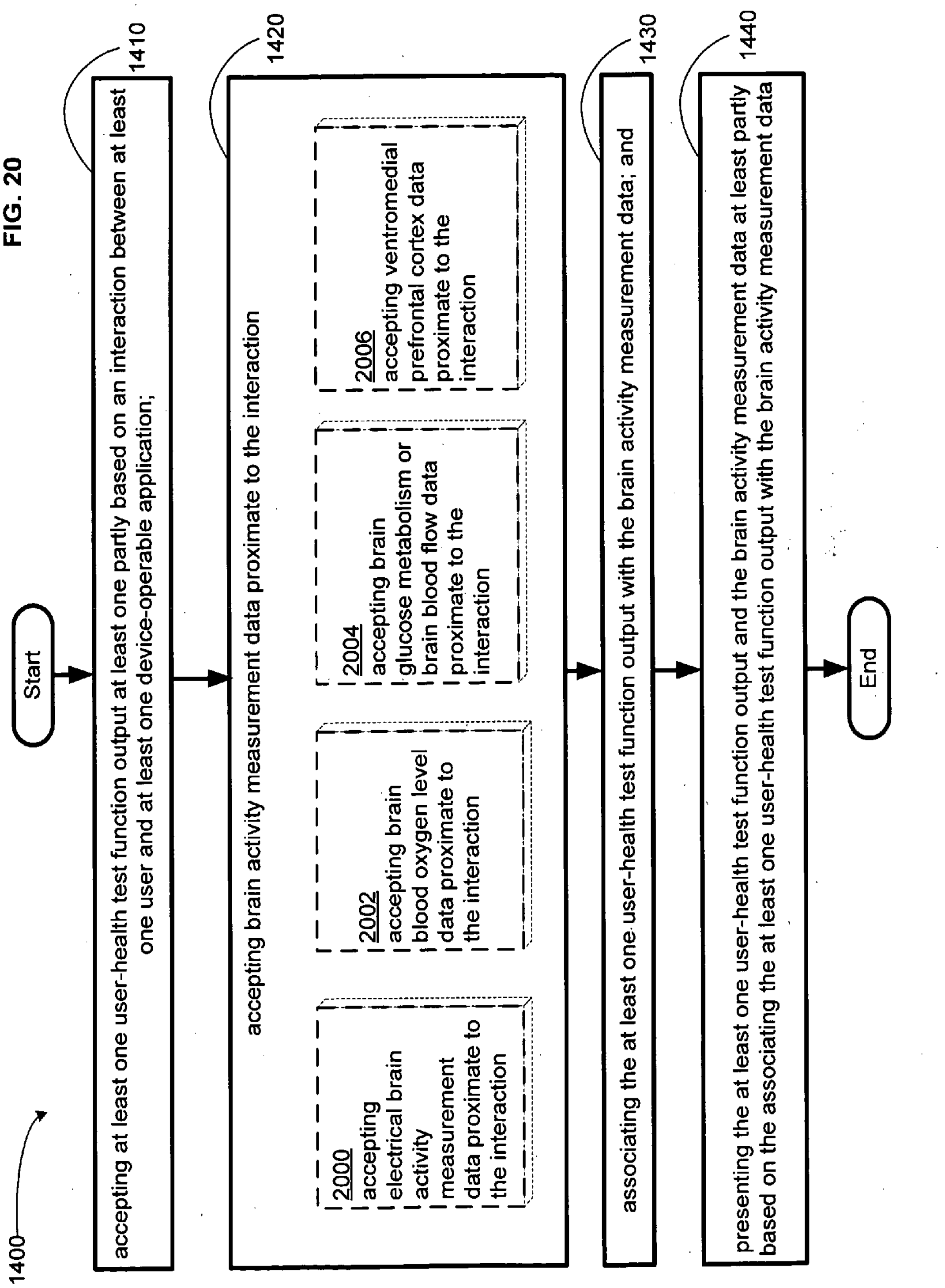

1400
Start
1410
accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
1420
accepting brain activity measurement data proximate to the interaction
2000 accepting electrical brain activity measurement data proximate to the interaction
2002 accepting brain blood oxygen level data proximate to the interaction
2004 accepting brain glucose metabolism or brain blood flow data proximate to the interaction
2006 accepting ventromedial prefrontal cortex data proximate to the interaction
1430
associating the at least one user-health test function output with the brain activity measurement data; and
1440
presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
End

FIG. 20

FIG. 21

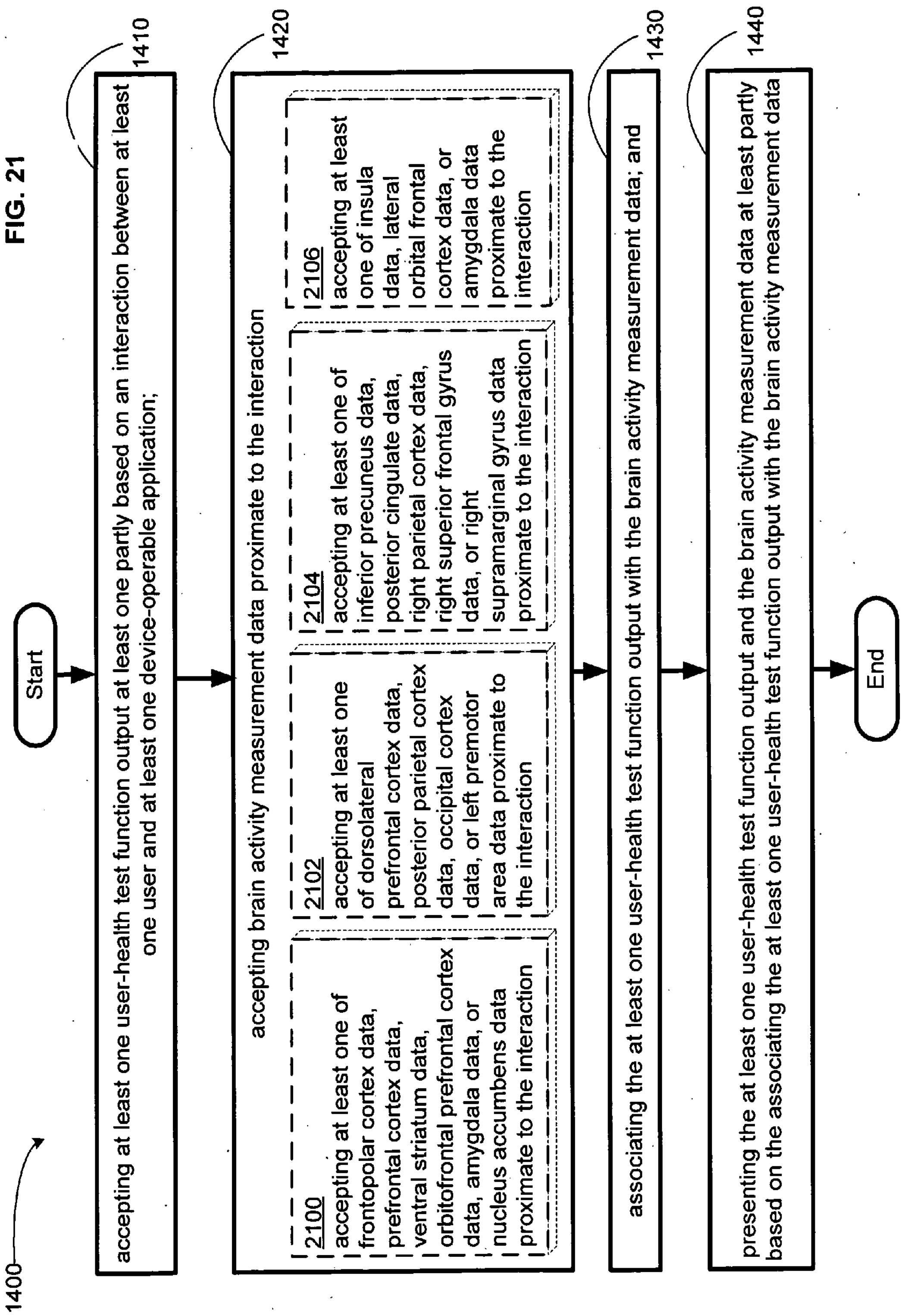

1400
Start
accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
1410
accepting brain activity measurement data proximate to the interaction
1420
2100
accepting at least one of frontopolar cortex data, prefrontal cortex data, ventral striatum data, orbitofrontal prefrontal cortex data, amygdala data, or nucleus accumbens data proximate to the interaction
2102
accepting at least one of dorsolateral prefrontal cortex data, posterior parietal cortex data, occipital cortex data, or left premotor area data proximate to the interaction
2104
accepting at least one of inferior precuneus data, posterior cingulate data, right parietal cortex data, right superior frontal gyrus data, or right supramarginal gyrus data proximate to the interaction
2106
accepting at least one of insula data, lateral orbital frontal cortex data, or amygdala data proximate to the interaction
associating the at least one user-health test function output with the brain activity measurement data; and
1430
presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
1440
End

FIG. 22

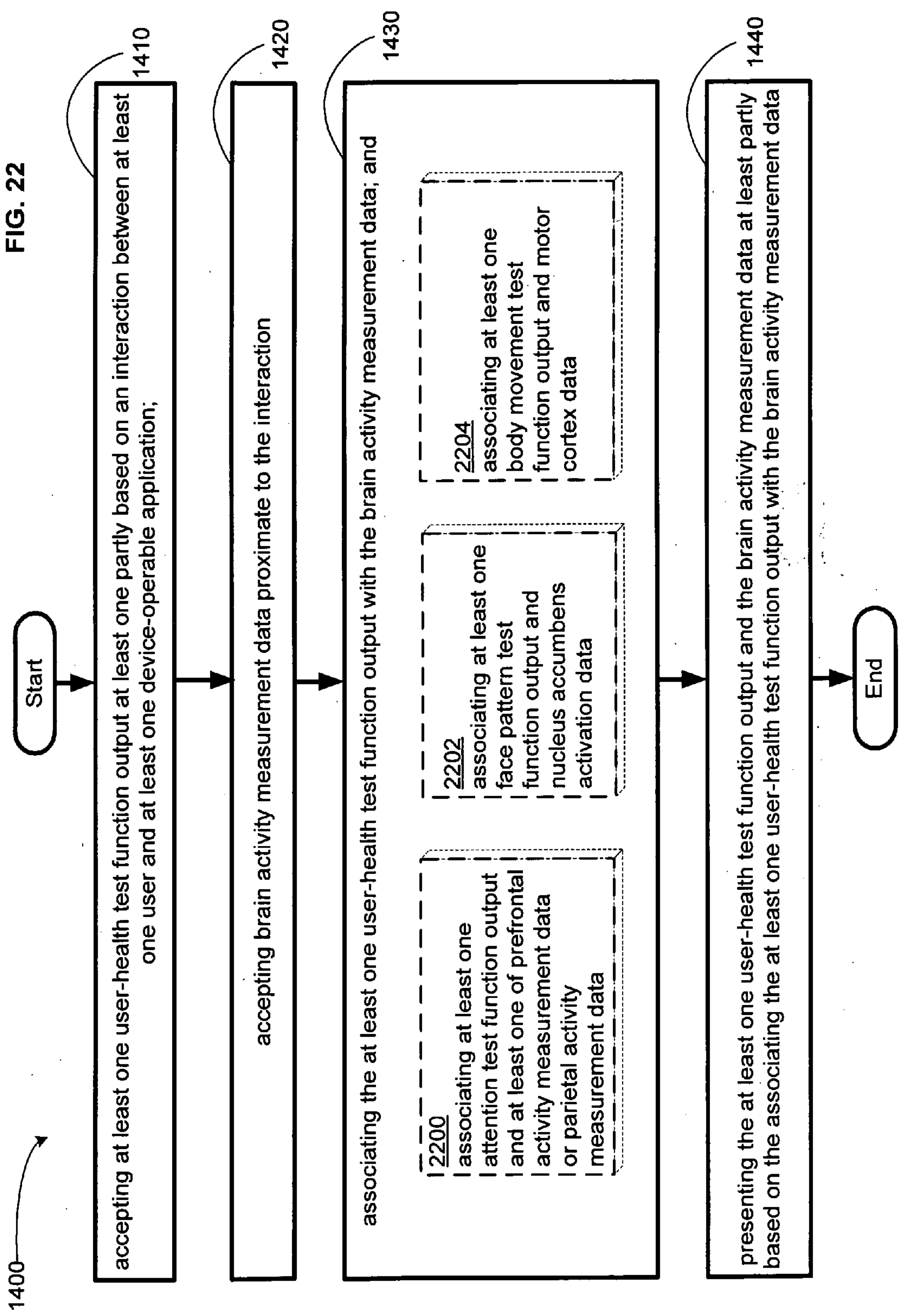

1400
Start
accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
1410
accepting brain activity measurement data proximate to the interaction
1420
associating the at least one user-health test function output with the brain activity measurement data; and
1430
2200
associating at least one attention test function output and at least one of prefrontal activity measurement data or parietal activity measurement data
2202
associating at least one face pattern test function output and nucleus accumbens activation data
2204
associating at least one body movement test function output and motor cortex data
presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
1440
End

FIG. 23

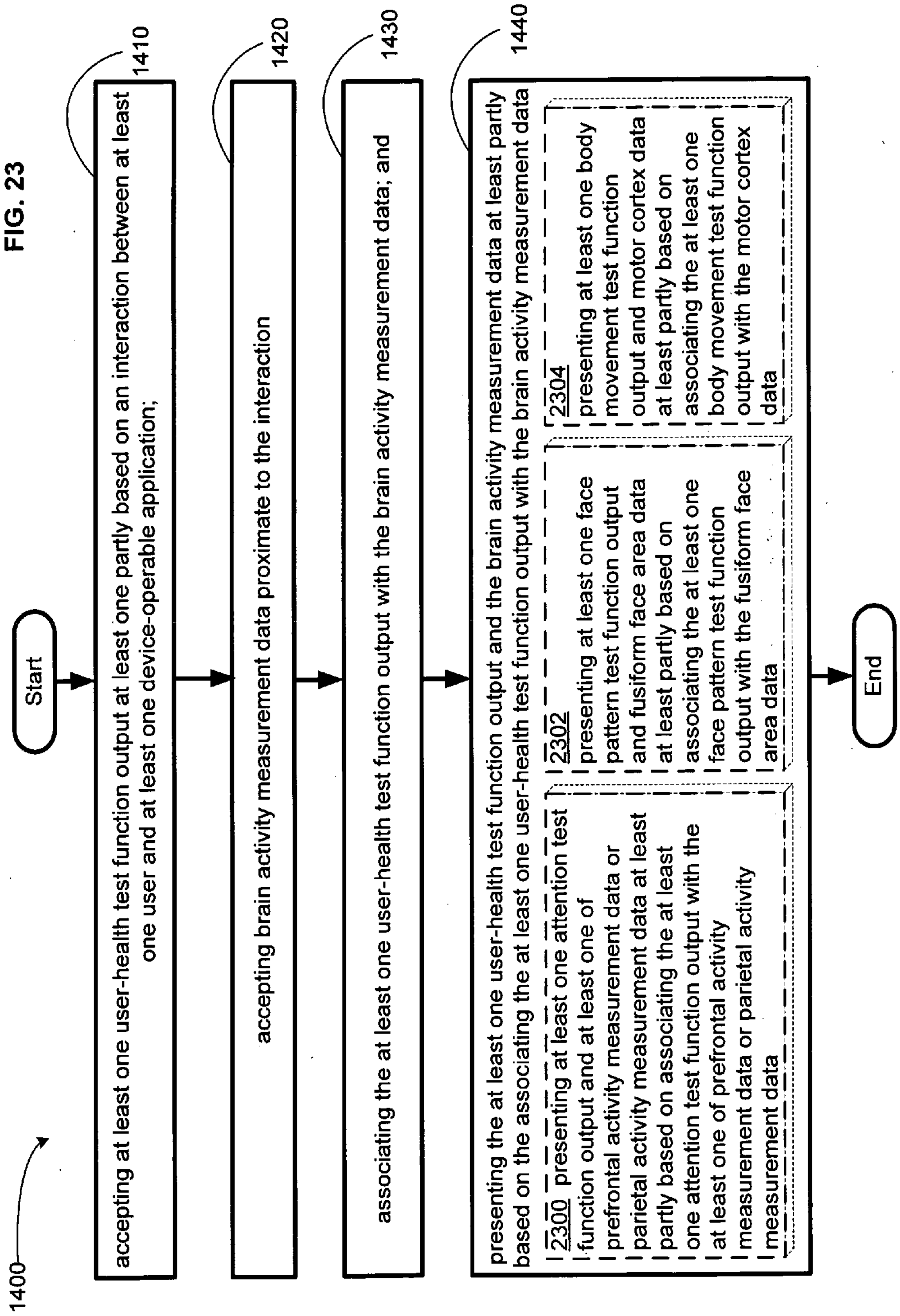

1400
Start
1410
accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
1420
accepting brain activity measurement data proximate to the interaction
1430
associating the at least one user-health test function output with the brain activity measurement data; and
1440
presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
2300 presenting at least one attention test function output and at least one of prefrontal activity measurement data or parietal activity measurement data at least partly based on associating the at least one attention test function output with the at least one of prefrontal activity measurement data or parietal activity measurement data
2302 presenting at least one face pattern test function output and fusiform face area data at least partly based on associating the at least one face pattern test function output with the fusiform face area data
2304 presenting at least one body movement test function output and motor cortex data at least partly based on associating the at least one body movement test function output with the motor cortex data
End

FIG. 24

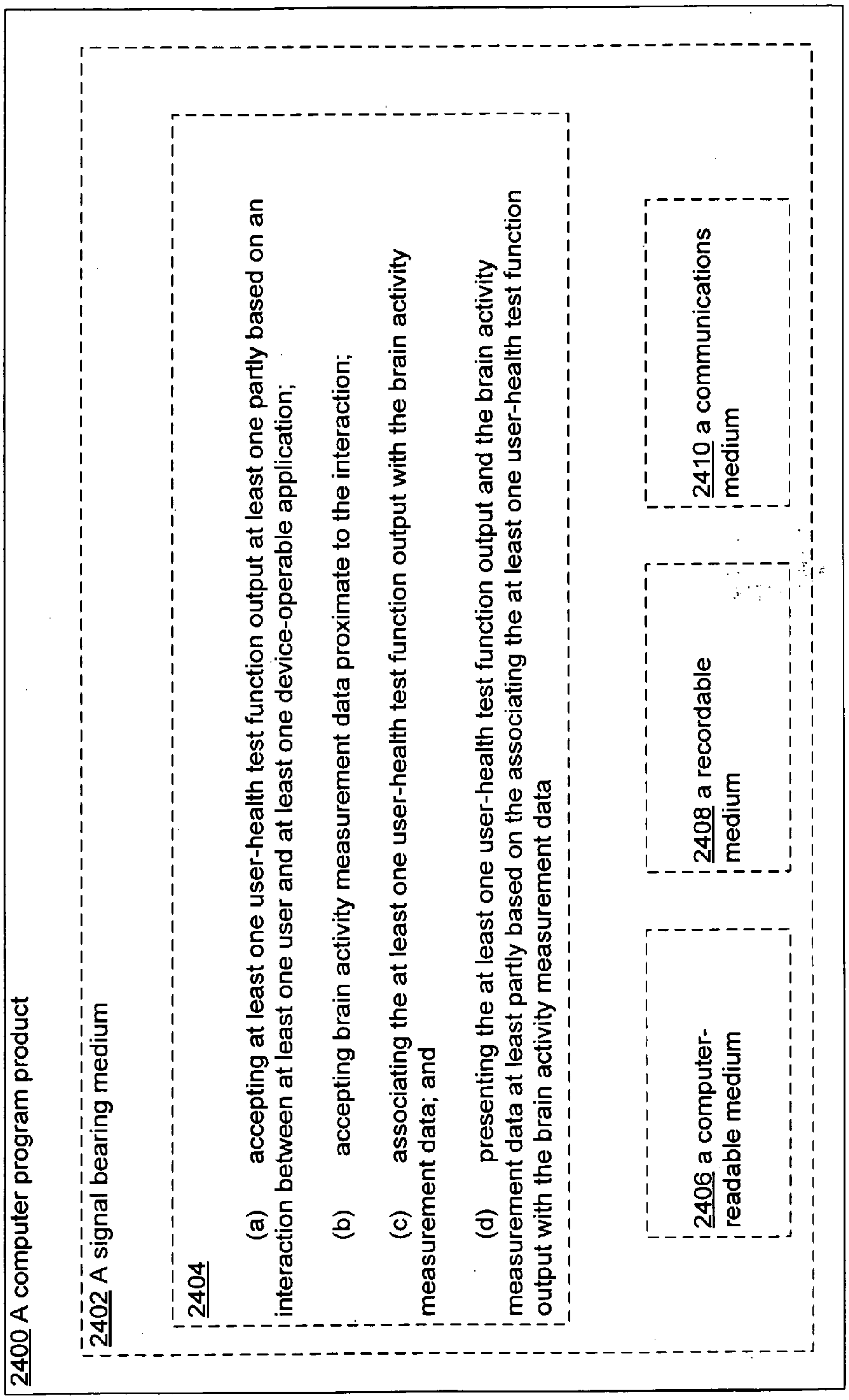
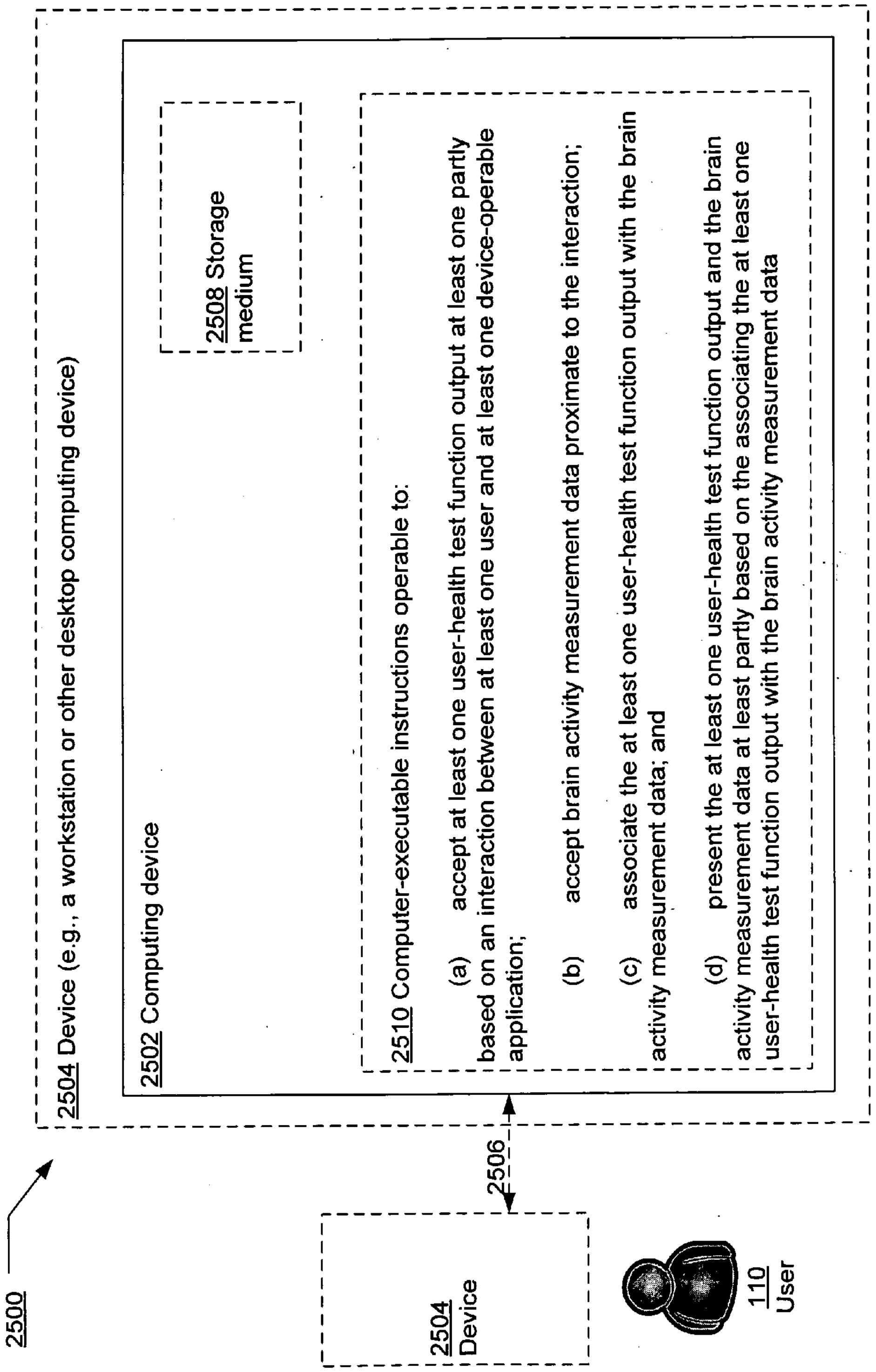

2400 A computer program product
2402 A signal bearing medium
2404
(a) accepting at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
(b) accepting brain activity measurement data proximate to the interaction;
(c) associating the at least one user-health test function output with the brain activity measurement data; and
(d) presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data
2406 a computer-readable medium
2408 a recordable medium
2410 a communications medium

FIG. 25


2500
2504 Device
2506
110 User
2504 Device (e.g., a workstation or other desktop computing device)
2502 Computing device
2508 Storage medium
2510 Computer-executable instructions operable to:
(a) accept at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;
(b) accept brain activity measurement data proximate to the interaction;
(c) associate the at least one user-health test function output with the brain activity measurement data; and
(d) present the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data

COMPUTATIONAL USER-HEALTH TESTING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is related to and claims the benefit of the earliest available effective filing date(s) from the following listed application(s) (the "Related Applications") (e.g., claims earliest available priority dates for other than provisional patent applications or claims benefits under 35 USC § 119(e) for provisional patent applications, for any and all parent, grandparent, great-grandparent, etc. applications of the Related Application(s)).

Related Applications

[0002] For purposes of the USPTO extra-statutory requirements, the present application constitutes a continuation-in-part of U.S. patent application Ser. No. 11/731,745, entitled EFFECTIVE RESPONSE PROTOCOLS FOR HEALTH MONITORING OR THE LIKE, naming Edward K. Y. Jung; Eric C. Leuthardt; Royce A. Levien; Robert W. Lord; and Mark A. Malamud as inventors, filed 30 Mar. 2007 which is currently co-pending, or is an application of which a currently co-pending application is entitled to the benefit of the filing date.

[0003] For purposes of the USPTO extra-statutory requirements, the present application constitutes a continuation-in-part of U.S. patent application Ser. No. 11/731,778, entitled CONFIGURING SOFTWARE FOR EFFECTIVE HEALTH MONITORING OR THE LIKE, naming Edward K. Y. Jung; Eric C. Leuthardt; Royce A. Levien; Robert W. Lord; and Mark A. Malamud as inventors, filed 30 Mar. 2007 which is currently co-pending, or is an application of which a currently co-pending application is entitled to the benefit of the filing date.

[0004] For purposes of the USPTO extra-statutory requirements, the present application constitutes a continuation-in-part of U.S. patent application Ser. No. 11/731,801, entitled EFFECTIVE LOW PROFILE HEALTH MONITORING OR THE LIKE, naming Edward K. Y. Jung; Eric C. Leuthardt; Royce A. Levien; Robert W. Lord; and Mark A. Malamud as inventors, filed 30 Mar. 2007 which is currently co-pending, or is an application of which a currently co-pending application is entitled to the benefit of the filing date.

[0005] For purposes of the USPTO extra-statutory requirements, the present application constitutes a continuation-in-part of U.S. patent application Ser. No. 11/804,304, entitled COMPUTATIONAL USER-HEALTH TESTING, naming Edward K. Y. Jung; Eric C. Leuthardt; Royce A. Levien; Robert W. Lord; and Mark A. Malamud as inventors, filed 15 May 2007 which is currently co-pending, or is an application of which a currently co-pending application is entitled to the benefit of the filing date.

[0006] The United States Patent Office (USPTO) has published a notice to the effect that the USPTO's computer programs require that patent applicants reference both a serial number and indicate whether an application is a continuation or continuation-in-part. Stephen G. Kunin, Benefit of Prior-Filed Application, USPTO Official Gazette Mar. 18, 2003, available at http://www.uspto.gov/web/offices/com/sol/og/2003/week11/patbene.htm. The present Applicant Entity (hereinafter "Applicant") has provided above a specific reference to the application(s) from which priority is being claimed as recited by statute. Applicant understands that the statute is unambiguous in its specific reference language and does not require either a serial number or any characterization, such as "continuation" or "continuation-in-part," for claiming priority to U.S. patent applications. Notwithstanding the foregoing, Applicant understands that the USPTO's computer programs have certain data entry requirements, and hence Applicant is designating the present application as a continuation-in-part of its parent applications as set forth above, but expressly points out that such designations are not to be construed in any way as any type of commentary and/or admission as to whether or not the present application contains any new matter in addition to the matter of its parent application(s).

[0007] All subject matter of the Related Applications and of any and all parent, grandparent, great-grandparent, etc. applications of the Related Applications is incorporated herein by reference to the extent such subject matter is not inconsistent herewith.

TECHNICAL FIELD

[0008] This description relates to data capture and data handling techniques.

SUMMARY

[0009] In one aspect, a method includes but is not limited to accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application; accepting brain activity measurement data proximate to the interaction; associating the at least one user-health test function output with the brain activity measurement data; and presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data. In addition to the foregoing, other method aspects are described in the claims, drawings, and text forming a part of the present disclosure.

[0010] In one or more various aspects, related systems include but are not limited to circuitry and/or programming for effecting the herein-referenced method aspects; the circuitry and/or programming can be virtually any combination of hardware, software, and/or firmware configured to effect the herein-referenced method aspects depending upon the design choices of the system designer.

[0011] In one aspect, a system includes but is not limited to means for accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application; means for accepting brain activity measurement data proximate to the interaction; means for associating the at least one user-health test function output with the brain activity measurement data; and means for presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data. In addition to the foregoing, other system aspects are described in the claims, drawings, and text forming a part of the present disclosure. In addition to the foregoing, various other method and/or system and/or program product aspects are set forth and described in the teachings such as text (e.g., claims and/or detailed description) and/or drawings of the present disclosure.

[0012] In one aspect, a computer program product includes but is not limited to a signal-bearing medium bearing (a) one or more instructions for accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application; (b) one or more instructions for accepting brain activity measurement data proximate to the interaction; (c) one or more instructions for associating the at least one user-health test function output with the brain activity measurement data; and (d) one or more instructions for presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data. In addition to the foregoing, other computer program product aspects are described in the claims, drawings, and text forming a part of the present disclosure.

[0013] In one aspect, a system includes but is not limited to a computing device and instructions. The instructions when executed on the computing device cause the computing device to (a) implement in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device; (b) obtain user data in response to an interaction between the user and the at least one application; (c) associate the at least one user-health test function output with the brain activity measurement data; and (d) present an output of the at least one user-health test function at least partly based on the user data. In addition to the foregoing, other system aspects are described in the claims, drawings, and text forming a part of the present disclosure.

[0014] The foregoing is a summary and thus may contain simplifications, generalizations, inclusions, and/or omissions of detail; consequently, those skilled in the art will appreciate that the summary is illustrative only and is NOT intended to be in any way limiting. Other aspects, features, and advantages of the devices and/or processes and/or other subject matter described herein will become apparent in the teachings set forth herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] With reference now to FIG. **1**, shown is an example of a user interaction and data processing system in which embodiments may be implemented, perhaps in a device, which may serve as a context for introducing one or more processes and/or devices described herein.

[0016] FIG. **2** illustrates certain alternative embodiments of the data capture and processing system of FIG. **1**.

[0017] With reference now to FIG. **3**, shown is an example of an operational flow representing example operations related to computational user-health testing, which may serve as a context for introducing one or more processes and/or devices described herein.

[0018] FIG. **4** illustrates an alternative embodiment of the example operational flow of FIG. **3**.

[0019] FIG. **5** illustrates an alternative embodiment of the example operational flow of FIG. **3**.

[0020] FIG. **6** illustrates an alternative embodiment of the example operational flow of FIG. **3**.

[0021] FIG. **7** illustrates an alternative embodiment of the example operational flow of FIG. **3**.

[0022] FIG. **8** illustrates an alternative embodiment of the example operational flow of FIG. **3**.

[0023] FIG. **9** illustrates an alternative embodiment of the example operational flow of FIG. **3**.

[0024] With reference now to FIG. **10**, shown is a partial view of an example computer program product that includes a computer program for executing a computer process on a computing device related to computational user-health testing, which may serve as a context for introducing one or more processes and/or devices described herein.

[0025] With reference now to FIG. **11**, shown is an example device in which embodiments may be implemented related to computational user-health testing, which may serve as a context for introducing one or more processes and/or devices described herein.

[0026] With reference now to FIG. **12**, shown is an example of a user interaction and data processing system in which embodiments may be implemented, perhaps in a device, which may serve as a context for introducing one or more processes and/or devices described herein.

[0027] FIG. **13** illustrates certain alternative embodiments of the data capture and processing system of FIG. **12**.

[0028] With reference now to FIG. **14**, shown is an example of an operational flow representing example operations related to computational user-health testing, which may serve as a context for introducing one or more processes and/or devices described herein.

[0029] FIG. **15** illustrates an alternative embodiment of the example operational flow of FIG. **14**.

[0030] FIG. **16** illustrates an alternative embodiment of the example operational flow of FIG. **14**.

[0031] FIG. **17** illustrates an alternative embodiment of the example operational flow of FIG. **14**.

[0032] FIG. **18** illustrates an alternative embodiment of the example operational flow of FIG. **14**.

[0033] FIG. **19** illustrates an alternative embodiment of the example operational flow of FIG. **14**.

[0034] FIG. **20** illustrates an alternative embodiment of the example operational flow of FIG. **14**.

[0035] FIG. **21** illustrates an alternative embodiment of the example operational flow of FIG. **14**.

[0036] FIG. **22** illustrates an alternative embodiment of the example operational flow of FIG. **14**.

[0037] FIG. **23** illustrates an alternative embodiment of the example operational flow of FIG. **14**.

[0038] With reference now to FIG. **24**, shown is a partial view of an example computer program product that includes a computer program for executing a computer process on a computing device related to computational user-health testing, which may serve as a context for introducing one or more processes and/or devices described herein.

[0039] With reference now to FIG. **25**, shown is an example device in which embodiments may be implemented related to computational user-health testing, which may serve as a context for introducing one or more processes and/or devices described herein.

[0040] The use of the same symbols in different drawings typically indicates similar or identical items.

DETAILED DESCRIPTION

[0041] FIG. **1** illustrates an example system **100** in which embodiments may be implemented. The system **100** includes a device **102**. The device **102** may contain, for example, an application **106** and a structurally distinct user-health test unit **104**. In some embodiments the user-health test unit **104** may be structurally distinct from the device **102** on which the application **106** is operable. In such embodiments the user-health test unit **104** may be implemented, for example, on external device **160**. Through interaction with application **106**, user **110** may generate user data **116** that may be obtained by device **102** and/or user-health test unit **104**. The application **106** may include, for example, a game **144**, a communication application **150**, a security application **152**, and/or a productivity application **154**.

[0042] The device **102** may optionally include a data capture module **112**, a data detection module **114**, a user input device **146**, and/or a user monitoring device **148**. The user-health test unit **104** may include an alertness or attention test module **118**, a memory test module **120**, a speech test module **122**, a calculation test module **124**, a neglect or construction test module **126**, a task sequencing test module **128**, a visual field test module **130**, a pupillary reflex or eye movement test module **132**, a face pattern test module **134**, a hearing test module **136**, a voice test module **138**, a motor skill test module **140**, or a body movement test module **142**.

[0043] In FIG. **1**, the device **102** is illustrated as possibly being included within a system **100**. Of course, virtually any kind of computing device may be used to implement the user-health test unit **104**, such as, for example, a workstation, a desktop computer, a networked computer, a collection of servers and/or databases, or a tablet PC.

[0044] Additionally, not all of the user-health test unit **104** need be implemented on a single computing device. For example, the user-health test unit **104** and/or application **106** may be implemented and/or operable on a remote computer, while the user interface **108** and/or user data **116** are implemented and/or stored on a local computer. Further, aspects of the user-health test unit **104** may be implemented in different combinations and implementations than that shown in FIG. **1**. For example, functionality of the user interface **108** may be incorporated into the user-health test unit **104**. The user-health test unit **104** may perform simple data relay functions and/or complex data analysis, including, for example, fuzzy logic and/or traditional logic steps. Further, many methods of searching databases known in the art may be used, including, for example, unsupervised pattern discovery methods, coincidence detection methods, and/or entity relationship modeling. In some embodiments, the user-health test unit **104** may process user data **116** according to health profiles available as updates through a network.

[0045] The user data **116** may be stored in virtually any type of memory that is able to store and/or provide access to information in, for example, a one-to-many, many-to-one, and/or many-to-many relationship. Such a memory may include, for example, a relational database and/or an object-oriented database, examples of which are provided in more detail herein.

[0046] FIG. **2** illustrates certain alternative embodiments of the system **100** of FIG. **1**. In FIG. **2**, the user **110** uses the user interface **108** to interact through a network **202** with the application **106** operable on a device **102**. A user-health test unit **104** may be implemented on the device **102** or on another device within the system **100** but separate from the device **102**. The device **102** may be in communication over a network **202** with a network destination **206** and/or healthcare provider **210**, which may interact with the device **102** and/or the user-health test unit **104** through, for example, a user interface **208**. Of course, it should be understood that there may be many users other than the specifically-illustrated user **110**, for example, each with access to a local instance of the application **106**.

[0047] In this way, the user **110**, who may be using a device that is connected through a network **202** with the system **100** (e.g., in an office, outdoors and/or in a public environment), may generate user data **116** as if the user **110** were interacting locally with the device **102** on which the application **106** is locally operable.

[0048] As referenced herein, the user-health test unit **104** may be used to perform various data querying and/or recall techniques with respect to the user data **116**, in order to present an output of the user-health test function at least partly based on the user data. For example, where the user data **116** is organized, keyed to, and/or otherwise accessible using one or more reference health condition attributes or profiles, various Boolean, statistical, and/or semi-boolean searching techniques may be performed to match user data **116** with reference health condition data, attributes, or profiles.

[0049] Many examples of databases and database structures may be used in connection with the user-health test unit **104**. Such examples include hierarchical models (in which data is organized in a tree and/or parent-child node structure), network models (based on set theory, and in which multi-parent structures per child node are supported), or object/relational models (combining the relational model with the object-oriented model).

[0050] Still other examples include various types of eXtensible Mark-up Language (XML) databases. For example, a database may be included that holds data in some format other than XML, but that is associated with an XML interface for accessing the database using XML. As another example, a database may store XML data directly. Additionally, or alternatively, virtually any semi-structured database may be used, so that context may be provided to/associated with stored data elements (either encoded with the data elements, or encoded externally to the data elements), so that data storage and/or access may be facilitated.

[0051] Such databases, and/or other memory storage techniques, may be written and/or implemented using various programming or coding languages. For example, object-oriented database management systems may be written in programming languages such as, for example, C++ or Java. Relational and/or object/relational models may make use of database languages, such as, for example, the structured query language (SQL), which may be used, for example, for interactive queries for information and/or for gathering and/or compiling data from the relational database(s).

[0052] For example, SQL or SQL-like operations over one or more of reference health condition may be performed, or Boolean operations using a reference health condition may be performed. For example, weighted Boolean operations may be performed in which different weights or priorities are assigned to one or more of the reference health conditions, perhaps relative to one another. For example, a number-weighted, exclusive-OR operation may be performed to request specific weightings of desired (or undesired) health reference data to be included or excluded.

[0053] Following are a series of flowcharts depicting implementations. For ease of understanding, the flowcharts are organized such that the initial flowcharts present implementations via an example implementation and thereafter the following flowcharts present alternate implementations and/or expansions of the initial flowchart(s) as either sub-component operations or additional component operations building on one or more earlier-presented flowcharts. Those having skill in the art will appreciate that the style of presentation utilized herein (e.g., beginning with a presentation of a flowchart(s) presenting an example implementation and thereafter providing additions to and/or further details in subsequent flowcharts) generally allows for a rapid and easy understanding of the various process implementations. In addition, those skilled in the art will further appreciate that the style of presentation used herein also lends itself well to modular and/or object-oriented program design paradigms.

[0054] FIG. **3** illustrates an operational flow **300** representing example operations related to computational user-health testing. In FIG. **3** and in following figures that include various examples of operational flows, discussion and explanation may be provided with respect to the above-described system environments of FIGS. **1-2**, and/or with respect to other examples and contexts. However, it should be understood that the operational flows may be executed in a number of other environment and contexts, and/or in modified versions of FIGS. **1-2**. Also, although the various operational flows are presented in the sequence(s) illustrated, it should be understood that the various operations may be performed in other orders than those which are illustrated, or may be performed concurrently.

[0055] After a start operation, operation **310** shows implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. The user-health test function may be implemented on a device **102** within a system **100**. The user-health function may be carried out by a user-health test unit **104** resident on device **102**. System **100** may also include application **106** that is operable on device **102**, to perform a primary function that is different from symptom detection. For example, a user-health test function may be implemented as a user-health test unit **104** residing on an external device **160**, which user-health test unit **104** communicates via a network **170**, for example, with the at least one device **102**. In this example, the user-health test function may be implemented in the at least one device **102** by virtue of its communication over the network **170**, and the user-health test function will be structurally distinct from at least one application **106** operable on the at least one device. The at least one application **106** may reside on the at least one device **102**, or the at least one application **106** may not reside on the at least one device **102** but instead be operable on the at least one device **102** from a remote location, for example, through a network or other link.

[0056] Operation **320** depicts obtaining user data in response to an interaction between a user and the at least one application. For example, a data detection module **114** and data capture module **112** of the at least one device **102** or associated with the at least one device **102** may obtain user data in response to an interaction between the user and the at least one application. For example, the data detection module **114** and/or data capture module **112** of the at least one device **102** or associated with the at least one device **102** may obtain user input data in response to an interaction between the user and the at least one application.

[0057] Operation **330** depicts presenting an output of the at least one user-health test function at least partly based on the user data. For example, the user-health test unit **104** may relay a summary of user data **116** relating to a hand-eye coordination test to a computer connected by a network to the device **102** or to at least one memory.

[0058] In this regard, it should be understood that a data signal may first be encoded and/or represented in digital form (i.e., as digital data), prior to the assignment to at least one memory. For example, a digitally-encoded representation of user eye movement data may be stored in a local memory, or may be transmitted for storage in a remote memory.

[0059] Thus, an operation may be performed relating either to a local or remote storage of the digital data, or to another type of transmission of the digital data. Of course, as discussed herein, operations also may be performed relating to accessing, querying, processing, recalling, or otherwise obtaining the digital data from a memory, including, for example, receiving a transmission of the digital data from a remote memory. Accordingly, such operation(s) may involve elements including at least an operator (e.g., either human or computer) directing the operation, a transmitting computer, and/or a receiving computer.

[0060] FIG. **4** illustrates alternative embodiments of the example operational flow **300** of FIG. **3**. FIG. **4** illustrates example embodiments where the implementing operation **310** may include at least one additional operation. Additional operations may include operation **402**.

[0061] Operation **402** depicts implementing in at least one desktop computing device the at least one user-health test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a user-health test function may be implemented in a personal computer of user **110**, the user-health test function being structurally distinct from at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the personal computer of user **110**.

[0062] FIG. **5** illustrates alternative embodiments of the example operational flow **300** of FIG. **3**. FIG. **5** illustrates example embodiments where the implementing operation **310** may include at least one additional operation. Additional operations may include operation **500**, **502**, **504**, **506**, **508**, **510**, **512**, **514**, **516**, **518**, and/or operation **520**.

[0063] Operation **500** depicts implementing in the at least one device at least one alertness or attention test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, an alertness or attention test module **118** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such an alertness or attention test module **118** may receive the user data **116** via a data capture module **112** and/or data detection module **114**.

[0064] Alertness or attention user attributes are indicators of a user's mental status. An example of an alertness test function may be a measure of reaction time as one objective manifestation. Examples of attention test functions may include ability to focus on simple tasks, ability to spell the word "world" forward and backward, or reciting a numerical sequence forward and backward as objective manifestations of an alertness problem. An alertness or attention test module **118** and/or user-health test unit **104** may require a user to enter a password backward as an alertness test function. Alternatively, a user may be prompted to perform an executive function as a predicate to launching an application such as a word processing program. For example, an alertness test function could be activated by a user command to open a word processing program, requiring performance of, for example, a spelling task as a preliminary step in launching the word processing program. Also, writing ability may be tested by requiring the user to write their name or write a sentence on a device, perhaps with a stylus on a touchscreen.

[0065] Reduced level of alertness or attention can indicate the following possible conditions where an acute reduction in alertness or attention is detected: stroke involving the reticular activating system, stroke involving the bilateral or unilateral thalamus, metabolic abnormalities such as hyper or hypoglycemia, toxic effects due to substance overdose (for example, benzodiazepines, or other toxins such as alcohol). Reduced level of alertness and attention can indicate the following possible conditions where a subacute or chronic reduction in alertness or attention is detected: dementia (caused by, for example, Alzheimer's disease, vascular dementia, Parkinson's disease, Huntingdon's disease, Creutzfeldt-Jakob disease, Pick disease, head injury, infection, normal pressure hydrocephalus, brain tumor, exposure to toxin (for example, lead or other heavy metals), metabolic disorders, hormone disorders, hypoxia, drug reactions, drug overuse, drug abuse, encephalitis (caused by, for example, enteroviruses, herpes viruses, or arboviruses), or mood disorders (for example, bipolar disorder, cyclothymic disorder, depression, depressive disorder NOS (not otherwise specified), dysthymic disorder, postpartum depression, or seasonal affective disorder)).

[0066] In the context of the above alertness or attention test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. A reduced level of alertness or attention may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of reduced alertness or attention, or the one or more types of user data indicative of a likely condition associated with reduced alertness or attention. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0067] Operation **502** depicts implementing in the at least one device at least one memory test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a memory test module **120** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a memory test module **120** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0068] A user's memory attributes are indicators of a user's mental status. An example of a memory test function may be a measure of a user's short-term ability to recall items presented, for example, in a story, or after a short period of time. Another example of a memory test function may be a measure of a user's long-term memory, for example their ability to remember basic personal information such as birthdays, place of birth, or names of relatives. Another example of a memory test function may be a memory test module **120** and/or user-health test unit **104** prompting a user to change and enter a password with a specified frequency during internet browser use. A memory test function involving changes to a password that is required to access an internet server can challenge a user's memory according to a fixed or variable schedule.

[0069] Difficulty with recall after about 1 to 5 minutes may indicate damage to the limbic memory structures located in the medial temporal lobes and medial diencephalon of the brain, or damage to the fornix. Dysfunction of these structures characteristically causes anterograde amnesia, meaning difficulty remembering new facts and events occurring after lesion onset. Reduced short-term memory function can also indicate the following conditions: head injury, Alzheimer's disease, Herpes virus infection, seizure, emotional shock or hysteria, alcohol-related brain damage, barbiturate or heroin use, general anaesthetic effects, electroconvulsive therapy effects, stroke, transient ischemic attack (i.e., a "mini-stroke"), complication of brain surgery. Reduced long-term memory function can indicate the following conditions: Alzheimer's disease, alcohol-related brain damage, complication of brain surgery, depressive pseudodementia, adverse drug reactions (e.g., to benzodiazepines, anti-ulcer drugs, analgesics, anti-hypertensives, diabetes drugs, beta-blockers, anti-Parkinson's disease drugs, anti-emetics, anti-psychotics, or certain drug combinations, such as haloperidol and methyldopa combination therapy), multi-infarct dementia, or head injury.

[0070] In the context of the above memory test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. A reduced level of memory function may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of reduced memory function, or the one or more types of user data indicative of a likely condition associated with reduced memory function. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and

Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0071] Operation **504** depicts implementing in the at least one device at least one speech test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a speech test module **122** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a speech test module **122** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0072] User speech attributes are indicators of a user's mental status. An example of a speech test function may be a measure of a user's fluency or ability to produce spontaneous speech, including phrase length, rate of speech, abundance of spontaneous speech, tonal modulation, or whether paraphasic errors (e.g., inappropriately substituted words or syllables), neologisms (e.g., nonexistent words), or errors in grammar are present. Another example of a speech test function is a program that can measure the number of words spoken by a user during a video conference. The number of words per interaction or per unit time could be measured. A marked decrease in the number of words spoken could indicate a speech problem.

[0073] Another example of a speech test function may be a measure of a user's comprehension of spoken language, including whether a user **110** can understand simple questions and commands, or grammatical structure. For example, a user **110** could be tested by a speech test module **122** and/or user-health test unit **104** asking the question "Mike was shot by John. Is John dead?" An inappropriate response may indicate a speech center defect. Alternatively a user-health test unit **104** and/or speech test module **122** may require a user to say a code or phrase and repeat it several times. Speech defects may become apparent if the user has difficulty repeating the code or phrase during, for example, a videoconference setup or while using speech recognition software.

[0074] Another example of a speech test function may be a measure of a user's ability to name simple everyday objects (e.g., pen, watch, tie) and also more difficult objects (e.g., fingernail, belt buckle, stethoscope). A speech test function may, for example, require the naming of an object prior to or during the interaction of a user **110** with an application **106**, as a time-based or event-based checkpoint. For example, a user **110** may be prompted by the user-health test unit **104** and/or the speech test module **122** to say "armadillo" after being shown a picture of an armadillo, prior to or during the user's interaction with, for example, a word processing or email program. A test requiring the naming of parts of objects is often more difficult for users with speech comprehension impairment. Another speech test gauges a user's ability to repeat single words and sentences (e.g., "no if's and's or but's"). A further example of a speech test measures a user's ability to read single words, a brief written passage, or the front page of the newspaper aloud followed by a test for comprehension.

[0075] Difficulty with speech or reading/writing ability may indicate, for example, lesions in the dominant (usually left) frontal lobe, including Broca's area (output area); the left temporal and parietal lobes, including Wernicke's area (input area); subcortical white matter and gray matter structures, including thalamus and caudate nucleus; as well as the non-dominant hemisphere. Typical diagnostic conditions may include, for example, stroke, head trauma, dementia, multiple sclerosis, Parkinson's disease, Landau-Kleffner syndrome (a rare syndrome of acquired epileptic aphasia).

[0076] In the context of the above speech test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. A reduced level of speech ability may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of reduced speech ability, or the one or more types of user data indicative of a likely condition associated with reduced speech ability. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0077] Operation **506** depicts implementing in the at least one device at least one calculation test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a calculation test module **124** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a calculation test module **124** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0078] A user's calculation attributes are indicators of a user's mental status. An example of a calculation test function may be a measure of a user's ability to do simple math such as addition or subtraction, for example. A calculation test module **124** and/or user-health test unit **104** may prompt a user **110** to solve an arithmetic problem in the context of interacting with application **106**, or alternatively, in the context of using the device in between periods of interacting with the application **106**. For example, a user may be prompted to enter the number of items and/or gold pieces collected during a segment of gameplay in the context of playing a game. In this and other contexts, user interaction with a device's operating system or other system function may also constitute user interaction with an application **106**. Difficulty in completing calculation tests may be indicative of stroke (e.g., embolic, thrombotic, or due to vasculitis), dominant parietal lesion, or brain tumor (e.g., glioma or meningioma). When a calculation ability deficiency is found with defects in user ability to distinguish right and left body parts (right-left confusion), ability to name and identify each finger (finger agnosia), and ability to write their name and a sentence, Gerstman's syndrome, a lesion in the dominant parietal lobe of the brain, may be present.

[0079] In the context of the above calculation test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. A reduced level of calculation ability may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of reduced calculation ability, or the one or more types of user data indicative of a likely condition associated with reduced calculation ability. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0080] Operation **508** depicts implementing in the at least one device at least one neglect or construction test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a neglect or construction test module **126** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a neglect or construction test module **126** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0081] Neglect or construction user attributes are indicators of a user's mental status. Neglect may include a neurological condition involving a deficit in attention to an area of space, often one side of the body or the other. A construction defect may include a deficit in a user's ability to draw complex figures or manipulate blocks or other objects in space as a result of neglect or other visuospatial impairment.

[0082] Hemineglect may include an abnormality in attention to one side of the universe that is not due to a primary sensory or motor disturbance. In sensory neglect, users ignore visual, somatosensory, or auditory stimuli on the affected side, despite intact primary sensation. This can often be demonstrated by testing for extinction on double simultaneous stimulation. Thus, a neglect or construction test module **126** and/or user-health test unit **104** may present a stimulus on one or both sides of a display for a user **110** to click on. A user with hemineglect may detect the stimulus on the affected side when presented alone, but when stimuli are presented simultaneously on both sides, only the stimulus on the unaffected side may be detected. In motor neglect, normal strength may be present, however, the user often does not move the affected limb unless attention is strongly directed toward it.

[0083] An example of a neglect test function may be a measure of a user's awareness of events occurring on one side of the user or the other. A user could be asked, "Do you see anything on the left side of the screen?" Users with anosognosia (i.e., unawareness of a disability) may be strikingly unaware of severe deficits on the affected side. For example, some people with acute stroke who are completely paralyzed on the left side believe there is nothing wrong and may even be perplexed about why they are in the hospital. Alternatively, a neglect or construction test module **126** and/or user-health test unit **104** may present a drawing task to a user in the context of an application **106** that involves similar activities. A construction test involves prompting a user to draw complex figures or to manipulate objects in space. Difficulty in completing such a test may be a result of neglect or other visuospatial impairment.

[0084] Another neglect test function is a test of a user's ability to acknowledge a series of objects on a display that span a center point on the display. For example, a user may be prompted to click on each of 5 hash marks present in a horizontal line across the midline of a display. If the user has a neglect problem, she may only detect and accordingly click on the hash marks on one side of the display, neglecting the others.

[0085] Hemineglect is most common in lesions of the right (nondominant) parietal lobe, causing users to neglect the left side. Left-sided neglect can also occasionally be seen in right frontal lesions, right thalamic or basal ganglia lesions, and, rarely, in lesions of the right midbrain. Hemineglect or difficulty with construction tasks may be indicative of stroke (e.g., embolic, thrombotic, or due to vasculitis), or brain tumor (e.g., glioma or meningioma). In the context of the above neglect or construction test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. A change in neglect or in construction ability may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of a change in neglect or in construction ability, or the one or more types of user data indicative of a likely condition associated with a change in neglect or in construction ability. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0086] Operation **510** depicts implementing in the at least one device at least one task sequencing test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a task sequencing test module **128** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a task sequencing test module **128** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0087] A user's task sequencing attributes are indicators of a user's mental status. An example of a task sequencing test function may be a measure of a user's perseveration. For example, a task sequencing test module **128** and/or user-health test unit **104** may ask a user to continue drawing a silhouette pattern of alternating triangles and squares (i.e., a written alternating sequencing task) for a time period. In users with perseveration problems, the user may get stuck on one shape and keep drawing triangles. Another common finding is motor impersistence, a form of distractibility in which users only briefly sustain a motor action in response to a command such as "raise your arms" or "Look to the right." Ability to suppress inappropriate behaviors can be tested by the auditory "Go-No-Go" test, in which the user moves a finger in response to one sound, but must keep it still in response to two sounds. Alternatively, a task sequencing test module **128** and/or user-health test unit **104** may prompt a user to perform a multi-step function in the context of an application **106**, for example. For example, a game may prompt a user to enter a character's name, equip an item from an inventory, an click on a certain direction of travel, in that order. Difficulty completing this task may indicate, for example, a frontal lobe defect associated with dementia.

[0088] Decreased ability to perform sequencing tasks may be indicative of stroke (e.g., embolic, thrombotic, or due to vasculitis), brain tumor (e.g., glioma or meningioma), or dementia (caused by, for example, Alzheimer's disease, vascular dementia, Parkinson's disease, Huntingdon's disease, Creutzfeldt-Jakob disease, Pick disease, head injury, infection (e.g., meningitis, encephalitis, HIV, or syphilis), normal pressure hydrocephalus, brain tumor, exposure to toxin (for example, lead or other heavy metals), metabolic disorders, hormone disorders, hypoxia (caused by, e.g., emphysema, pneumonia, or congestive heart failure), drug reactions (e.g., anti-cholinergic side effects, drug overuse, drug abuse (e.g., cocaine or heroin).

[0089] In the context of the above task sequencing test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. A reduced level of task sequencing ability may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of reduced task sequencing ability, or the one or more types of user data indicative of a likely condition associated with reduced task sequencing ability. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0090] Operation **512** depicts implementing in the at least one device at least one visual field test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a visual field test module **130** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a visual field test module **130** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0091] An example of a visual field test function may be a measure of a user's gross visual acuity, for example using a Snellen eye chart or visual equivalent on a display. Alternatively, a campimeter may be used to conduct a visual field test. A visual field test module **130** and/or user-health test unit **104** can prompt a user to activate a portion of a display when the user can detect an object entering their field of view from a peripheral location relative to a fixed point of focus, either with both eyes or with one eye covered at a time. Such testing could be done in the context of, for example, new email alerts that require clicking and that appear in various locations on a display. Based upon the location of decreased visual field, the defect can be localized, for example in a quadrant system. A pre-chiasmatic lesion results in ipsilateral eye blindness. A chiasmatic lesion can result in bi-temporal hemianopsia (i.e., tunnel vision). Post-chiasmatic lesions proximal to the geniculate ganglion can result in left or right homonymous hemianopsia. Lesions distal to the geniculate ganglion can result in upper or lower homonymous quadrantanopsia.

[0092] Visual field defects may indicate optic nerve conditions such as pre-chiasmatic lesions, which include fractures of the sphenoid bone (e.g., transecting the optic nerve), retinal tumors, or masses compressing the optic nerve. Such conditions may result in unilateral blindness and unilaterally unreactive pupil (although the pupil may react to light applied to the contralateral eye). Bi-temporal hemianopsia can be caused by glaucoma, pituitary adenoma, craniopharyngioma or saccular Berry aneurysm at the optic chiasm. Post-chiasmatic lesions are associated with homonymous hemianopsia or quadrantanopsia depending on the location of the lesion.

[0093] In the context of the above visual field test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. A reduced visual field may indicate-certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of reduced visual field, or the one or more types of user data indicative of a likely condition associated with reduced visual field. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0094] Operation **514** depicts implementing in the at least one device at least one pupillary reflex or eye movement test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a pupillary reflex or eye movement test module **132** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a pupillary reflex or eye movement test module **132** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0095] An example of a pupillary reflex test function may be a measure of a user's pupils when exposed to light or objects at various distances. A pupillary reflex or eye movement test module **132** and/or user-health test unit **104** may assess the size and symmetry of a user's pupils before and after a stimulus, such as light or focal point. Anisocoria (i.e., unequal pupils) of up to 0.5 mm is fairly common, and is benign provided pupillary reaction to light is normal. Pupillary reflex can be tested in a darkened room by shining light in one pupil and observing any constriction of the ipsilateral pupil (direct reflex) or the contralateral pupil (contralateral reflex). If abnormality is found with light reaction, pupillary accommodation can be tested by having the user focus on an object at a distance, then focus on the object at about 10 cm from the nose. Pupils should converge and constrict at close focus.

[0096] Pupillary abnormalities may be a result of either optic nerve or oculomotor nerve lesions. An optic nerve lesion (e.g., blind eye) will not react to direct light and will not elicit a consensual pupillary constriction, but will constrict if light is shown in the opposite eye. A Horner's syndrome lesion (sympathetic chain lesion) can also present as a pupillary abnormality. In Horner's syndrome, the affected pupil is smaller but constricts to both light and near vision and may be associated with ptosis and anhydrosis. In an oculomotor nerve lesion, the affected pupil is fixed and dilated and may be associated with ptosis and lateral deviation (due to unopposed action of the abducens nerve). Small pupils that do not react to light but do constrict with near vision (i.e., accommodate but do not react to light) can be seen in central nervous system syphilis ("Argyll Robertson pupil").

[0097] Pupillary reflex deficiencies may indicate damage to the oculomotor nerve in basilar skull fracture or uncal herniation as a result of increased intracranial pressure. Masses or tumors in the cavernous sinus, syphilis, or aneurysm may also lead to compression of the oculomotor nerve. Injury to the oculomotor nerve may result in ptosis, inferolateral displacement of the ipsilateral eye (which can present as diplopia or strabismus), or mydriasis.

[0098] An example of an eye movement test function may be a pupillary reflex or eye movement test module **132** and/or user-health test unit **104** measurement of a user's ability to follow a target on a display with her eyes throughout a 360° range. Such testing may be done in the context of a user playing a game or participating in a videoconference. In such examples, user data **116** may be obtained through a camera in place as a user monitoring device **148** that can monitor the eye movements of the user during interaction with the application **106**.

[0099] Testing of the trochlear nerve or the abducens nerve for damage may involve measurement of extraocular movements. The trochlear nerve performs intorsion, depression, and abduction of the eye. A trochlear nerve lesion may present as extorsion of the ipsilateral eye and worsened diplopia when looking down. Damage to the abducens nerve may result in a decreased ability to abduct the eye.

[0100] Abnormalities in eye movement may indicate fracture of the sphenoid wing, intracranial hemorrhage, neoplasm, or aneurysm. Such insults may present as extorsion of the ipsilateral eye. Individuals with this condition complain of worsened diplopia with attempted downgaze, but improved diplopia with head tilted to the contralateral side. Injury to the abducens nerve may be caused by aneurysm, a mass in the cavernous sinus, or a fracture of the skull base. Such insults may result in extraocular palsy defined by medial deviation of the ipsilateral eye. Users with this condition may present with diplopia that improves when the contralateral eye is abducted.

[0101] Nystagmus is a rapid involuntary rhythmic eye movement, with the eyes moving quickly in one direction (quick phase), and then slowly in the other direction (slow phase). The direction of nystagmus is defined by the direction of its quick phase (e.g., right nystagmus is due to a right-moving quick phase). Nystagmus may occur in the vertical or horizontal directions, or in a semicircular movement. Terminology includes downbeat nystagmus, upbeat nystagmus, seesaw nystagmus, periodic alternating nystagmus, and pendular nystagmus. There are other similar alterations in periodic eye movements (saccadic oscillations) such as opsoclonus or ocular flutter. One can think of nystagmus as the combination of a slow adjusting eye movement (slow phase) as would be seen with the vestibulo-ocular reflex, followed by a quick saccade (quick phase) when the eye has reached the limit of its rotation.

[0102] In medicine, the clinical importance of nystagmus is that it indicates that the user's spatial sensory system perceives rotation and is rotating the eyes to adjust. Thus it depends on the coordination of activities between two major physiological systems: the vision and the vestibular apparatus (which controls posture and balance). This may be physiological (i.e., normal) or pathological.

[0103] Vestibular nystagmus may be central or peripheral. Important differentiating features between central and peripheral nystagmus include the following: peripheral nystagmus is unidirectional with the fast phase opposite the lesion; central nystagmus may be unidirectional or bidirectional; purely vertical or torsional nystagmus suggests a central location; central vestibular nystagmus is not dampened or inhibited by visual fixation; tinnitus or deafness often is present in peripheral vestibular nystagmus, but it usually is absent in central vestibular nystagmus. According to Alexander's law, the nystagmus associated with peripheral lesions becomes more pronounced with gaze toward the side of the fast-beating component; with central nystagmus, the direction of the fast component is directed toward the side of gaze (e.g., left-beating in left gaze, right-beating in right gaze, and up-beating in upgaze).

[0104] Downbeat nystagmus is defined as nystagmus with the fast phase beating in a downward direction. The nystagmus usually is of maximal intensity when the eyes are deviated temporally and slightly inferiorly. With the eyes in this position, the nystagmus is directed obliquely downward. In most users, removal of fixation (e.g., by Frenzel goggles) does not influence slow phase velocity to a considerable extent, however, the frequency of saccades may diminish.

[0105] The presence of downbeat nystagmus is highly suggestive of disorders of the cranio-cervical junction (e.g., Arnold-Chiari malformation). This condition also may occur with bilateral lesions of the cerebellar flocculus and bilateral lesions of the medial longitudinal fasciculus, which carries optokinetic input from the posterior semicircular canals to the third nerve nuclei. It may also occur when the tone within pathways from the anterior semicircular canals is relatively higher than the tone within the posterior semicircular canals. Under such circumstances, the relatively unopposed neural activity from the anterior semicircular canals causes a slow upward pursuit movement of the eyes with a fast, corrective downward saccade. Additional causes include demyelination (e.g., as a result of multiple sclerosis), microvascular disease with vertebrobasilar insufficiency, brain stem encephalitis, tumors at the foramen magnum (e.g., meningioma, or cerebellar hemangioma), trauma, drugs (e.g., alcohol, lithium, or anti-seizure medications), nutritional imbalances (e.g., Wernicke encephalopathy, parenteral feeding, magnesium deficiency), or heat stroke.

[0106] Upbeat nystagmus is defined as nystagmus with the fast phase beating in an upward direction. Daroff and Troost described two distinct types. The first type consists of a large amplitude nystagmus that increases in intensity with upward gaze. This type is suggestive of a lesion of the anterior vermis of the cerebellum. The second type consists of a small amplitude nystagmus that decreases in intensity with upward gaze and increases in intensity with downward gaze. This type is suggestive of lesions of the medulla, including the perihypoglossal nuclei, the adjacent medial vestibular nucleus, and the nucleus intercalatus (structures important in gaze-holding). Upbeat nystagmus may also be an indication of benign paroxysmal positional vertigo.

[0107] Torsional (rotary) nystagmus refers to a rotary movement of the globe about its anteroposterior axis. Torsional nystagmus is accentuated on lateral gaze. Most nystagmus resulting from dysfunction of the vestibular system has a torsional component superimposed on a horizontal or vertical nystagmus. This condition occurs with lesions of the anterior and posterior semicircular canals on the same side (e.g., lateral medullary syndrome or Wallenberg syndrome). Lesions of the lateral medulla may produce a torsional nystagmus with the fast phase directed away from the side of the lesion. This type of nystagmus can be accentuated by otolithic stimulation by placing the user on their side with the intact side down (e.g., if the lesion is on the left, the nystagmus is accentuated when the user is placed on his right side).

[0108] This condition may occur when the tone within the pathways of the posterior semicircular canals is relatively higher than the tone within the anterior semicircular canals, and it can occur from lesions of the ventral tegmental tract or the brachium conjunctivum, which carry optokinetic input from the anterior semicircular canals to the third nerve nuclei.

[0109] Pendular nystagmus is a multivectorial nystagmus (i.e., horizontal, vertical, circular, and elliptical) with an equal velocity in each direction that may reflect brain stem or cerebellar dysfunction. Often, there is marked asymmetry and dissociation between the eyes. The amplitude of the nystagmus may vary in different positions of gaze. Causes of pendular nystagmus may include demyelinating disease, monocular or binocular visual deprivation, oculapalatal myoclonus, internuclear opthalmoplegia, or brain stem or cerebellar dysfunction.

[0110] Horizontal nystagmus is a well-recognized finding in patients with a unilateral disease of the cerebral hemispheres, especially with large, posterior lesions. It often is of low amplitude. Such patients show a constant velocity drift of the eyes toward the intact hemisphere with fast saccade directed toward the side of the lesion.

[0111] Seesaw nystagmus is a pendular oscillation that consists of elevation and intorsion of one eye and depression and extorsion of the fellow eye that alternates every half cycle. This striking and unusual form of nystagmus may be seen in patients with chiasmal lesions, suggesting loss of the crossed visual inputs from the decussating fibers of the optic nerve at the level of the chiasm as the cause or lesions in the rostral midbrain. This type of nystagmus is not affected by otolithic stimulation. Seesaw nystagmus may also be caused by parasellar lesions or visual loss secondary to retinitis pigmentosa.

[0112] Gaze-evoked nystagmus is produced by the attempted maintenance of an extreme eye position. It is the most common form of nystagmus. Gaze-evoked nystagmus is due to a deficient eye position signal in the neural integrator network. Thus, the eyes cannot be maintained at an eccentric orbital position and are pulled back toward primary position by the elastic forces of the orbital fascia. Then, corrective saccade moves the eyes back toward the eccentric position in the orbit.

[0113] Gaze-evoked nystagmus may be caused by structural lesions that involve the neural integrator network, which is dispersed between the vestibulocerebellum, the medulla (e.g., the region of the nucleus prepositus hypoglossi and adjacent medial vestibular nucleus "NPH/MVN"), and the interstitial nucleus of Cajal ("INC"). Patients recovering from a gaze palsy go through a period where they are able to gaze in the direction of the previous palsy, but they are unable to sustain gaze in that direction; therefore, the eyes drift slowly back toward primary position followed by a corrective saccade. When this is repeated, a gaze-evoked or gaze-paretic nystagmus results.

[0114] Gaze-evoked nystagmus often is encountered in healthy users; in which case, it is called end-point nystagmus. End-point nystagmus usually can be differentiated from gaze-evoked nystagmus caused by disease, in that the former has lower intensity and, more importantly, is not associated with other ocular motor abnormalities. Gaze-evoked nystagmus also may be caused by alcohol or drugs including anti-convulsants (e.g., phenobarbital, phenytoin, or carbamazepine) at therapeutic dosages.

[0115] Spasmus nutans is a rare condition with the clinical triad of nystagmus, head nodding, and torticollis. Onset is from age 3-15 months with disappearance by 3 or 4 years. Rarely, it may be present to age 5-6 years. The nystagmus typically consists of small-amplitude, high frequency oscillations and usually is bilateral, but it can be monocular, asymmetric, and variable in different positions of gaze. Spasmus nutans occurs in otherwise healthy children. Chiasmal, suprachiasmal, or third ventricle gliomas may cause a condition that mimics spasmus nutans.

[0116] Periodic alternating nystagmus is a conjugate, horizontal jerk nystagmus with the fast phase beating in one direction for a period of approximately 1-2 minutes. The nystagmus has an intervening neutral phase lasting 10-20 seconds; the nystagmus begins to beat in the opposite direction for 1-2 minutes; then the process repeats itself. The mechanism may be disruption of the vestibulo-ocular tracts at the pontomedullary junction. Causes of periodic alternating nystagmus may include Arnold-Chiari malformation, demyelinating disease, spinocerebellar degeneration, lesions of the vestibular nuclei, head trauma, encephalitis, syphilis, posterior fossa tumors, or binocular visual deprivation (e.g., ocular media opacities).

[0117] Abducting nystagmus of internuclear opthalmoplegia ("INO") is nystagmus in the abducting eye contralateral to a medial longitudinal fasciculus ("MLF") lesion.

[0118] In the context of the above pupillary reflex or eye movement test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. Altered pupillary reflex or eye movement may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of altered pupillary reflex or eye movement, or the one or more types of user data indicative of a likely condition associated with altered pupillary reflex or eye movement. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0119] Operation **516** depicts implementing in the at least one device at least one face pattern test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a face pattern test module **134** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a face pattern test module **134** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0120] An example of a face pattern test function may be a face pattern test module **134** and/or user-health test unit **104** that can compare a user's face while at rest, specifically looking for nasolabial fold flattening or drooping of the corner of the mouth, with the user's face while moving certain facial features. The user may be asked to raise her eyebrows, wrinkle her forehead, show her teeth, puff out her cheeks, or close her eyes tight. Such testing may done via facial pattern recognition software used in conjunction with, for example, a videoconferencing application. Any weakness or asymmetry may indicate a lesion in the facial nerve. In general, a peripheral lesion of the facial nerve may affect the upper and lower face while a central lesion may only affect the lower face.

[0121] Abnormalities in facial expression or pattern may indicate a petrous fracture. Peripheral facial nerve injury may also be due to compression, tumor, or aneurysm. Bell's Palsy is thought to be caused by idiopathic inflammation of the facial nerve within the facial canal. A peripheral facial nerve lesion involves muscles of both the upper and lower face and can involve loss of taste sensation from the anterior ⅔ of the tongue (via the chorda tympani). A central facial nerve palsy due to tumor or hemorrhage results in sparing of upper and frontal orbicularis occuli due to crossed innervation. Spared ability to raise eyebrows and wrinkle the forehead helps differentiate a peripheral palsy from a central process. This also may indicate stroke or multiple sclerosis.

[0122] In the context of the above face pattern test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. Altered face pattern may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of altered face pattern, or the one or more types of user data indicative of a likely condition associated with altered face pattern. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0123] Operation **518** depicts implementing in the at least one device at least one hearing test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a hearing test module **136** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a hearing test module **136** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0124] An example of a hearing test function may be a hearing test module **136** and/or user-health test unit **104** conducting a gross hearing assessment of a user's ability to hear sounds. This can be done by simply presenting sounds to the user or determining if the user can hear sounds presented to each of the ears. For example, a hearing test module **136** and/or user-health test unit **104** may vary volume settings or sound frequency on a user's device **102** or within an application **106** over time to test user hearing. Alternatively, a hearing test module **136** and/or user-health test unit **104** in a mobile phone device may carry out various hearing test functions.

[0125] Petrous fractures that involve the vestibulocochlear nerve may result in hearing loss, vertigo, or nystagmus (frequently positional) immediately after the injury. Severe middle ear infection can cause similar symptoms but have a more gradual onset. Acoustic neuroma is associated with gradual ipsilateral hearing loss. Due to the close proximity of the vestibulocochlear nerve with the facial nerve, acoustic neuromas often present with involvement of the facial nerve. Neurofibromatosis type II is associated with bilateral acoustic neuromas. Vertigo may be associated with anything that compresses the vestibulocochlear nerve including vascular abnormalities, inflammation, or neoplasm.

[0126] In the context of the above hearing test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. Reduced hearing function may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of reduced hearing function, or the one or more types of user data indicative of a likely condition associated with reduced hearing function. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0127] Operation **520** depicts implementing in the at least one device at least one voice test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a voice test module **138** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a voice test module **138** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0128] An example of a voice test function may be a measure of symmetrical elevation of the palate when the user says "aah," or a test of the gag reflex. In an ipsilateral lesion of the vagus nerve, the uvula deviates towards the affected side. As a result of its innervation (through the recurrent laryngeal nerve) to the vocal cords, hoarseness may develop as a symptom of vagus nerve injury. A voice test module **138** and/or user-health test unit **104** may monitor user voice frequency or volume data during, for example, gaming, videoconferencing, speech recognition software use, or mobile phone use. Injury to the recurrent laryngeal nerve can occur with lesions in the neck or apical chest. The most common lesions are tumors in the neck or apical chest. Cancers may include lung cancer, esophageal cancer, or squamous cell cancer.

[0129] Other voice test functions may involve first observing the tongue (while in floor of mouth) for fasciculations. If present, fasciculations may indicate peripheral hypoglossal nerve dysfunction. Next, the user may be prompted to protrude the tongue and move it in all directions. When protruded, the tongue will deviate toward the side of a lesion (as the unaffected muscles push the tongue more than the weaker side). Gross symptoms of pathology may result in garbled sound in speech (as if there were marbles in the user's mouth). Damage to the hypoglossal nerve affecting voice/speech may indicate neoplasm, aneurysm, or other external compression, and may result in protrusion of the tongue away from side of the lesion for an upper motor neuron process and toward the side of the lesion for a lower motor neuron process. Accordingly, a voice test module **138** and/or user-health test unit **104** may assess a user's ability to make simple sounds or to say words, for example, consistently with an established voice pattern for the user.

[0130] In the context of the above voice test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. Altered voice function may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of altered voice function, or the one or more types of user data indicative of a likely condition associated with altered voice function. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0131] FIG. **6** illustrates alternative embodiments of the example operational flow **300** of FIG. **3**. FIG. **6** illustrates example embodiments where the implementing operation **310** may include at least one additional operation. Additional operations may include operation **600** and/or operation **602**.

[0132] Operation **600** depicts implementing in the at least one device at least one motor skill test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a motor skill test module **140** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a motor skill test module **140** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0133] An example of a motor skill test function may be a measure of a user's ability to perform a physical task, or a measure of tremor in a body part (i.e., a rhythmic, involuntary, or oscillating movement of a body part occurring in isolation or as part of a clinical syndrome). A motor skill test module **140** and/or user-health test unit **104** may measure, for example, a user's ability to traverse a path on a display in straight line with a pointing device, to type a certain sequence of characters without error, or to type a certain number of characters without repetition. For example, a wobbling cursor on a display may indicate ataxia in the user, or a wobbling cursor while the user is asked to maintain the cursor on a fixed point on a display may indicate early Parkinson's disease symptoms. Alternatively, a user may be prompted to switch tasks, for example, to alternately type some characters using a keyboard and click on some target with a mouse. If a user has a motor skill deficiency, she may have difficulty stopping one task and starting the other task.

[0134] In clinical practice, characterization of tremor is important for etiologic consideration and treatment. Common types of tremor include resting tremor, postural tremor, action or kinetic tremor, task-specific tremor, or intention or terminal tremor. Resting tremor occurs when a body part is at complete rest against gravity. Tremor amplitude tends to decrease with voluntary activity. Causes of resting tremor may include Parkinson's disease, Parkinson-plus syndromes (e.g., multiple system atrophy, progressive supranuclear palsy, or corticobasal degeneration), Wilson's disease, drug-induced Parkinsonism (e.g., neuroleptics, Reglan, or phenthiazines), or long-standing essential tremor.

[0135] Postural tremor occurs during maintenance of a position against gravity and increases with action. Action or kinetic tremor occurs during voluntary movement. Examples of postural and action tremors may include essential tremor (primarily postural), metabolic disorders (e.g., thyrotoxicosis, pheochromocytoma, or hypoglycemia), drug-induced parkinsonism (e.g., lithium, amiodarone, or beta-adrenergic agonists), toxins (e.g., alcohol withdrawal, heavy metals), neuropathic tremor (e.g., neuropathy).

[0136] Task-specific tremor emerges during specific activity. An example of this type is primary writing tremor. Intention or terminal tremor manifests as a marked increase in tremor amplitude during a terminal portion of targeted movement. Examples of intention tremor include cerebellar tremor and multiple sclerosis tremor.

[0137] In the context of the above motor skill test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. Altered motor skill function may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of altered motor skill function, or the one or more types of user data indicative of a likely condition associated with altered motor skill function. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. Examples of relevant websites can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1; and at http://www.jeffmann.net/NeuroGuidemaps/tremor.html. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0138] Operation **602** depicts implementing in the at least one device at least one body movement test function that is structurally distinct from the at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device. For example, a body movement test module **142** may be implemented in the at least one device **102** that can receive user data **116** from an interaction between the user **110** and the at least one application **106** whose primary function is different from symptom detection, the at least one application **106** being operable on the at least one device **102**. Such a body movement test module **142** may receive the user data **116** via a data capture module **112** or data detection module **114**.

[0139] An example of a body movement test function may be first observing the user for atrophy or fasciculation in the trapezius muscles, shoulder drooping, or displacement of the scapula. A body movement test module **142** and/or user-health test unit **104** may then instruct the user to turn the head and shrug shoulders against resistance. Weakness in turning the head in one direction may indicate a problem in the contralateral spinal accessory nerve, while weakness in shoulder shrug may indicate an ipsilateral spinal accessory nerve lesion. Ipsilateral paralysis of the sternocleidomastoid and trapezius muscles due to neoplasm, aneurysm, or radical neck surgery also may indicate damage to the spinal accessory nerve. A body movement test module **142** and/or user-health test unit **104** may perform gait analysis, for example, in the context of a security system surveillance application involving video monitoring of the user.

[0140] Cerebellar disorders can disrupt body coordination or gait while leaving other motor functions relatively intact. The term ataxia is often used to describe the abnormal movements seen in coordination disorders. In ataxia, there are medium- to large-amplitude involuntary movements with an irregular oscillatory quality superimposed on and interfering with the normal smooth trajectory of movement. Overshoot is also commonly seen as part of ataxic movements and is sometimes referred to as "past pointing" when target-oriented movements are being discussed. Another feature of coordination disorders is dysdiadochokinesia (i.e., abnormal alternating movements). Cerebellar lesions can cause different kinds of coordination problems depending on their location. One important distinction is between truncal ataxia and appendicular ataxia. Appendicular ataxia affects movements of the extremities and is usually caused by lesions of the cerebellar hemispheres and associated pathways. Truncal ataxia affects the proximal musculature, especially that involved in gait stability, and is caused by midline damage to the cerebellar vermis and associated pathways.

[0141] Fine movements of the hands and feet also may be tested by a body movement test module **142** and/or user-health test unit **104**. Rapid alternating movements, such as wiping one palm alternately with the palm and dorsum of the other hand, may be tested as well. A common test of coordination is the finger-nose-finger test, in which the user is asked to alternately touch their nose and an examiner's finger as quickly as possible. Ataxia may be revealed if the examiner's finger is held at the extreme of the user's reach, and if the examiner's finger is occasionally moved suddenly to a different location. Overshoot may be measured by having the user raise both arms suddenly from their lap to a specified level in the air. In addition, pressure can be applied to the user's outstretched arms and then suddenly released. To test the accuracy of movements in a way that requires very little strength, a user can be prompted to repeatedly touch a line drawn on the crease of the user's thumb with the tip of their forefinger; alternatively, a body movement test module **142**

and/or user-health test unit **104** may prompt a user to repeatedly touch an object on a touchscreen display.

[0142] Normal performance of motor tasks depends on the integrated functioning of multiple sensory and motor subsystems. These include position sense pathways, lower motor neurons, upper motor neurons, the basal ganglia, and the cerebellum. Thus, in order to convincingly demonstrate that abnormalities are due to a cerebellar lesion, one should first test for normal joint position sense, strength, and reflexes and confirm the absence of involuntary movements caused by basal ganglia lesions. As discussed above, appendicular ataxia is usually caused by lesions of the cerebellar hemispheres and associated pathways, while truncal ataxia is often caused by damage to the midline cerebellar vermis and associated pathways.

[0143] Another body movement test is the Romberg test, which may indicate a problem in the vestibular or proprioception system. A user is asked to stand with feet together (touching each other). Then the user is prompted to close their eyes. If a problem is present, the user may begin to sway or fall. With the eyes open, three sensory systems provide input to the cerebellum to maintain truncal stability. These are vision, proprioception, and vestibular sense. If there is a mild lesion in the vestibular or proprioception systems, the user is usually able to compensate with the eyes open. When the user closes their eyes, however, visual input is removed and instability can be brought out. If there is a more severe proprioceptive or vestibular lesion, or if there is a midline cerebellar lesion causing truncal instability, the user will be unable to maintain this position even with their eyes open.

[0144] In the context of the above body movement test function, as set forth herein available data arising from the user-health test function are one or more of various types of user data described in FIG. **8** and its supporting text. Altered body movement function may indicate certain of the possible conditions discussed above. One skilled in the art can establish or determine parameters or values relating to the one or more types of user data indicative of altered body movement function, or the one or more types of user data indicative of a likely condition associated with altered body movement function. Parameters or values can be set by one skilled in the art based on knowledge, direct experience, or using available resources such as websites, textbooks, journal articles, or the like. An example of a relevant website can be found in the online Merck Manual at http://www.merck.com/mmhe/sec06/ch077/ch077c.html#tb077_1. Examples of relevant textbooks include Patten, J. P., "Neurological Differential Diagnosis," Second Ed., Springer-Verlag, London, 2005; Kasper, Braunwald, Fauci, Hauser, Longo, and Jameson, "Harrison's Principles of Internal Medicine," 16th Ed., McGraw-Hill, New York, 2005; Greenberg, M. S., "Handbook of Neurosurgery," 6th Ed., Thieme, Lakeland, 2006; and Victor, M., and Ropper, A. H., "Adams and Victor's Principles of Neurology," 7th Ed., McGraw-Hill, New York, 2001.

[0145] FIG. **7** illustrates alternative embodiments of the example operational flow **300** of FIG. **3**. FIG. **7** illustrates example embodiments where the implementing operation **310** may include at least one additional operation. Additional operations may include operation **700**, **702**, **704**, and/or operation **706**.

[0146] Operation **700** depicts implementing in the at least one device the at least one user-health test function that is structurally distinct from at least one game, the at least one game being operable on the at least one device. For example, a device **102** may have installed on it a user-health test unit **104** that is structurally distinct from at least one game **144**. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the game **144**, whose primary function is different from symptom detection, the game **144** being operable on the at least one device **102**. Such a game **144** may generate user data **116** via a user input device **146** or a user monitoring device **148**. Examples of a user input device **146** include a text entry device such as a keyboard, a pointing device such as a mouse, a touchscreen, or the like. Examples of a user monitoring device **148** include a microphone, a photography device, a video device, or the like.

[0147] Examples of a game **144** may include a computer game such as, for example, solitaire, puzzle games, role-playing games, first-person shooting games, strategy games, sports games, racing games, adventure games, or the like. Such games may be played offline or through a network (e.g., online games).

[0148] Operation **702** depicts implementing in the at least one device the at least one user-health test function that is structurally distinct from at least one communication application, the at least one communication application being operable on the at least one device. For example, a user-health test unit **104** may be implemented over a network **202** on the at least one device **102**, the user-health test unit being structurally distinct from at least one communication application **150** operable on the at least one device **102**. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the communication application **150**, whose primary function is different from symptom detection. Such a communication application **150** may generate user data **116** via a user input device **146** or a user monitoring device **148**.

[0149] Examples of a communication application **150** may include various forms of one-way or two-way information transfer, typically to, from, between, or among devices. Some examples of communications applications include: an email program, a telephony application, a videocommunications function, an internet or other network messaging program, a cell phone communication application, or the like. Such a communication application may operate via text, voice, video, or other means of communication, combinations of these, or other means of communication.

[0150] Operation **704** depicts implementing in the at least one device the at least one user-health test function that is structurally distinct from at least one security application, the at least one security application being operable on the at least one device. For example, a user-health test unit **104** may be implemented over a network **202** on a device **102**, the user-health test unit being structurally distinct from at least one security application **152** operable on the at least one device **102**. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the security application **152**, whose primary function is different from symptom detection. Such a security application **152** may generate user data **116** via a user input device **146** or a user monitoring device **148**.

[0151] Examples of a security application **152** may include a password entry program, a code entry system, a biometric identification application, a video monitoring system, or the like.

[0152] Operation **706** depicts implementing in the at least one device the at least one user-health test function that is structurally distinct from at least one productivity application, the at least one productivity application being operable on the at least one device. For example, a user-health test unit **104** may be implemented over a network **202** on the at least one device **102**, the user-health test unit being structurally distinct from at least one productivity application **154** operable on the at least one device **102**. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the productivity application **154**, whose primary function is different from symptom detection. Such a productivity application **154** may generate user data **116** via a user input device **146** or a user monitoring device **148**.

[0153] Examples of a productivity application **154** may include a word processing program, a spreadsheet program, business software, or the like.

[0154] FIG. **8** illustrates alternative embodiments of the example operational flow **300** of FIG. **3**. FIG. **8** illustrates example embodiments where the obtaining operation **320** may include at least one additional operation. Additional operations may include operation **800**, **802**, **804**, **806**, **808**, **810**, **812**, and/or operation **814**.

[0155] Operation **800** depicts obtaining user reaction time data in response to the interaction between the user and the at least one application. For example, a device **102** may have installed on it at least one application **106** that is structurally distinct from a user-health test unit **104** that is installed on an external device **160** that has access to the user data **116** generated by device **102** on which the application **106** is installed. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the application **106**, whose primary function is different from symptom detection, the application **106** being operable on the device **102**. Such an application **106** may generate user data **116** via a user input device **146** or a user monitoring device **148**. User-health test unit **104**, either resident on device **102** or in this example resident on an external device **160** that communicates with device **102**, can obtain user reaction time data, for example, in response to an interaction between the user and the at least one application **106**, for example via user interface **108**.

[0156] Examples of reaction time data may include speed of a user **110**'s response to a prompting icon on a display, for example by clicking with a mouse or other pointing device or by some other response mode. For example, within a game situation a user may be prompted to click on a target as a test of alertness or awareness. Data may be collected once or many times for this task. A multiplicity of data points indicating a change in reaction time may be indicative of a change in alertness, awareness, neglect, construction, memory, hearing, or other user-health attribute as discussed above.

[0157] Operation **802** depicts obtaining user movement data in response to the interaction between the user and the at least one application. For example, a device **102** may have installed on it at least one application **106** that is structurally distinct from a user-health test unit **104** that is installed on an external device **160** that has access to the user data **116** generated by device **102** on which the application **106** is installed. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the application **106**, whose primary function is different from symptom detection, the application **106** being operable on the device **102**. Such an application **106** may generate user data **116** via a user input device **146** or a user monitoring device **148**. User-health test unit **104**, either resident on device **102** or in this example resident on an external device **160** that communicates with device **102**, can obtain user movement data in response to an interaction between the user and the at least one application **106**, for example via user interface **108**.

[0158] An example of user movement data may include data from a pointing device when a user is prompted to activate or click a specific area on a display to test, for example, visual field range or motor skill function. Another example is visual data of a user's body, for example during a videoconference, wherein changes in facial movement, limb movement, or other body movements are detectable, as discussed above.

[0159] Operation **804** depicts obtaining user cognitive function data in response to the interaction between the user and the at least one application. For example, a device **102** may have installed on it at least one application **106** that is structurally distinct from a user-health test unit **104** that is installed on an external device **160** that has access to the user data **116** generated by device **102** on which the application **106** is installed. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the application **106**, whose primary function is different from symptom detection, the application **106** being operable on the device **102**. Such an application **106** may generate user data **116** via a user input device **146** or a user monitoring device **148**. User-health test unit **104**, either resident on device **102** or in this example resident on an external device **160** that communicates with device **102**, can obtain user cognitive function data in response to an interaction between the user and the at least one application **106**, for example via user interface **108**.

[0160] An example of user cognitive function data may include data from a text or number input device or user monitoring device when a user is prompted to, for example, spell, write, speak, or calculate in order to test, for example, alertness, ability to calculate, speech, motor skill function, or the like, as discussed above.

[0161] Operation **806** depicts obtaining user memory function data in response to the interaction between the user and the at least one application. For example, a device **102** may have installed on it at least one application **106** that is structurally distinct from a user-health test unit **104** that is installed on an external device **160** that has access to the user data **116** generated by device **102** on which the application **106** is installed. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the application **106**, whose primary function is different from symptom detection, the application **106** being operable on the device **102**. Such an application **106** may generate user data **116** via a user input device **146** or a user monitoring device **148**. User-health test unit **104**, either resident on device **102** or in this example resident on an external device **160** that communicates with device **102**, can obtain user memory function data in response to an interaction between the user and the at least one application **106**, for example via user interface **108**.

[0162] An, example of user memory function data may include data from a text or number input device or user monitoring device when a user is prompted to, for example, spell, write, speak, or calculate in order to test, for example, short-term memory, long-term memory, or the like, as discussed above.

[0163] Operation **808** depicts obtaining user voice or speech data in response to the interaction between the user and the at least one application. For example, a device **102** may have installed on it at least one application **106** that is structurally distinct from a user-health test unit **104** that is installed on an external device **160** that has access to the user data **116** generated by device **102** on which the application **106** is installed. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the application **106**, whose primary function is different from symptom detection, the application **106** being operable on the device **102**. Such an application **106** may generate user data **116** via a user input device **146** or a user monitoring device **148**. User-health test unit **104**, either resident on device **102** or in this example resident on an external device **160** that communicates with device **102**, can obtain user voice or speech data in response to an interaction between the user and the at least one application **106**, for example via user interface **108**.

[0164] An example of user voice or speech data may include data from a speech or voice input device or user monitoring device, such as a telephonic device or a video communication device with sound receiving/transmission capability, for example when a user task requires, for example, speaking, singing, or other vocalization, as discussed above.

[0165] Operation **810** depicts obtaining user eye movement data in response to the interaction between the user and the at least one application. For example, a device **102** may have installed on it at least one application **106** that is structurally distinct from a user-health test unit **104** that is installed on an external device **160** that has access to the user data **116** generated by device **102** on which the application **106** is installed. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the application **106**, whose primary function is different from symptom detection, the application **106** being operable on the device **102**. Such an application **106** may generate user data **116** via a user input device **146** or a user monitoring device **148**. User-health test unit **104**, either resident on device **102** or in this example resident on an external device **160** that communicates with device **102**, can obtain user eye movement data in response to an interaction between the user and the at least one application **106**, for example via user interface **108**.

[0166] An example of user eye movement data may include data from a user monitoring device, such as a video communication device, for example, when a user task requires tracking objects on a display, reading, or during resting states between activities in an application, as discussed above. A further example includes pupillary reflex data from the user at rest or during an activity required by an application or user-health test function.

[0167] Operation **812** depicts obtaining user internet usage data in response to the interaction between the user and the at least one application. For example, a device **102** may have installed on it at least one application **106** that is structurally distinct from a user-health test unit **104** that is also installed on the device **102**. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the application **106**, whose primary function is different from symptom detection, the application **106** being operable on the device **102**. Such an application **106** may generate user data **116** via a user input device **146** or a user monitoring device **148**. User-health test unit **104** can obtain user internet usage data in response to an interaction between the user **110** and the at least one application **106**, for example via user interface **108**.

[0168] An example of user internet usage data may include data from a user's pointing device (including ability to click on elements of a web page, for example), browser history/function (including sites visited, ability to navigate from one site to another, ability to go back to a previous website if prompted, or the like), monitoring device, such as a video communication device, for example, when an application task or user-health test function task requires interaction with a web browser. Such data may indicate cognitive, memory, or motor skill function impairment, or the like, as discussed above. Other examples of internet usage data may include data from a user's offline interaction with internet content obtained while online.

[0169] Operation **814** depicts obtaining user image data in response to the interaction between the user and the at least one application. For example, a device **102** may have installed on it at least one application **106** that is structurally distinct from a user-health test unit **104** that is also installed on the device **102**. The user-health test unit **104** can receive user data **116** from an interaction between user **110** and the application **106**, whose primary function is different from symptom detection, the application **106** being operable on the device **102**. Such an application **106** may generate user data **116** via a user input device **146** or a user monitoring device **148**. User-health test unit **104** can obtain user image data in response to an interaction between the user **110** and the at least one application **106**, for example via user interface **108**.

[0170] An example of user image data may include data from a user's video capture device, monitoring device, such as a video communication device, for example, when a user inputs a photograph or video when using an application, or when a user's image is captured when communicating via a photography or video-based application. Other examples of user image data may include biometric data such as facial pattern data, eye scanning data, or the like. Such user image data may indicate, for example, alertness, attention, motor skill function impairment, or the like, as discussed above.

[0171] FIG. **9** illustrates alternative embodiments of the example operational flow **300** of FIG. **3**. FIG. **9** illustrates example embodiments where the presenting operation **330** may include at least one additional operation. Additional operations may include operation **900**, **902**, and/or operation **904**.

[0172] Operation **900** depicts sending to a healthcare provider the output of the at least one user-health test function at least partly based on the user data. For example, a user-health test unit **104** may be installed on an external device **160** with access to user data **116** generated by a user **110** interaction with application **106** whose primary function is different from symptom detection, application **106** being operable on device **102**. The user-health test unit **104** can receive user data **116**, and based at least partly on user data **116** can send an output to a healthcare provider **210**, for example, over a network **202**. Examples of a healthcare provider **210** may include physicians, therapists, nurses, counselors, hospitals, health maintenance organizations, or the like.

[0173] Operation **902** depicts displaying on the at least one device the output of the at least one user-health test function at least partly based on the user data. For example, a user-health test unit **104** may be installed on an external device **160** with access to user data **116** generated by a user **110** interaction with application **106** whose primary function is different from symptom detection, application **106** being operable on device **102**. The user-health test unit **104** can receive user data **116**, and based at least partly on user data **116** can send an output to a display on the device **102**. Examples of outputs displayed on a device **102** may include an alert message in an email application, a notification window in a desktop area of an operating system running on the device, a program window that shows the output to the user in the context of the user-health test function, or the like.

[0174] Examples of an output of a user-health test function or user-health test unit may include baseline user attributes such as reaction time, motor skill function, visual field range, or the like. Further examples of an output of a user-health test function or user-health test unit **104** may include an aggregation or distillation of user data acquired over a period of time. Statistical filters may be applied to user data by the user-health test function, or profiles corresponding to various health-related problems may be matched with user data or a distillation of user data.

[0175] Operation **904** depicts sending to a network destination the output of the at least one user-health test function at least partly based on the user data. For example, a user-health test unit **104** may be installed on an external device **160** with access to user data **116** generated by a user **110** interaction with application **106** whose primary function is different from symptom detection, application **106** being operable on device **102**. The user-health test unit **104** can receive user data **116**, and based at least partly on user data **116** can send an output to a network destination **206**, for example, over a network **202**. Examples of network destinations may include devices including computers connected to, for example, a home network accessible by parents of a child user, devices connected by the internet to the device **102** or user interface **108**, or the like.

[0176] FIG. **10** illustrates a partial view of an example computer program product **1000** that includes a computer program **1004** for executing a computer process on a computing device. An embodiment of the example computer program product **1000** is provided using a signal bearing medium **1002**, and may include one or more instructions for implementing in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device; one or more instructions for obtaining user data in response to an interaction between a user and the at least one application; and one or more instructions for presenting an output of the at least one user-health test function at least partly based on the user data. The one or more instructions may be, for example, computer executable and/or logic-implemented instructions. In one implementation, the signal-bearing medium **1002** may include a computer-readable medium **1006**. In one implementation, the signal bearing medium **1002** may include a recordable medium **1008**. In one implementation, the signal bearing medium **1002** may include a communications medium **1010**.

[0177] FIG. **11** illustrates an example system **1100** in which embodiments may be implemented. The system **1100** includes a computing system environment. The system **1100** also illustrates the user **110** using a device **1104**, which is optionally shown as being in communication with a computing device **1102** by way of an optional coupling **1106**. The optional coupling **1106** may represent a local, wide-area, or peer-to-peer network, or may represent a bus that is internal to a computing device (e.g., in example embodiments in which the computing device **1102** is contained in whole or in part within the device **1104**). A storage medium **1108** may be any computer storage media.

[0178] The computing device **1102** includes computer-executable instructions **1110** that when executed on the computing device **1102** cause the computing device **1102** to (a) implement in at least one device at least one user-health test function that is structurally distinct from at least one application whose primary function is different from symptom detection, the at least one application being operable on the at least one device; (b) obtain user data in response to an interaction between the user and the at least one application; and (c) present an output of the user-health test function at least partly based on the user data. As referenced above and as shown in FIG. **11**, in some examples, the computing device **1102** may optionally be contained in whole or in part within the device **1104**.

[0179] In FIG. **11**, then, the system **1100** includes at least one computing device (e.g., **1102** and/or **1104**). The computer-executable instructions **1110** may be executed on one or more of the at least one computing device. For example, the computing device **1102** may implement the computer-executable instructions **1110** and output a result to (and/or receive data from) the computing device **1104**. Since the computing device **1102** may be wholly or partially contained within the computing device **1104**, the device **1104** also may be said to execute some or all of the computer-executable instructions **1110**, in order to be caused to perform or implement, for example, various ones of the techniques described herein, or other techniques.

[0180] The device **1104** may include, for example, a portable computing device, workstation, or desktop computing device. In another example embodiment, the computing device **1102** is operable to communicate with the device **1104** associated with the user **110** to receive information about the input from the user **110** for performing data access and data processing and presenting an output of the user-health test function at least partly based on the user data.

[0181] Although a user **110** is shown/described herein as a single illustrated figure, those skilled in the art will appreciate that a user **110** may be representative of a human user, a robotic user (e.g., computational entity), and/or substantially any combination thereof (e.g., a user may be assisted by one or more robotic agents). In addition, a user **110**, as set forth herein, although shown as a single entity may in fact be composed of two or more entities. Those skilled in the art will appreciate that, in general, the same may be said of "sender" and/or other entity-oriented terms as such terms are used herein.

[0182] FIG. **4** shows diagrammatic views of the surface of the human brain. Lateral surface of the brain with Brodmann's areas **400** shows various numbered areas of a lateral aspect of the human brain. Medial surface of the brain with Brodmann's areas **402** shows various numbered areas of the medial aspect of the human brain.

[0183] Measuring at least one physiologic activity of a member of population cohort **102** may include measuring magnetic, electrical, hemodynamic, and/or metabolic activity in the brain.

[0184] Magnetoencephalography

[0185] One method of measuring at least one physiologic activity may include measuring the magnetic fields produced by electrical activity in the brain via magnetoencephalography (MEG) using magnetometers such as superconducting quantum interference devices (SQUIDs) or other devices. Such measurements are commonly used in both research and clinical settings to, e.g., assist researchers in determining the function of various parts of the brain. Synchronized neuronal currents induce very weak magnetic fields that can be measured by magnetoencephalography. However, the magnetic field of the brain is considerably smaller at 10 femtotesla (fT) for cortical activity and 103 fT for the human alpha rhythm than the ambient magnetic noise in an urban environment, which is on the order of 108 fT. Two essential problems of biomagnetism arise: weakness of the signal and strength of the competing environmental noise. The development of extremely sensitive measurement devices such as SQUIDs facilitates analysis of the brain's magnetic field in spite of the relatively low signal versus ambient magnetic signal noise. Magnetoencephalography (and EEG) signals derive from the net effect of ionic currents flowing in the dendrites of neurons during synaptic transmission. In accordance with Maxwell's equations, any electrical current will produce an orthogonally oriented magnetic field. It is this field that is measured with MEG. The net currents can be thought of as current dipoles, which are currents having an associated position, orientation, and magnitude, but no spatial extent. According to the right-hand rule, a current dipole gives rise to a magnetic field that flows around the axis of its vector component.

[0186] In order to generate a detectable signal, approximately 50,000 active neurons are needed. Because current dipoles must have similar orientations to generate magnetic fields that reinforce each other, it is often the layer of pyramidal cells in the cortex, which are generally perpendicular to its surface, that give rise to measurable magnetic fields. Further, it is often bundles of these neurons located in the sulci of the cortex with orientations parallel to the surface of the head that project measurable portions of their magnetic fields outside of the head.

[0187] Smaller magnetometers are in development, including a mini-magnetometer that uses a single milliwatt infrared laser to excite rubidium in the context of an applied perpendicular magnetic field. The amount of laser light absorbed by the rubidium atoms varies predictably with the magnetic field, providing a reference scale for measuring the field. The stronger the magnetic field, the more light is absorbed. Such a system is currently sensitive to the 70 fT range, and is expected to increase in sensitivity to the 10 fT range. See Physorg.com, "New mini-sensor may have biomedical and security applications," Nov. 1, 2007, http://www.physorg.com/news113151078.html.

[0188] Electroencephalography

[0189] Another method of measuring at least one physiologic activity may include measuring the electrical activity of the brain by recording from electrodes placed on the scalp or, in special cases, subdurally, or in the cerebral cortex. The resulting traces are known as an electroencephalogram (EEG) and represent a summation of post-synaptic potentials from a large number of neurons. EEG is most sensitive to a particular set of post-synaptic potentials: those which are generated in superficial layers of the cortex, on the crests of gyri directly abutting the skull and radial to the skull. Dendrites that are deeper in the cortex, inside sulci, are in midline or deep structures (such as the cingulate gyrus or hippocampus) or that produce currents that are tangential to the skull make a smaller contribution to the EEG signal.

[0190] One application of EEG is event-related potential (ERP) analysis. An ERP is any measured brain response that is directly the result of a thought or perception. ERPs can be reliably measured using electroencephalography (EEG), a procedure that measures electrical activity of the brain, typically through the skull and scalp. As the EEG reflects thousands of simultaneously ongoing brain processes, the brain response to a certain stimulus or event of interest is usually not visible in the EEG. One of the most robust features of the ERP response is a response to unpredictable stimuli. This response is known as the P300 (P3) and manifests as a positive deflection in voltage approximately 300 milliseconds after the stimulus is presented.

[0191] The most robust ERPs are seen after many dozens or hundreds of individual presentations are averaged together. This technique cancels out noise in the data allowing only the voltage response to the stimulus to stand out clearly. While evoked potentials reflect the processing of the physical stimulus, event-related potentials are caused by higher processes, such as memory, expectation, attention, or other changes in mental state.

[0192] A two-channel wireless brain wave monitoring system powered by a thermo-electric generator has been developed by IMEC (Interuniversity Microelectronics Centre, Leuven, Belgium). This device uses the body heat dissipated naturally from the forehead as a means to generate its electrical power. The wearable EEG system operates autonomously with no need to change or recharge batteries. The EEG monitor prototype is wearable and integrated into a headband where it consumes 0.8 milliwatts. A digital signal processing block encodes extracted EEG data, which is sent to a PC via a 2.4-GHz wireless radio link. The thermoelectric generator is mounted on the forehead and converts the heat flow between the skin and air into electrical power. The generator is composed of 10 thermoelectric units interconnected in a flexible way. At room temperature, the generated power is about 2 to 2.5-mW or 0.03-mW per square centimeter, which is the theoretical limit of power generation from the human skin. Such a device is proposed to associate emotion with EEG signals. See Clarke, "IMEC has a brain wave: feed EEG emotion back into games," EE Times online, http://www.eetimes.eu/design/202801063 (Nov. 1, 2007).

[0193] EEG can be recorded at the same time as MEG so that data from these complimentary high-time-resolution techniques can be combined.

[0194] Measuring at least one physiologic activity of a member of population cohort **102** may also include measuring metabolic or hemodynamic responses to neural activity. For example, in positron emission tomography (PET), positrons, the antiparticles of electrons, are emitted by certain radionuclides that have the same chemical properties as their non-radioactive isotopes and that can replace the latter in biologically-relevant molecules. After injection or inhalation of tiny amounts of these modified molecules, e.g., modified glucose (FDG) or neurotransmitters, their spatial distribution can be detected by a PET-scanner. This device is sensitive to radiation resulting from the annihilation of emitted positrons when they collide with ubiquitously-present electrons. Detected distribution information concerning metabolism or brain perfusion can be derived and visualized in tomograms. Spatial resolution is on the order of about 3-6 mm, and temporal resolution is on the order of several minutes to fractions of an hour.

[0195] Functional Near-Infrared Imaging

[0196] Another method for measuring physiologic activity is functional near-infrared imaging (fNIR). fNIR is a spectroscopic neuro-imaging method for measuring the level of neuronal activity in the brain. The method is based on neuro-vascular coupling, i.e., the relationship between neuronal metabolic activity and oxygen level (oxygenated hemoglobin) in blood vessels in proximity to the neurons.

[0197] Time-resolved frequency-domain spectroscopy (the frequency-domain signal is the Fourier transform of the original, time-domain signal) may be used in fNIR to provide quantitation of optical characteristics of the tissue and therefore offer robust information about oxygenation. Diffuse optical tomography (DOT) in fNIR enables researchers to produce images of absorption by dividing the region of interest into thousands of volume units, called voxels, calculating the amount of absorption in each (the forward model) and then putting the voxels back together (the inverse problem). fNIR systems commonly have multiple sources and detectors, signifying broad coverage of areas of interest, and high sensitivity and specificity. fNIR systems today often consist of little more than a probe with fiber optic sources and detectors, a piece of dedicated hardware no larger than a small suitcase and a laptop computer. Thus, fNIR systems can be portable; indeed battery operated, wireless continuous wave fNIR devices have been developed at the Optical Brain Imaging Lab of Drexel University. fNIR employs no ionizing radiation and allows for a wide range of movement; it's possible, for example, for a subject to walk around a room while wearing a fNIR probe. fNIR studies have examined cerebral responses to visual, auditory and somatosensory stimuli, as well as the motor system and language, and subsequently begun to construct maps of functional activation showing the areas of the brain associated with particular stimuli and activities.

[0198] For example, a fNIR spectroscopy device (fNIRS) has been developed that looks like a headband and uses laser diodes to send near-infrared light through the forehead at a relatively shallow depth e.g., (two to three centimeters) to interact with the brain's frontal lobe. Light ordinarily passes through the body's tissues, except when it encounters oxygenated or deoxygenated hemoglobin in the blood. Light waves are absorbed by the active, blood-filled areas of the brain and any remaining light is diffusely reflected to fNIRS detectors: See "Technology could enable computers to 'read the minds' of users," Physorg.com http://www.physorg.com/news110463755.html (1 Oct. 2007).

[0199] There are three types of fNIR: (1) CW—continuous wave—In this method, infrared light shines at the same intensity level during the measurement period. The detected signal is lower intensity static signal (dc valued); (2) FD—frequency domain—In this method, input signal is a modulated sinusoid at some frequency and detected output signal has changes in amplitude and phase; (3) TR—time resolved—In time resolve spectroscopy, a very short pulse is introduced to be measured and the pulse length is usually on the order of picoseconds. The detected signal is usually a longer signal and has a decay time.

[0200] In one approach, an infrared imager captures an image of a portion of the user. For example, the imager may capture a portion of the user's forehead. Infrared imaging may provide an indication of blood oxygen levels which in turn may be indicative of brain activity. With such imaging, the infrared imager may produce a signal indicative of brain activity. According to one method, hemoglobin oxygen saturation and relative hemoglobin concentration in a tissue may be ascertained from diffuse reflectance spectra in the visible wavelength range. This method notes that while oxygenated and deoxygenated hemoglobin contributions to light attenuation are strongly variable functions of wavelength, all other contributions to the attenuation including scattering are smooth wavelength functions and can be approximated by Taylor series expansion. Based on this assumption, a simple, robust algorithm suitable for real time monitoring of the hemoglobin oxygen saturation in the tissue was derived. This algorithm can be used with different fiber probe configurations for delivering and collecting light passed through tissue. See Stratonnikov et al., "Evaluation of blood oxygen saturation in vivo from diffuse reflectance spectra," J. Biomed. Optics, vol. 6, pp. 457-467 (2001).

[0201] Functional Magnetic Resonance Imaging

[0202] Another method of measuring at least one physiologic activity may include measuring blood oxygen level dependent effects by, for example, functional magnetic resonance imaging (fMRI). fMRI involves the use of magnetic resonance scanners to produce sets of cross sections—tomograms—of the brain, detecting weak but measurable resonance signals that are emitted by tissue water subjected to a very strong magnetic field after excitation with a high frequency electromagnetic pulse. Acquired resonance signals can be attributed to their respective spatial origins, and cross sectional images can be calculated. The signal intensity, often coded as a gray value of a picture element, depends on water content and certain magnetic properties of the local tissue. In general, structural MR imaging is used to depict brain morphology with good contrast and high resolution. Visualizing brain function by MRI relies on the relationship between increased neural activity of a brain region and increased hemodynamic response or blood flow to that brain region. The increased perfusion of activated brain tissue is the basis of the so-called Blood Oxygenation Level Dependent (BOLD)-effect: hemoglobin, the oxygen carrying molecule in blood, has different magnetic properties depending on its oxygenation state. While oxyhemoglobin is diamagnetic, deoxyhemoglobin is paramagnetic, which means that it locally distorts the magnetic field, leading to a local signal loss. In activated brain tissue the increased oxygen consumption is accompanied by a blood flow response. Thus, during activation of a brain region, deoxyhemoglobin is partly replaced by oxyhemoglobin, leading to less distortion of the local magnetic field and increased signal intensity. Color-coded statistical parametric activation maps (SPMs) are typically generated from statistical analyses of fMRI time series comparing signal intensity during different activation states.

[0203] Temporal and spatial resolution of fMRI depends on both scanning technology and the underlying physiology of the detected signal intensity changes. Structural images are usually obtained with a resolution of at least 1 mm×1 mm×1 mm voxels (the equivalent of a pixel in a volume), while fMRI voxels typically have edge lengths of about 3-5 mm. Temporal resolution of fMRI is on the order of between 1 and 3 seconds. The cerebral blood flow (CBF) response to a brain activation is delayed by about 3-6 seconds. There is a balance between temporal and spatial resolution, allowing whole brain scans in less than 3 seconds, and non-invasiveness, permitting repeated measurements without adverse events. In addition, the choice of scanning parameters allows increasing one parameter at the expense of the other. Recent fMRI approaches show that for some neural systems the temporal resolution can be improved down to milliseconds and spatial resolution can be increased to the level of cortical columns as basic functional units of the cortex.

[0204] In one embodiment, an fMRI protocol may include fMRI data may be acquired with an MRI scanner such as a 3

T Magnetom Trio Siemens scanner. T2*-weighted functional MR images may be obtained using axially oriented echo-planar imaging. For each subject, data may be acquired in three scanning sessions or functional runs. The first four volumes of each session may be discarded to allow for T1 equilibration effects. For anatomical reference, a high-resolution T1-weighted anatomical image may be obtained. Foam cushioning may be placed tightly around the side of the subject's head to minimize artifacts from head motion. Data preprocessing and statistical analysis may be carried out using a statistical parametric mapping function, such as SPM99 (Statistical Parametric Mapping, Wellcome Institute of Cognitive Neurology, London, UK). Individual functional images may be realigned, slice-time corrected, normalized into a standard anatomical space (resulting in isotropic 3 mm voxels) and smoothed with a Gaussian kernel of 6 mm. In one embodiment, a standard anatomical space may be based on the ICBM 152 brain template (MNI, Montreal Neurological Institute). A block-design model with a boxcar regressor convoluted with the hemodynamic response function may be used as the predictor to compare activity related to a stimulus versus a control object. High frequency noise may be removed using a low pass filter (e.g., Gaussian kernel with 4.0 s FWHM) and low frequency drifts may be removed via a high pass filter. Effects of the conditions for each subject may be compared using linear contrast, resulting in a t-statistic for each voxel. A group analysis may be carried out on a second level using a whole brain random-effect analysis (one-sample t-test). Regions that contain a minimum of five contiguous voxels thresholded at $P<0.001$ (uncorrected for multiple comparisons) may be considered to be active. See Schaefer et al., "Neural correlates of culturally familiar brands of car manufacturers," NeuroImage vol. 31, pp. 861-865 (2006).

[0205] Mapping Brain Activity

[0206] When brain activity data are collected from groups of individuals, data analysis across individuals may take into account variation in brain anatomy between and among individuals. To compare brain activations between individuals, the brains are usually spatially normalized to a template or control brain. In one approach they are transformed so that they are similar in overall size and spatial orientation. Generally, the goal of this transformation is to bring homologous brain areas into the closest possible alignment. In this context the Talairach stereotactic coordinate system is often used. The Talairach system involves a coordinate system to identify a particular brain location relative to anatomical landmarks; a spatial transformation to match one brain to another; and an atlas describing a standard brain, with anatomical and cytoarchitectonic labels. The coordinate system is based on the identification of the line connecting the anterior commissure (AC) and posterior commissure (PC)—two relatively invariant fiber bundles connecting the two hemispheres of the brain. The AC-PC line defines the y-axis of the brain coordinate system. The origin is set at the AC. The z-axis is orthogonal to the AC-PC-line in the foot-head direction and passes through the interhemispheric fissure. The x-axis is orthogonal to both the other axes and points from AC to the right. Any point in the brain can be identified relative to these axes.

[0207] Accordingly, anatomical regions may be identified using the Talairach coordinate system or the Talairach daemon (TD) and the nomenclature of Brodmann. The Talairach daemon is a high-speed database server for querying and retrieving data about human brain structure over the internet. The core components of this server are a unique memory-resident application and memory-resident databases. The memory-resident design of the TD server provides high-speed access to its data. This is supported by using TCP/IP sockets for communications and by minimizing the amount of data transferred during transactions. A TD server data may be searched using x-y-z coordinates resolved to 1×1×1 mm volume elements within a standardized stereotaxic space. An array, indexed by x-y-z coordinates, that spans 170 mm (x), 210 mm (y) and 200 mm (z), provides high-speed access to data. Array dimensions are approximately 25% larger than those of the Co-planar Stereotaxic Atlas of the Human Brain (Talairach and Tournoux, 1988). Coordinates tracked by a TD server are spatially consistent with the Talairach Atlas. Each array location stores a pointer to a relation record that holds data describing what is present at the corresponding coordinate. Data in relation records are either Structure Probability Maps (SP Maps) or Talairach Atlas Labels, though others can be easily added. The relation records are implemented as linked lists to names and values for brain structures. The TD server may be any computing device, such as a Sun Sparcstation **20** with 200 Mbytes of memory. Such a system provides 24-hour access to the data using a variety of client applications.

[0208] Some commercially available analysis software such as SPM5 (available for download from http://www.fil.ion.ucl.ac.uk/spm/software/spm5/) uses brain templates created by the Montreal Neurological Institute (MNI), based on the average of many normal MR brain scans. Although similar, the Talairach and the MNI templates are not identical, and care should be given to assigning localizations given in MNI coordinates correctly to, for example, cytoarchitectonically defined brain areas like the Brodmann areas (BA's), which are regions in the brain cortex defined in many different species based on its cytoarchitecture. Cytoarchitecture is the organization of the cortex as observed when a tissue is stained for nerve cells. Brodmann areas were originally referred to by numbers from 1 to 52. Some of the original areas have been subdivided further and referred to, e.g., as "23a" and "23b." The Brodmann areas for the human brain include the following:

[0209] Areas 1, 2 & 3—Primary Somatosensory Cortex (frequently referred to as Areas 3, 1, 2 by convention)

[0210] Area 4—Primary Motor Cortex

[0211] Area 5—Somatosensory Association Cortex

[0212] Area 6—Pre-Motor and Supplementary Motor Cortex (Secondary Motor Cortex)

[0213] Area 7—Somatosensory Association Cortex

[0214] Area 8—Includes Frontal eye fields

[0215] Area 9—Dorsolateral prefrontal cortex

[0216] Area 10—Frontopolar area (most rostral part of superior and middle frontal gyri)

[0217] Area 11—Orbitofrontal area (orbital and rectus gyri, plus part of the rostral part of the superior frontal gyrus)

[0218] Area 12—Orbitofrontal area (used to be part of BA11, refers to the area between the superior frontal gyrus and the inferior rostral sulcus)

[0219] Area 13—Insular cortex

[0220] Area 17—Primary Visual Cortex (V1)

[0221] Area 18—Visual Association Cortex (V2)

[0222] Area 19—V3

[0223] Area 20—Inferior Temporal gyrus

[0224] Area 21—Middle Temporal gyrus

[0225] Area 22—Superior Temporal Gyrus, of which the rostral part participates to Wernicke's area

[0226] Area 23—Ventral Posterior cingulate cortex
[0227] Area 24—Ventral Anterior cingulate cortex
[0228] Area 25—Subgenual cortex
[0229] Area 26—Ectosplenial area
[0230] Area 28—Posterior Entorhinal Cortex
[0231] Area 29—Retrosplenial cingular cortex
[0232] Area 30—Part of cingular cortex
[0233] Area 31—Dorsal Posterior cingular cortex
[0234] Area 32—Dorsal anterior cingulate cortex
[0235] Area 34—Anterior Entorhinal Cortex (on the Parahippocampal gyrus)
[0236] Area 35—Perirhinal cortex (on the Parahippocampal gyrus)
[0237] Area 36—Parahippocampal cortex (on the Parahippocampal gyrus)
[0238] Area 37—Fusiform gyrus
[0239] Area 38—Temporopolar area (most rostral part of the superior and middle temporal gyri
[0240] Area 39—Angular gyrus, part of Wernicke's area
[0241] Area 40—Supramarginal gyrus part of Wernicke's area
[0242] Areas 41 & 42—Primary and Auditory Association Cortex
[0243] Area 43—Subcentral area (between insula and post/precentral gyrus)
[0244] Area 44—pars opercularis, part of Broca's area
[0245] Area 45—pars triangularis Broca's area
[0246] Area 46—Dorsolateral prefrontal cortex
[0247] Area 47—Inferior prefrontal gyrus
[0248] Area 48—Retrosubicular area (a small part of the medial surface of the temporal lobe)
[0249] Area 52—Parainsular area (at the junction of the temporal lobe and the insula)

[0250] Associating Brain Activity with Brain Function or Mental State

[0251] The brain performs a multitude of functions. It is the location of memory, including working memory, semantic memory, and episodic memory. Attention is controlled by the brain, as is language, cognitive abilities, and visual-spatial functions. The brain also receives sensory signals and generates motor impulses. The frontal lobes of the brain are involved in most higher-level cognitive tasks as well as episodic and semantic memory. There is some degree of lateralization of the frontal lobes, e.g., the right frontal lobe is a locus for sustained attention and episodic memory retrieval, and the left frontal lobe is a locus for language, semantic memory retrieval, and episodic memory encoding.

[0252] The cingulated regions of the brain are associated with memory, initiation and inhibition of behavior, and emotion. The parietal regions of the brain are associated with attention, spatial perception and imagery, thinking involving time and numbers, working memory, skill learning, and successful episodic memory retrieval. The lateral temporal lobe of the brain is associated with language and semantic memory encoding and retrieval, while the medial temporal lobe is associated with episodic memory encoding and retrieval. The occipital temporal regions of the brain are associated with vision and visual-spatial processing.

[0253] Attention

[0254] Attention can be divided into five categories: sustained attention, selective attention, Stimulus-Response compatibility, orientation of attention, and division of attention. The tasks included in the sustained attention section involved continuous monitoring of different kinds of stimuli (e.g., somatosensory stimulation). The selective attention section includes studies in which subjects selectively attended to different attributes of the same set of stimuli (e.g., attend to color only for stimuli varying with respect to both color and shape). The stimulus-response (SR) compatibility section also includes studies examining selective attention, with the important difference that they involve a "conflict component." In all cases, this is implemented by employing the Stroop task.

[0255] Prefrontal and parietal areas, preferentially in the right hemisphere, are frequently engaged during tasks requiring attention. An fMRI study involving a visual vigilance task was in close agreement with the results of a PET study showing predominantly right-sided prefrontal and parietal activation. Observed data is consistent with a right fronto-parietal network for sustained attention. Selective attention to one sensory modality is correlated with suppressed activity in regions associated with other modalities. For example, studies have found deactivations in the auditory cortex during attention area activations. Taken together, the results suggest the existence of a fronto-parietal network underlying sustained attention. Direct support for fronto-parietal interactions during sustained attention has been provided by structural equation modeling of fMRI data. Studies on the effects of attention on thalamic (intralaminar nuclei) and brain stem (midbrain tegmentum) activity have shown that these areas may control the transition from relaxed wakefulness to high general attention.

[0256] Selective attention is characterized by increased activity in posterior regions involved in stimulus processing. Different regions seem to be involved depending on the specific attribute that is attended to. Studies have shown attentional modulation of auditory regions, and modulation of activity in the lingual and fusiform gyri during a color attention task has also been demonstrated. Attending to motion activates a region in occipito-temporal cortex, and it has also been shown that, in addition to extrastriate regions, attention to motion increased activity in several higher-order areas as well. It may be that activity in extrastriate regions may be modulated by prefrontal, parietal and thalamic regions. Similarly, modulation of activity in specific posterior regions is mediated by regions in parietal and anterior cingulate cortices, as well as the pulvinar. A role of parietal cortex, especially the inferior parietal lobe, in control of selective attention has also been suggested. The prefrontal cortex may also play a role in attentional modulation. As long as attentional load is low, task-irrelevant stimuli are perceived and elicit neural activity, however, when the attentional load is increased, irrelevant perception and its associated activity is strongly reduced.

[0257] The stimulus-response compatibility panel includes selective attention studies on the Stroop test. The Stroop test is associated with activations in the anterior cingulate cortex. SR compatibility studies point to a role of both the anterior cingulate and the left prefrontal cortex. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0258] Activation of the thalamic reticular nucleus is also associated with selective attention. See Contreras et al., "Inactivation of the Interoceptive Insula Disrupts Drug Craving and Malaise Induced by Lithium," Science, vol. 318, pp. 655-658 (26 Oct. 2007).

[0259] The category "orientation of attention" includes studies associating shifts of spatial attention to parietal and prefrontal regions. Another study found activations in superior parietal regions during a visual search for conjunction of features. Based on the similarities in activation patterns, it appears that serial shifts of attention took place during the search task. There is also evidence for a large-scale neural system for visuospatial attention that includes the right posterior parietal cortex. PET and fMRI have been employed to study attentional orienting to spatial locations (left vs. right) and to time intervals (short vs. long stimulus onset times). Both spatial and temporal orienting were found to activate a number of brain regions, including prefrontal and parietal brain regions. Other analyses revealed that activations in the intraparietal sulcus were right-lateralized for spatial attention and left lateralized for temporal attention. Moreover, simultaneous spatial and temporal attention activate mainly parietal regions, suggesting that the parietal cortex, especially in the right hemisphere, is a site for interactions between different attentional processes. Parietal activation has also been demonstrated in an fMRI study of nonspatial attention shifting. In addition, the cerebellum has been implicated in attention shifting, and this is consistent with other findings of attentional activation of the cerebellum. It has also been shown that spatial direction of attention can influence the response of the extrastriate cortex. Specifically, it was demonstrated that while multiple stimuli in the visual field interact with each other in a suppressive way, spatially directed attention partially cancels out the suppressive effects.

[0260] With respect to division of attention, activity in the left prefrontal cortex increases under divided-attention conditions. In this context, it is also relevant to mention that if two tasks activate overlapping brain areas, there may be significant interference effects when the tasks are performed simultaneously. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0261] Perception

[0262] Perception processes can be divided into object, face, space/motion, smell and "other" categories. Object perception is associated with activations in the ventral pathway (ventral brain areas 18, 19, and 37). The ventral occipito-temporal pathway is associated with object information, whereas the dorsal occipito-parietal pathway is associated with spatial information. For example, it has been shown that viewing novel, as well as familiar, line drawings, relative to scrambled drawings, activated a bilateral extrastriate area near the border between the occipital and temporal lobes. Based on these findings, it appears that this area is concerned with bottom-up construction of shape descriptions from simple visual features. It has also been shown that a region termed the "lateral occipital complex" (LO) is selectively activated by different kinds of shapes (e.g., shapes defined by motion, texture, and luminance contours). Greater activity in lingual gyrus (Area 19) and/or inferior fusiform gyrus (Area 37) is seen when subjects make judgments about appearance than when they make judgments about locations, providing confirmation that object identity preferentially activates regions in the ventral pathway. Both ventral and dorsal activations during shape-based object recognition suggests that visual object processing involves both pathways to some extent (a similar conclusion has been drawn based on network analysis of PET data).

[0263] Face perception involves the same ventral pathway as object perception, but there is a tendency for right-lateralization of activations for faces, but not for objects. For example, bilateral fusiform gyrus activation is seen for faces, but with more extensive activation in the right hemisphere. Faces are perceived, at least in part, by a separate processing stream within the ventral object pathway. In an fMRI study, a region was identified that is more responsive to faces than to objects, termed the "fusiform face area" or FF area.

[0264] Whereas perception of objects and faces tends to preferentially activate regions in the ventral visual pathway, perception of spatial location tends to selectively activate more dorsal regions located in parietal cortex. Greater activity in the superior parietal lobe (area 7) as well as in the premotor cortex is seen during location judgments than during object judgments. The dorsal pathway is not only associated with space perception, but also with action. For example, perception of scripts of goal-directed hand action engage parts of the parietal cortex. Comparison have been done of meaningful actions (e.g., pantomime of opening a bottle) and meaningless actions (e.g., signs from the American Sign Language that were unknown to subjects). Whereas meaningless actions activated the dorsal pathway, meaningful actions activated the ventral pathway. Meaningless actions appear to be decoded in terms of spatiotemporal layout, while meaningful actions are processed by areas that allow semantic processing and memory storage. Thus, as object perception, location/action perception may involve both dorsal and ventral pathways to some extent.

[0265] Activations in the orbitofrontal cortex (where the secondary olfactory cortex is located), particularly in the right hemisphere, and the cerebellum are associated with smelling, as well as increased activity in the primary olfactory cortex (piriform cortex). Odorants (regardless of sniffing) activate the posterior lateral cerebellum, whereas sniffing (nonodorized air) activate anterior parts of the cerebellum. Thus the cerebellum receives olfactory information for modulating sniffing. Odorants (regardless of sniffing) activate the anterior and lateral orbitofrontal cortex whereas sniffing (even in the absence of odorants) activates the piriform and medial/posterior orbitofrontal cortices. In sum, smell perception involves primarily the orbitofrontal cortex and parts of the cerebellum and its neural correlates can be dissociated from those of sniffing.

[0266] With respect to the "other" category, fMRI has been employed to define a "parahippocampal place area" (PPA) that responds selectively to passively viewed scenes. A region probably overlapping with PPA responds selectively to buildings, and this brain region may respond to stimuli that have orienting value (e.g., isolated landmarks as well as scenes). The neural correlates of music perception have been localized to specialized neural systems in the right superior temporal cortex, which participate in perceptual analysis of melodies. Attention to changes in rhythm activate Broca's/insular regions in the left hemisphere, pointing to a role of this area in the sequencing of auditory input. Further, studies of "emotional perception" suggest that perception of different kinds of emotion are based on separate neural systems, with a possible convergence in prefrontal regions (area 47). Consistent with the role of the amygdala in fear conditioning, the amygdala is more activated for fearful faces relative to happy faces. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0267] Imagery

[0268] Imagery can be defined as manipulating sensory information that comes not from the senses, but from memory. The memory representations manipulated can be in working memory (e.g., holding three spatial locations for 3 seconds), episodic memory (e.g., retrieving the location of an object in the study phase), or semantic memory (e.g., retrieving the shape of a bicycle). Thus, imagery-related contrasts could be classified within working memory, episodic retrieval, and semantic retrieval sections. Imagery contrasts can be described as visuospatial retrieval contrasts, and vice versa.

[0269] A central issue in the field of imagery has been whether those visual areas that are involved when an object is perceived are also involved when an object is imagined. In its strictest form, this idea would imply activation of the primary visual cortex in the absence of any visual input. A series of PET experiments provides support for similarities between visual perception and visual imagery by showing increased blood flow in Area 17 during imagery. In particular, by comparing tasks involving image formation for small and large letters, respectively, these studies provide evidence that imagery activates the topographically mapped primary visual cortex. A subsequent PET study, involving objects of three different sizes, provides additional support that visual imagery activates the primary visual cortex.

[0270] Increased activation in extrastriate visual regions is also associated with imaging tasks. The left inferior temporal lobe (area 37) is most reliably activated across subjects (for some subjects the activation extended into area 19 of the occipital lobe). Compared with a resting state, a left posterior-inferior temporal region was also activated. Moreover, mental imagery of spoken, concrete words has been shown to activate the inferior-temporal gyrus/fusiform gyrus bilaterally. Thus, right temporal activation may be related to more complex visual imagery.

[0271] Color imagery and color perception engage overlapping networks anterior to region V4 (an area specialized for color perception), whereas areas V1-V4 were selectively activated by color perception. There is an increase in primary visual-cortex activity during negative imagery, as compared to neutral imagery. The primary visual cortex therefore appears to have a role in visual imagery, and emotion appears to affect the quality of the image representations.

[0272] Mental rotation of visual stimuli involves lateral parietal areas (BA47 and BA40). The bulk of the computation for this kind of mental rotation is performed in the superior parietal lobe. PET has been employed to study a mental-rotation task in which subjects were asked to decide whether letters and digits, tilted in 120°, 180°, or 240°, were in normal or mirror image form. The left parietal cortex is activated in this task.

[0273] Mental "exploration" of maps or routes has been studied using PET, revealing that this task is associated with increased activity in the right superior occipital cortex, the supplementary motor area (SMA) and the cerebellar vermis. The latter two activations are related to eye movements, and it appears that the superior occipital cortex has a specific role in generation and maintenance of visual mental images. In a subsequent PET study, occipital activation was again observed, although this time the peak was in left middle occipital gyrus. This activation was specific to a task involving mental navigation—static visual imagery was not associated with occipital activation. Mental navigation tasks appears to tap visual memory to a high extent, and feedback influences from areas involved in visual memory may activate visual (occipital) areas during certain imagery tasks.

[0274] Thus, visual mental imagery is a function of the visual association cortex, although different association areas seem to be involved depending on the task demands. In addition, prefrontal areas have been activated in many of the reported comparisons. Partly, these effects may be driven by eye movements (especially for areas 6 and 8), but other factors, such as image generation and combination of parts into a whole, may account for some activations as well.

[0275] Neuroanatomical correlates of motor imagery via a mental writing task implicate a left parietal region in motor imagery, and, more generally, show similarities between mental writing and actual writing. Similarities between perception and imagery are seen in both musical imagery and perception. For example, relative to a visual baseline condition, an imagery task is associated with increased activity in the bilateral secondary auditory cortex. This was so despite the fact that the contrast included two entirely silent conditions. Similarly, a comparison of a task involving imaging a sentence being spoken in another person's voice with a visual control task reveals left temporal activation. Activation of the supplementary motor area was also seen, suggesting that both input and output speech mechanisms are engaged in auditory mental imagery. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0276] Language

[0277] Language mapping studies are commonly divided into four categories: spoken and written word recognition crossed with spoken or no-spoken response. Word recognition, regardless of input modality and whether or not a spoken response is required, has consistently been found to activate areas 21 and 22 in the temporal cortex. In general, this activation tends to be bilateral, although in the category of written word recognition all activations are left-lateralized. The cortical surface covered by these areas is most likely made up by several distinct regions that can be functionally dissociated. Involvement of left superior temporal gyrus/Wemicke's area in word recognition is in agreement with the traditional view implicating this area in comprehension.

[0278] Whereas left temporal brain regions have been associated with word comprehension, left inferior prefrontal cortex/Broca's area has traditionally been linked to word production. However, comparing conditions involving spoken response with conditions involving no spoken response do not suggest that (left) prefrontal involvement is greater when spoken responses are required. Instead, the major difference between these two classes is that conditions involving spoken responses tend to activate the cerebellum to a higher extent. Broca's area is involved in word perception, as well as in word production, and in addition to having an output function, the left prefrontal areas may participate in receptive language processing in the uninjured state. An fMRI study has shown that cerebellar activation is related to the articulatory level of speech production.

[0279] Visual areas are more frequently involved in the case of written word recognition, and regardless of output (spoken/no spoken), written word recognition tends to differentially activate left prefrontal and anterior cingulate regions. Moreover, left inferior prefrontal activation has been associated with semantic processing.

[0280] A posterior left temporal region (BA 37) is a multimodal language region. Both blind and sighted subjects activate this area during tactile vs. visual reading (compared to non-word letter strings). This area may not contain linguistic codes per se, but may promote activity in other areas that jointly lead to lexical or conceptual access. Area 37 has been activated in several studies of written word recognition but not in studies of spoken word recognition. Lip-reading activates the auditory cortex in the absence of auditory speech sounds. The activation was observed for silent speech as well as pseudo-speech, but not for nonlinguistic facial movements, suggesting that lip-reading modulates the perception of auditory speech at a prelexical level.

[0281] There are few differences between sign language and spoken language, and sign language in bilingual persons activates a similar network as that underlying spoken language. The difference in activation in ventral temporal cortex (area 37) related to sign language appears to relate to an attention mechanism that assigns importance to signing hands and facial expressions. With respect to the processing of native and foreign languages, native-language processing, relative to processing of a foreign language, selectively activates several brain regions leading to the conclusion that some brain areas are shaped by early exposure to the maternal language, and that these regions may not be activated when people process a language that they have learned later in life. In Broca's area, second languages acquired in adulthood are spatially separated from native languages, whereas second languages acquired at an early age tend to activate overlapping regions within Broca's area. In Wernicke's area, no separation based on age of language acquisition is observed. Further, fMRI has been used to determine brain activity related to aspects of language processing. During phonological tasks, brain activation in males was lateralized to the left inferior frontal gyrus, whereas the pattern was more diffuse for females.

[0282] Activation patterns related to the processing of particular aspects of information show that a set of brain regions in the right hemisphere is selectively activated when subjects try to appreciate the moral of a story as opposed to semantic aspects of the story. Brain activation associated with syntactic complexity of sentences indicates that parts of Broca's area increase their activity when sentences increase in syntactic complexity. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0283] Working Memory

[0284] Working memory consists of three main components: a phonological loop for the maintenance of verbal information, a visuospatial sketchpad for the maintenance of visuospatial information, and a central executive for attentional control. Dozens of functional neuroimaging studies of working memory have been carried out. Working memory is associated with activations in prefrontal, parietal, and cingulate regions. There also may be involvement of occipital and cerebellar regions discriminations between different Brodmann's areas.

[0285] Working memory is almost always associated with increased activity in the prefrontal cortex. This activity is typically found in areas 6, 44, 9 and 46. Area 44 activations are more prevalent for verbal/numeric tasks than for visuospatial tasks, and tend to be lateralized to the left hemisphere (i.e., Broca's area), suggesting that they reflect phonological processing. Area 6 activations are common for verbal, spatial, and problem-solving tasks, and, hence, they are likely related to general working memory operations (i.e., they are not material or task-specific). In contrast, activations in areas 9 and 46 seem to occur for certain kinds of working memory tasks but not others. Activations in these two areas tend to be more prevalent for tasks that require manipulation of working memory contents, such as N-back tasks, than for tasks that require only uninterrupted maintenance, such as delayed response tasks. Ventrolateral prefrontal regions are involved in simple short-term operations, whereas mid-dorsal prefrontal regions perform higher-level executive operations, such as monitoring. Object working memory may be left-lateralized while spatial-working memory is right-lateralized.

[0286] In addition to prefrontal activations, working memory studies normally show activations in parietal regions, particularly areas 7 and 40. In the case of verbal/numeric tasks, these activations tend to be left-lateralized, suggesting that they are related to linguistic operations. The phonological loop consists of a phonological store, where information is briefly stored, and a rehearsal process, which refreshes the contents of this store. Left parietal activations may reflect the phonological store, whereas left prefrontal activations in area 44 (Broca's area) may reflect the rehearsal process. When nonverbal materials are employed, parietal activations, particularly those in area 7, tend to be bilateral, and to occur for spatial but not for object working memory. Thus the distinction between a ventral pathway for object-processing and a dorsal pathway for spatial processing may also apply to working memory.

[0287] Working memory tasks are also associated with anterior cingulate, occipital, and cerebellar activations. Anterior cingulate activations are often found in Area 32, but they may not reflect working memory operations per se. Activity in dorsolateral prefrontal regions (areas 9 and 46) varies as a function of delay, but not of readability of a cue, and activity in the anterior cingulate (and in some right ventrolateral prefrontal regions) varies as a function of readability but not of delay of a cue. Thus, the anterior cingulate activation seems to be related to task difficulty, rather than to working memory per se. Occipital activations are usually found for visuospatial tasks, and may reflect increased visual attention under working memory conditions. Cerebellar activations are common during verbal working memory tasks, particularly for tasks involving phonological processing (e.g., holding letters) and tasks that engage Broca's area (left area 44).

[0288] Consistent with the idea that mid-dorsal areas 9/46 are involved in higher-level working memory operations, activations in these areas are prominent in the reasoning and planning tasks. Area 10 activations are also quite prevalent, and may be related to episodic memory aspects of problem-solving tasks (see episodic memory retrieval section above). Tasks involving sequential decisions, such as conceptual reasoning and card sorting consistently engage the basal ganglia, thalamic, and cerebellar regions. These regions are typical skill learning regions and may reflect the skill-learning aspects of sequential problem-solving tasks. Also, the basal ganglia, thalamus, and prefrontal cortex are intimately linked and dysfunction of this circuitry could underlie planning deficits in Parkinson disease. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0289] Semantic Memory Retrieval

[0290] Semantic memory refers to knowledge we share with other members of our culture, such as knowledge about the meaning of words (e.g., a banana is a fruit), the properties of objects (e.g., bananas are yellow), and facts (e.g., bananas grow in tropical climates). Semantic memory may be divided into two testing categories, categorization tasks and generation tasks. In categorization tasks, subjects classify words into different categories (e.g., living vs. nonliving), whereas in generation tasks, they produce one (e.g., word stem completion) or several (for example, fluency tasks) words in response to a cue. Semantic memory retrieval is associated with activations in prefrontal, temporal, anterior cingulate, and cerebellar regions.

[0291] Prefrontal activity during semantic memory tasks frequently found in the left hemisphere but not in the right. This is so even when the stimuli are nonverbal materials, such as objects and faces. This striking left-lateralization is in sharp contrast with the right-lateralization of prefrontal activity typically observed during episodic memory retrieval. This asymmetric pattern has been conceptualized in terms of a hemispheric encoding/retrieval asymmetry (HERA) model. This model consists of three hypotheses: (1) the left prefrontal cortex is differentially more involved in semantic memory retrieval than is the right prefrontal cortex; (2) the left prefrontal cortex is differentially more involved in encoding information into episodic memory than is the right prefrontal cortex; and (3) the right prefrontal cortex is differentially more involved in episodic memory retrieval than is the left prefrontal cortex. Thus, the left-lateralization of prefrontal activations supports the first hypothesis of the model. The second and third hypotheses are addressed by episodic memory encoding and episodic memory retrieval testing, respectively, as discussed above.

[0292] Within the frontal lobes, activations are found in most prefrontal regions, including ventrolateral (areas 45 and 47), ventromedial (area 11), posterior (areas 44 and 6), and mid-dorsal (areas 9 and 46) regions. Activations in ventrolateral regions occur during both classification and generation tasks and under a variety of conditions, suggesting that they are related to generic semantic retrieval operations. In contrast, area 11 activations are more common for classification than for generation tasks, and could be related to a component of classification tasks, such as decision-making. Conversely, activations in posterior and dorsal regions are more typical for generation tasks than for classification tasks. Many posterior activations (areas 44 and 6) occur at or near Broca's area, thus they may reflect overt or covert articulatory processes during word generation. Activations in dorsal regions (areas 9 and 46) are particularly frequent for fluency tasks. Because fluency tasks require the monitoring of several items in working memory, these activations may reflect working memory, rather than semantic memory, per se. Accordingly, when subjects complete word stems, areas 9/10 are more active for stems with many completions than for stems with few completions. These areas may therefore be involved in selecting among competing candidate responses.

[0293] Semantic retrieval tasks are also commonly associated with temporal, anterior cingulate, and cerebellar regions. Temporal activations occur mainly in the left middle temporal gyrus (area 21) and in bilateral occipito-temporal regions (area 37). Left area 21 is activated not only for words but also pictures and faces, suggesting it is involved in higher-level semantic processes that are independent of input modality. In contrast, area 37 activations are more common for objects and faces, so they could be related to the retrieval of visual properties of these stimuli. Anterior cingulate activations are typical for generation tasks. The anterior cingulate—like the dorsal prefrontal cortex—is more active for stems with many than with few completions, whereas the cerebellum shows the opposite pattern. The anterior cingulate may therefore be involved in selecting among candidate responses, while the cerebellum may be involved in memory search processes. Accordingly cerebellar activations are found during single-word generation, but not during fluency tasks.

[0294] The retrieval of animal information is associated with left occipital regions and the retrieval of tool information with left prefrontal regions. Occipital activations could reflect the processing of the subtle differences in physical features that distinguish animals, whereas prefrontal activations could be related to linguistic or motor aspects of tool utilization. Animal knowledge activates a more anterior region (area 21) of the inferior temporal lobe than the one associated with tool knowledge (area 37). Whereas generating color words activates fusiform areas close to color perception regions, generating action words activates a left temporo-occipital area close to motion perception regions. Thus knowledge about object attributes is stored close to the regions involved in perceiving these attributes. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0295] Episodic Memory Encoding

[0296] Episodic memory refers to memory for personally experienced past events, and it involves three successive stages: encoding, storage, and retrieval. Encoding refers to processes that lead to the formation of new memory traces. Storage designates the maintenance of memory traces over time, including consolidation operations that make memory traces more permanent. Retrieval refers to the process of accessing stored memory traces. Encoding and retrieval processes are amenable to functional neuroimaging research, because they occur at specific points in time, whereas storage/consolidation processes are not, because they are temporally distributed. It is very difficult to differentiate the neural correlates of encoding and retrieval on the basis of the lesion data, because impaired memory performance after brain damage may reflect encoding deficits, retrieval deficits, or both. In contrast, functional neuroimaging allows separate measures of brain activity during encoding and retrieval.

[0297] Episodic encoding can be intentional, when subjects are informed about a subsequent memory test, or incidental, when they are not. Incidental learning occurs, for example, when subjects learn information while performing a semantic retrieval task, such as making living/nonliving decisions. Semantic memory retrieval and incidental episodic memory encoding are closely associated. Semantic processing of information (semantic retrieval) usually leads to successful storage of new information. Further, when subjects are instructed to learn information for a subsequent memory test (intentional encoding), they tend to elaborate the meaning of the information and make associations on the basis of their knowledge (semantic retrieval). Thus, most of the regions (for example, left prefrontal cortex) associated with semantic retrieval tasks are also associated with episodic memory encoding.

[0298] Episodic encoding is associated primarily with prefrontal, cerebellar, and medial temporal brain regions. In the case of verbal materials, prefrontal activations are always left lateralized. This pattern contrasts with the right lateralization of prefrontal activity during episodic retrieval for the same kind of materials. In contrast, encoding conditions involving nonverbal stimuli sometimes yield bilateral and right-lateralized activations during encoding. Right-lateralized encoding activations may reflect the use of non-nameable stimuli, such as unfamiliar faces and textures, but encoding of non-nameable stimuli has been also associated with left-lateralized activations with unfamiliar faces and locations. Contrasting encoding of verbal materials with encoding of nonverbal materials may speak to the neural correlates of different materials rather than to the neural correlates of encoding per se.

[0299] The prefrontal areas most commonly activated for verbal materials are areas 44, 45, and 9/46. Encoding activations in left area 45 reflects semantic processing while those in left area 44 reflects rote rehearsal. Areas 9/46 may reflect higher-order working memory processes during encoding. Activation in left area 9 increases as a function of organizational processes during encoding, and is attenuated by distraction during highly organizational tasks. Cerebellar activations occur only for verbal materials and show a tendency for right lateralization. The left-prefrontal/right-cerebellum pattern during language, verbal-semantic memory, and verbal-episodic encoding tasks is consistent with the fact that fronto-cerebellar connections are crossed.

[0300] Medial-temporal activations are seen with episodic memory encoding and can predict not only what items will be remembered, but also how well they will be remembered. Medial-temporal activations show a clear lateralization pattern: they are left-lateralized for verbal materials and bilateral for nonverbal materials. Under similar conditions, medial-temporal activity is stronger during the encoding of pictures than during the encoding of words, perhaps explaining why pictures are often remembered better than words. In the case of nonverbal materials, medial-temporal activity seems to be more pronounced for spatial than for nonspatial information, consistent with the link between the hippocampus and spatial mapping shown by animal research. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0301] Episodic Memory Retrieval

[0302] Episodic memory retrieval refers to the search, access, and monitoring of stored information about personally experienced past events, as well as to the sustained mental set underlying these processes. Episodic memory retrieval is associated with seven main regions: prefrontal, medial temporal, medial parieto-occipital, lateral parietal, anterior cingulate, occipital, and cerebellar regions.

[0303] Prefrontal activations during episodic memory retrieval are sometimes bilateral, but they show a clear tendency for right-lateralization. The right lateralization of prefrontal activity during episodic memory retrieval contrasts with the left lateralization of prefrontal activity during semantic memory retrieval and episodic memory encoding. Left prefrontal activations during episodic retrieval tend to occur for tasks that require more reflectively complex processing. These activations may be related to semantic retrieval processes during episodic retrieval. Semantic retrieval can aid episodic retrieval particularly during recall, and bilateral activations tend to be more frequent during recall than during recognition. Moreover, left prefrontal activity during episodic retrieval is associated with retrieval effort, and is more common in older adults than in young adults.

[0304] Prefrontal activity changes as a function of the amount of information retrieved during the scan have been measured by varying encoding conditions (e.g., deep vs. shallow), or by altering the proportion of old items (e.g., targets) during the scan. As more information is retrieved during the scan, prefrontal activity may increase (retrieval success), decrease (retrieval effort), or remain constant (retrieval mode). These three outcomes are not necessarily contradictory; they may correspond to three different aspects of retrieval: maintaining an attentional focus on a particular past episode (retrieval mode), performing a demanding memory search (retrieval effort), and monitoring retrieved information (retrieval success).

[0305] These different aspects of retrieval may map to distinct prefrontal regions. The region most strongly associated to retrieval mode is the right anterior prefrontal cortex (area 10). A combined PET/ERP study associated a right area 10 activation with task-related rather than item-related activity during episodic retrieval. Activations associated with retrieval effort show a tendency to be left lateralized, specifically in left areas 47 and 10. Bilateral Areas 10, 9, and 46 are sometimes associated with retrieval success. Prefrontal activity is also seen to increase with success activations when subjects are warned about the proportion of old and new items during the scan (biasing).

[0306] Medial-temporal activations have been seen in the typical pattern of episodic retrieval in PET and fMRI studies, for both verbal and nonverbal materials. In contrast with medial-temporal activations during episodic encoding, those during episodic retrieval tend to occur in both hemispheres, regardless of the materials employed. That they are sometimes found in association with retrieval success, but never in association with retrieval effort or retrieval mode, suggest that they are related to the level of retrieval performance. Medial-temporal activity increases as linear function of correct old word recognition, and this activity may reflect successful access to stored-memory representations. Further, hippocampal activity has been associated with conscious recollection. Hippocampal activity is also sensitive to the match between study and test conditions, such as the orientation of study and test objects. However, recollection need not be accurate; for example in the case of significant hippocampal activations during the recognition of false targets. Accurate recognition yields additional activations in a left temporoparietal region, possibly reflecting the retrieval of sensory properties of auditorily studied words. Further, intentional retrieval is not a precondition for hippocampal activity; activations in this area are found for old information encountered during a non-episodic task, suggesting that they can also reflect spontaneous reminding of past events.

[0307] After the right prefrontal cortex, the most typical region in PET/fMRI studies of episodic retrieval is the medial parieto-occipital area that includes retrosplenial (primarily areas 29 and 30), precuneus (primarily medial area 7 and area 31), and cuneus (primarily medial areas 19, 18, and 17) regions. The critical role of the retrosplenial cortex in memory retrieval is supported by evidence that lesions in this region can cause severe memory deficits (e.g., retrosplenial amnesia. The role of the precuneus has been attributed to imagery and to retrieval success. Retrieval-related activations in the precuneus are more pronounced for imageable than for nonimageable words. However, the precuneus region was not more activated for object recall than for word recall. Imagery-related activations are more anterior than activations typically associated with episodic retrieval. The precuneus is activated for both imageable and abstract words, and for both visual and auditory study presentations. Thus this region appears to be involved in episodic retrieval irrespective of imagery content. The precuneus cortex is more active in a high-target than in low-target recognition condition.

[0308] Episodic memory retrieval is also associated with activations in lateral parietal, anterior cingulate, occipital, and cerebellar regions. Lateral parietal regions have been associated with the processing of spatial information during episodic memory retrieval and with the perceptual component of recognition. Anterior cingulate activations (areas 32 and 24) have been associated with response selection and initiation of action. Anterior cingulate activations may be related to language processes because they are more frequent for verbal than for nonverbal materials. As expected, occipital activations are more common during nonverbal retrieval, possibly reflecting not only more extensive processing of test stimuli but also memory-related imagery operations. Cerebellar activations have been associated with self-initiated retrieval operations. This idea of initiation is consistent with the association of cerebellar activations with retrieval mode and effort, rather than with retrieval success.

[0309] With respect to context memory, a fusiform region is more active for object identity than for location retrieval, whereas an inferior parietal region shows the opposite pattern. Thus the ventral/dorsal distinction applies also to episodic retrieval. In the time domain, recognition memory (what) has been contrasted with recency memory (when). Medial-temporal regions are more active during item memory than during temporal-order memory, whereas dorsal prefrontal and parietal regions are more active during temporal-order memory than during item memory. Parietal activations during temporal-order memory suggest that the dorsal pathway may be associated not only with "where" but also with "when."

[0310] Prefrontal regions were similarly activated in both recall and recognition tests. This may signify the use of associative recognition—a form of recognition with a strong recollection component, or to the careful matching of task difficulty in the two tests. A comparison of free and cued recall found a dissociation in the right prefrontal cortex between dorsal cortex (areas 9 and 46), which is more active during free recall, and the ventrolateral cortex (area 47/frontal insula), which is more active during cued recall. Thus some of the activations observed during episodic-memory retrieval tasks may reflect the working-memory components of these tasks. Autobiographic retrieval is associated with activations along a right fronto-temporal network.

[0311] Episodic memory retrieval is associated with activations in prefrontal, medial temporal, posterior midline, parietal, anterior cingulate, occipital, and cerebellar regions. Prefrontal activations tend to be right-lateralized, and have been associated with retrieval mode, retrieval effort, and retrieval success. The engagement of medial temporal regions has been linked to retrieval success and recollection. Posterior midline activations also seem related to retrieval success. Parietal activations may reflect processing of spatial context, and anterior cingulate activations may reflect selection/initiation processes. Cerebellar involvement has been attributed to self-initiated retrieval. Spatial retrieval engaged parietal regions, and object retrieval activated temporal regions. Parietal regions are also activated during temporal-order retrieval, suggesting a general role in context memory. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0312] Priming

[0313] Priming can be divided into perceptual and conceptual priming. In several studies, perceptual priming has been explored by studying completion of word-stems. In the primed condition, it is possible to complete the stems with previously presented words, whereas this is not possible in the unprimed condition. Visual perceptual priming is associated with decreased activity in the occipital cortex. PET and fMRI studies on non-verbal visual perceptual priming have revealed priming-related reduction in activation of regions in the occipital and inferior temporal brain regions. Priming effects can persist over days; repetition priming (item-specific learning) as measured by fMRI shows that learning-related neural changes that accompany these forms of learning partly involve the same regions.

[0314] Comparisons of blood flow responses associated with novel vs. familiar stimuli (across memory tasks) show that novel stimuli are associated with higher activity in several regions, including fusiform gyrus and cuneus. Thus, priming-related reductions in activity in visual areas occur even after subliminal presentation.

[0315] Priming cannot only facilitate perceptual processes, but may also influence conceptual processes. The primed condition is associated with decreased activity in several regions, including the left inferior prefrontal cortex. Similarly, several fMRI studies that have included repeated semantic processing of the same items have found reduced left prefrontal activation associated with the primed condition. Left prefrontal reduction of activation is not seen when words are non-semantically reprocessed, suggesting that the effect reflects a process-specific change (not a consequence of mere repeated exposure). This process-specific effect can be obtained regardless of the perceptual format of the stimuli (e.g., pictures or words). Many memory tests rely upon a mixture of processes, and even the stem-completion task, which has been used in several studies of perceptual priming, has been associated with priming-related left prefrontal reductions. This may be taken as evidence that this task, too, taps both perceptual and conceptual processes.

[0316] With respect to a neural correlate of priming, repeating items during performance of the same task, or even during performance of different tasks, can lead to decreases in the amount of activation present in specific brain areas. This effect may reflect enhanced processing of the involved neurons or/and a specification of the involved neuronal population, resulting in a spatially less diffuse response. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0317] Procedural Memory

[0318] Procedural memory processes can be divided into three subcategories: conditioning, motor-skill learning, and nonmotor skill learning. With respect to conditioning, studies on eye-blink conditioning point to a consistent role of the cerebellum in this form of learning (e.g., decreased activity in the cerebellum following conditioning). Conditioning is also associated with increased activity in the auditory cortex.

[0319] Motor-skill learning is associated with activation of motor regions. Area 6 is involved, and learning-related changes have also repeatedly been demonstrated in the primary motor cortex (area 4). The size of the activated area in the primary motor cortex increases as a function of training. There is also parietal involvement in motor skill learning; fronto-parietal interactions may underlie task performance.

With respect to nonmotor skill learning, cerebellar activation is observed across tasks, as is consistent involvement of parietal brain regions. This is in line with the pattern observed for motor-skill learning, and the overlap in activation patterns may reflect common processes underlying these two forms of procedural memory. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0320] Preference

[0321] Neural correlates of preference can be detected through neuroimaging studies. For example, in a simulated buying decision task between similar fast moving consumer goods, only a subject's preferred brand elicited a reduced activation in the dorsolateral prefrontal, posterior parietal and occipital cortices and the left premotor area (Brodmann areas 9, 46, 7/19 and 6), and only when the target brand was the subjects' favorite one. Simultaneously, activity was increased in the inferior precuneus and posterior cingulated (BA 7), right superior frontal gyrus (BA 10), right supramarginal gyrus (BA 40) and most pronounced in the ventromedial prefrontal cortex ("VMPFC", BA 10).

[0322] In fMRI analyses, activation of the nucleus accumbens is associated with product preference, and the medial prefrontal cortex is associated with evaluation of gains and losses. When these areas of the brain are activated, subjects bought a product at an accuracy rate of 60%. In other fMRI analyses, early stage romantic love has been associated with activation of subcortical reward regions such as the right ventral tegmental area and the dorsal caudate area. Subjects in more extended romantic love showed more activity in the ventral pallidum. In still another fMRI analysis, in subjects experiencing a mistake, activation of the rostral anterior cingulated cortex increased in proportion to a financial penalty linked to the mistake. See Wise, "Thought Police: How Brain Scans Could Invade Your Private Life," Popular Mechanics, (November 2007).

[0323] With respect to brand discrimination, brain activations in product choice differ from those for height discrimination, and there is a positive relationship between brand familiarity and choice time. Neural activation during choice tasks involves brain areas responsible for silent vocalization. Decision processes take approximately 1 second as measured by magnetoencephalography and can be seen as two halves. The first period involves gender-specific problem recognition processes, and the second half concerns the choice itself (no gender differences). MEG measurements can be categorized in four stages:

[0324] Stage 1-V (visual): Activation of the primary visual cortices at around 90 ms after stimulus onset.

[0325] Stage 2-T (temporal): Neuronal activity predominantly over left anterior-temporal and middle-temporal cortices at approximately 325 ms after stimulus onset. Some specific activity was also found over the left frontal and right extra-striate cortical areas.

[0326] Stage 3-F (frontal): Activation of the left inferior frontal cortices at about 510 ms after stimulus onset. These signals are consistent with activation of Broca's speech area.

[0327] Stage UP (parietal): Activation of the right posterior parietal cortices (P) at around 885 ms after stimulus onset.

[0328] Male brain activity differed from female in the second stage (T) but not in the other three stages (V, F and P). Left anterior temporal activity is present in both groups, but malesseem to activate right hemispherical regions much more strongly during memory recall than females do. As noted above, response times also differed for male and female subjects. See Amber et al., "Salience and Choice: Neural Correlates of Shopping Decisions," Psychology & Marketing, Vol. 21(4), pp. 247-261 (April 2004).

[0329] In an fMRI study, a consistent neural response in the ventromedial prefrontal cortex was associated with subjects' behavioral preferences for sampled anonymized beverages. In a brand-cued experiment, brand knowledge of one of the beverages had a dramatic influence on expressed behavioral preferences and on the measured brain responses. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0330] In an fMRI study, only the presence of a subject's favorite brand indicating a distinctive mode of decision-making was associated with activation of regions responsible for integrating emotions. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0331] Emotion

[0332] Various emotions may be identified through detection of brain activity. As discussed below, activation of the anterior insula has been associated with pain, distress, and other negative emotional states. Conversely, as discussed below, positive emotional processes are reliably associated with a series of structures representing a reward center, including the striatum and caudate, and areas of the midbrain and cortex to which they project, such as the ventromedial prefrontal cortex, orbitofrontal cortex, and anterior cingulated cortex, as well as other areas such as the amygdala and the insula.

[0333] In addition, approval and/or disapproval may be determined based on brain activity. For example, in an fMRI study, blood-oxygen-level-dependent signal changes were measured in subjects viewing facial displays of happiness, sadness, anger, fear, and disgust, as well as neutral faces. Subjects were tasked with discriminating emotional valence (positive versus negative) and age (over 30 versus under 30) of the faces. During the task, normal subjects showed activation in the fusiform gyrus, the occipital lobe, and the inferior frontal cortex relative to the resting baseline condition. The increase was greater in the amygdala and hippocampus during the emotional valence discrimination task than during the age discrimination task. See Gur et al., "An fMRI study of Facial Emotion Processing in Patients with Schizophrenia," Am. J. Psych., vol. 159, pp. 1992-1999 (2002).

[0334] Frustration is associated with decreased activation in the ventral striatum, and increased activation in the anterior insula and the right medial prefrontal cortex by fMRI. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0335] Fairness Altruism and Trust

[0336] fMRI has been used to show that perceived unfairness correlates with activations in the anterior insula and the dorsolateral, prefrontal cortex ("DLPFC"). Anterior insula activation is consistently seen in neuroimaging studies focusing on pain and distress, hunger and thirst, and autonomic arousal. Activation of the insula has also been associated with negative emotional states, and activation in the anterior insula has been linked to a negative emotional response to an unfair offer, indicating an important role for emotions in decision-making.

[0337] In contrast to the insula region, the DLPFC has been linked to cognitive processes such as goal maintenance and executive control. Thus, DLPFC activation may indicate objective recognition of benefit despite an emotional perception of unfairness.

[0338] Event-related hyperscan-fMRI ("hfMRI" which means that two volunteers are measured parallel in two scanners) has been used to measure the neural correlates of trust. By this method, the caudate nucleus has been shown to be involved in trust-building and reciprocity in economic exchange. The caudate nucleus is commonly active when learning about relations between stimuli and responses. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0339] In a PET study, sanctions against defectors were associated with activity in reward-processing brain regions. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0340] Reward

[0341] In an fMRI study, activation changes in the sublenticular extended amygdala (SLEA) and orbital gyrus were associated with expected values of financial gain. Responses to actual experience of rewards increased monotonically with monetary value in the nucleus accumbens, SLEA, and thalamus. Responses to prospective rewards and outcomes were generally, but not always, seen in the same regions. Overlaps with activation changes seen previously in response to tactile stimuli, gustatory stimuli, and euphoria-inducing drugs were found. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0342] In another fMRI study, within a group of cooperative subjects the prefrontal cortex showed activation changes when subjects playing a human compared to playing a computer. Within a group of non-cooperators, no significant activation changes in the prefrontal cortex were seen between computer and human conditions. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0343] In an fMRI study, products symbolizing wealth and status were associated with increased activity in reward-related brain areas. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0344] In a PET study, participants were risk averse in gains and risk-seeking in losses; and ambiguity-seeking in neither gains nor losses. Interactions between attitudes and beliefs were associated with neural activation changes in dorsomedial and ventromedial brain areas. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0345] In an fMRI study, increasing monetary gains were associated with increased activity in a subcortical region of the ventral striatum in a magnitude-proportional manner. This ventral striatal activation was not evident during anticipation of losses. Actual gain outcomes were associated with activation of a region of the medial prefrontal cortex. During anticipation of gain, ventral striatal activation was associated with feelings characterized by increasing arousal and positive valence. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0346] In an fMRI study, activation of parts of the limbic system were associated with decisions involving immediate rewards. Activity changes in the lateral prefrontal cortex and posterior parietal cortex were associated with inter-temporal choices. Greater relative fronto-parietal activity was associated with a subject's choice of longer term options. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0347] Brain Activation by Region

[0348] Prefrontal Regions

[0349] The prefrontal cortex is involved in almost all high-level cognitive tasks. Prefrontal activations are particularly prominent during working memory and memory retrieval (episodic and semantic), and less prevalent during perception and perceptual priming tasks. This pattern is consistent with the idea that the prefrontal cortex is involved in working memory processes, such as monitoring, organization, and planning. However, some of the same prefrontal regions engaged by working tasks are also recruited by simple detection tasks that do not involve a maintenance component. Thus the prefrontal cortex is not devoted solely to working memory operations.

[0350] Regarding lateralization, prefrontal activations during language, semantic memory retrieval, and episodic memory encoding are usually left-lateralized, those during sustained attention and episodic retrieval are mostly right-lateralized, and those during working memory are typically bilateral.

[0351] With respect to distinctions between different prefrontal areas, ventrolateral regions (areas 45 and 47) are involved in selecting, comparing, or deciding on information held in short-term and long-term memory, whereas mid-dorsal regions (areas 9 and 46) are involved when several pieces of information in working memory need to be monitored and manipulated. Area 45/47 activations were found even in simple language tasks, while activations in areas 9/46 were associated with working memory and episodic encoding and retrieval. However, areas 9/46 were also activated during sustained attention tasks, which do not involve the simultaneous consideration of several pieces of information. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0352] Humans restrain self-interest with moral and social values. They are the only species known to exhibit reciprocal fairness, which implies the punishment of other individuals' unfair behaviors, even if it hurts the punisher's economic self-interest. Reciprocal fairness has been demonstrated in the Ultimatum Game, where players often reject their bargaining partner's unfair offers. It has been shown that disruption of the right, but not the left, dorsolateral prefrontal cortex (DLPFC) by low-frequency repetitive transcranial magnetic stimulation substantially reduces subjects' willingness to reject their partners' intentionally unfair offers, which suggests that subjects are less able to resist the economic temptation to accept these offers. Importantly, however, subjects still judge such offers as very unfair, which indicates that the right DLPFC plays a key role in the implementation of fairness-related behaviors. See Knoch et al., "Diminishing Reciprocal Fairness by Disrupting the Right Prefrontal Cortex," Science, vol. 314, pp. 829-832 (3 Nov. 2006).

[0353] Differences across tasks can be found in frontopolar (area 10), opercular (area 44), and dorsal (areas 6 and 8) prefrontal regions. Frontopolar activations were typical for episodic memory retrieval and problem-solving tasks. In the case of episodic retrieval, they are found for both retrieval success and retrieval mode, suggesting they are probably not related to performance level or task difficulty. Area 10 is involved in maintaining the mental set of episodic retrieval, but also has an involvement in problem-solving tasks. Activations in left area 44, which corresponds to Broca's area, were commonly found for reading, verbal working memory and semantic generation. Right area 44 is engaged by nonverbal episodic retrieval tasks. Area 6 plays a role in spatial processing (orientation of attention, space/motion perception and imagery), working memory, and motor-skill learning. Midline area 6 activations correspond to SMA and are common for silent reading tasks. Area 8 is involved in problem-solving tasks, possibly reflecting eye movements. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0354] The frontopolar cortex has been shown to be active during the initial stages of learning, gradually disengaging over the course of learning. Frontopolar cortex activity specifically correlates with the amount of uncertainty remaining between multiple putative options that subjects are simultaneously tracking. The frontopolar cortex is also active whenever subjects depart from an a priori optimal option to check alternative ones. Thus the frontopolar cortex contribution to learning and exploration appears to be associated with maintaining and switching back and forth between multiple behavioral alternatives in search of optimal behavior. The frontopolar cortex has also been implicated in memory retrieval, relational reasoning, and multitasking behaviors. These subfunctions are thought to be integrated in the general function of contingently switching back and forth between independent tasks by maintaining distractor-resistant representations of postponed tasks during the performance of another task. For example, the frontopolar cortex is specifically activated when subjects suspend execution of an ongoing task set associated with a priori the largest expected future rewards in order to explore a possibly more-rewarding task set. See Keochlin et al., "Anterior Prefrontal Function and the Limits of Human Decision-Making," Science, vol. 318, pp. 594-598 (26 Oct. 2007).

[0355] Activation of the medial prefrontal cortex and anterior paracingulate cortex indicate that a subject is thinking and acting on the beliefs of others, for example, either by guessing partner strategies or when comparing play with another human to play with a random device, such as a computer partner. Accordingly, these regions may be involved in intention detection, i.e., assessing the meaning of behavior from another agent. The tempo-parietal junction is also implicated in this function. Further, publication brand-related bias in the credibility of ambiguous news headlines is associated with activation changes in the medial prefrontal cortex. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0356] In situations in which people gain some useful good (e.g., money, juice, or other incentive) by using judgment, activation can be observed in the so-called "reward areas" of the brain. Therefore, a "feeling" of approval or utility may correlate with the activation in the reward areas of the brain. Reward areas of the brain include the ventral striatum and the orbitofrontal prefrontal cortex-amygdala-nucleus accumbens circuit. Monetary payoffs induce activation in the nucleus accumbens. The nucleus accumbens is densely innervated by dopaminergic fibers originating from neurons in the midbrain. Sudden release of dopamine after an unexpected reward may lead to acceptance of risk. Accordingly, defects in the orbitofrontal cortex-amygdala-nucleus accumbens reward circuit may accompany extreme risk-seeking behavior. This reward system is also associated with the perception of utility of objects.

[0357] Cingulate Regions

[0358] Cingulate regions can be roughly classified as anterior (for example, areas 32 and 24), central (areas 23 and 31), and posterior (posterior area 31, retrosplenial). Posterior cingulate activations are consistently seen during successful episodic memory retrieval, as are other posterior midline activations (e.g., medial parietal, cuneus, precuneus). Anterior cingulate activations occur primarily in area 32 and are consistently found for S-R compatibility (Stroop test), working memory, semantic generation, and episodic memory tasks.

[0359] There are three main views of the anterior cingulate function: initiation, inhibitory, and motor. According to the initiation view, the anterior cingulate cortex is involved in "attention to action," that is, in attentional processes required to initiate behavior. This is consistent with evidence that damage to this region sometimes produces akinetic mutism, that is, an almost complete lack of spontaneous motor or verbal behavior. This is also consistent with the involvement of this region in demanding cognitive tasks, such as working memory and episodic retrieval.

[0360] The inhibitory view postulates that the anterior cingulate is involved in suppressing inappropriate responses. This idea accounts very well not only for its involvement in the Stroop task, in which prepotent responses must be inhibited, but also in working memory, in which interference from previous trials must be controlled. The initiation and inhibition views are not incompatible: the anterior cingulate cortex may both initiate appropriate responses and suppress inappropriate ones. Moreover, these views share the idea that the anterior cingulate cortex plays an "active" role in cognition by controlling the operations of other regions, including the prefrontal cortex.

[0361] In contrast, the motor view conceptualizes the anterior cingulate as a more "passive" structure: it receives cognitive/motor "commands" from various regions (for example, prefrontal cortex), and "funnels" them to the appropriate motor system. This view assumes that different anterior cingulate regions are engaged, depending on whether responses are ocular, manual, or verbal. For example, due to its close connections to the auditory cortex, area 32 is assumed to play a role in vocalization and speech. This idea accounts for activations during tasks involving verbal materials, such as Stroop, semantic generation, and verbal episodic retrieval tasks. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0362] Lying is associated with increased activity in several areas of the cortex, including the anterior cingulate cortex, the parietal cortex, and the superior frontal gyrus. See Henig, "Looking for the Lie," New York Times http://www.nytimes.com/2006/02/05/magazine/05lying.html?pagewanted=print (5 Feb. 2006).

[0363] Parietal Regions

[0364] Parietal regions are consistently activated during tasks involving attention, spatial perception and imagery, working memory, spatial episodic encoding, episodic retrieval, and skill learning. Medial parietal activations are frequently found during episodic memory retrieval. In general, lateral parietal activations relate either to spatial perception/attention or to verbal working memory storage. Parietal regions may be part of a dorsal occipito-parietal pathway involved in spatial perception, and/or part of a "posterior attention system" involved in disengaging spatial attention. These spatial views account for parietal activations during spatial tasks of perception, imagery, and episodic encoding, as well as for those during skill-learning tasks, which, typically, involve an important spatial component.

[0365] According to the working memory interpretation, parietal regions are involved in the storage of verbal information in working memory. This is consistent with evidence that left posterior parietal lesions can impair verbal short-term memory. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0366] Temporal Regions

[0367] The temporal lobes can be subdivided into four broad regions: lateral (insula, 42, 22, 21, and 20), medial (areas 28, 34-36, and hippocampal regions), posterior (area 37), and polar (area 38). Area 38 is likely to have a very important role in cognition, for example, by linking frontal-lobe and temporal-lobe regions.

[0368] Lateral temporal activations are consistently found for language and semantic memory retrieval and are mostly left-lateralized. Spoken word-recognition tasks usually yield bilateral activations, possibly reflecting the auditory component of these tasks. The involvement of the left superior and middle temporal gyrus (areas 22 and 21) in language operations is consistent with research on aphasic patients. Since area 21 is also consistently activated during semantic retrieval tasks—not only for verbal but also for nonverbal materials—it is possible that this area reflects semantic, rather than linguistic, operations. This is supported by the involvement of this region in object perception.

[0369] Medial-temporal lobe activations are repeatedly found for episodic memory encoding and nonverbal episodic memory retrieval. The involvement of medial temporal regions in episodic memory is consistent with lesion data. Based on PET data, encoding-related activations are more common in anterior hippocampal regions, whereas retrieval-related activations are more prevalent in posterior hippocampal regions, a pattern described as the hippocampal encoding/retrieval (HIPER) model. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0370] Occipito-Temporal Regions

[0371] The engagement of temporo-occipital regions (areas 37, 19, 18, and 17) in cognitive tasks seems to be of two kinds: activations associated with perceiving and manipulating visuospatial information, and deactivations associated with perceptual priming. Visual processing along the ventral pathway is assumed to be organized hierarchically, with early image analyses engaging areas close to the primary visual cortex and higher-order object recognition processes involving more anterior areas. Consistent with this idea, activations in areas 18 and 19 occur for most visuospatial tasks, whereas activations in area 37 are associated with object processing. For example, area 37 activation is found when subjects perceive objects and faces, maintain images of objects in working memory, and intentionally encode objects. Perception-related occipital activations are enhanced by visual attention and they therefore can be expected during visual-attentional tasks, as well as during demanding visual-skill learning tasks (e.g., mirror reading).

[0372] Most activations in occipito-temporal regions occur during the processing of visual information coming from eyes (perception) or from memory (imagery), and weaken when the same information is repeatedly processed (priming). See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0373] Subcortical Regions

[0374] With respect to activations in the basal ganglia, the thalamus, and the cerebellum, basal ganglia activations were common during motor-skill learning, and the cerebellum was consistently activated in several different processes. Evolutionary, anatomical, neuropsychological, and functional neuroimaging evidence indicates that the cerebellum plays an important role in cognition. The cognitive role of the cerebellum has been related as motor-preparation, sensory acquisition, timing, and attention/anticipation. Each of these views can account for some cerebellar activations, but not for all of them. For example, the motor preparation view accounts well for activations during tasks involving motor responses, such as word production and conditioning, while the sensory-acquisition view can accommodate activations during perceptual tasks, such as smelling. The timing view accounts for activations during tasks involving relations between successive events, such as conditioning and skill learning, while the attention/anticipation view explains activations during attention and problem solving. See Cabeza et al, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," J. Cognitive Neurosci., vol. 12, pp. 1-47 (2000).

[0375] Mesolimbic Dopamine System

[0376] Activity in the striatum scales directly with the magnitude of monetary reward or punishment. The striatum is also involved in social decisions, above and beyond a financial component. The striatum also encodes abstract rewards such as positive feeling as a result of mutual cooperation. In addition, the caudate is activated in situations where a subject has an intention to trust another. Emotional processes are reliably associated with a series of structures including the striatum and caudate, and areas of the midbrain and cortex to which they project, such as the ventromedial prefrontal cortex, orbitofrontal cortex, and anterior cingulated cortex, as well as other areas such as the amygdala and the insula. Indeed, subjects with lesions in the ventromedial prefrontal cortex and having associated emotional deficits are impaired in performing gambling tasks. The anterior insula is associated with increased activation as unfairness or inequity of an offer is increased. Activation of the anterior insula predicts an Ultimatum Game player's decision to either accept or reject an offer, with rejections associated with significantly higher activation than acceptances. Activation of the anterior insula is also associated with physically painful, distressful, and/or disgusting stimuli. Thus, the anterior insula and associated emotion-processing areas may play a role in marking an interaction as aversive and undeserving of trust in the future. See Sanfey, "Social Decision-Making: Insights from Game Theory and Neuroscience," Science, vol. 318, pp. 598-601 (26 Oct. 2007).

[0377] Activation in the ventral striatum is seen by fMRI when subjects provide a correct answer to a question, resulting in a reward. Similarly, a wrong answer and no payment results in a reduction in activity (i.e., oxygenated blood flow) to the ventral striatum. Moreover, activation of the reward centers of the brain including the ventral striatum over and above that seen from a correct response and reward is seen when a subject receives a reward that is known to be greater than that of a peer in the study. Thus, stimulation of the reward center appears to be linked not only to individual success and reward, but also to the success and rewards of others. See BBC news story "Men motivated by 'superior wage,'" http://news.bbc.co.uk/1/hi/sci/tech/7108347.stm, (23 Nov. 2007).

[0378] In a multi-round trust game, reciprocity expressed by one player strongly predicts future trust expressed by their partner—a behavioral finding mirrored by neural responses in the dorsal striatum as measured by fMRI. Analyses within and between brains show two signals—one encoded by response magnitude, and the other by response timing. Response magnitude correlates with the "intention to trust" on the next play of the game, and the peak of these "intention to trust" responses shifts its time of occurrence by 14 seconds as player reputations develop. This temporal transfer resembles a similar shift of reward prediction errors common to reinforcement learning models, but in the context of a social exchange. See King-Casas et al., "Getting to Know You: Reputation and Trust in a Two-Person Economic Exchange," Science, vol. 308, pp. 78-83 (1 Apr. 2005).

[0379] Activity in the head of the caudate nucleus is associated with the processing of information about the fairness of a social partner's decision and the intention to repay with trust, as measured by hyperscan-fMRI. See Kenning et al., "Neuroeconomics: an overview from an economic perspective," Brain Res. Bull., vol. 67, pp. 343-354 (2005).

[0380] Activation of the insular cortex is associated with the perception of bodily needs, providing direction to motivated behaviors. For example, imaging studies have shown activation of the insula in addicts with cue-induced drug craving, and activation of the insular cortex has been associated with subjective reports of drug craving. See Contreras et al., "Inactivation of the Interoceptive Insula Disrupts Drug Craving and Malaise Induced by Lithium," Science, vol. 318, pp. 655-658 (26 Oct. 2007).

[0381] Visual Cortex

[0382] The visual cortex is located in and around the calcarine fissure in the occipital lobe. In one visual cortex study, subjects were shown two patterns in quick succession. The first appeared for just 15 milliseconds, too fast to be consciously perceived by the viewer. By examining fMRI images of the brain, a specific image that had been flashed in front of the subjects could be identified. The information was perceived in the brain even if the subjects were not consciously aware of it. The study probed the part of the visual cortex that detects a visual stimulus, but does not perceive it. It encodes visual information that the brain does not process as "seen." See "Mind-reading machine knows what you see," NewScientist.com http://www.newscientist.com/article.ns?id=dn7304&feedId=online-news_rss20 (25 Apr. 2005).

[0383] Hippocampus

[0384] Activation of the hippocampus can modulate eating behaviors linked to emotional eating and lack of control in eating. Activation of brain areas known to be involved in drug craving in addicted subjects, such as the orbitofrontal cortex, hippocampus, cerebellum, and striatum, suggests that similar brain circuits underlie the enhanced motivational drive for food and drugs seen in obese and drug-addicted subjects. See Wang et al., "Gastric stimulation in obese subjects activates the hippocampus and other regions involved in brain reward circuitry," PNAS, vol. 103, pp. 15641-45 (2006).

[0385] Surrogate Markers of Mental State

[0386] Surrogate markers of mental state may include indicators of attention, approval, disapproval, recognition, cognition, memory, trust, or the like in response to a stimulus, other than measurement of brain activity associated with the stimulus.

[0387] Examples of surrogate markers may include a skin response to a stimulus; a face pattern indicative of approval, disapproval, or emotional state; eye movements or pupil movements indicating visual attention to an object; voice stress patterns indicative of a mental state, or the like. Surrogate markers may be used in conjunction with brain activity measurements for higher confidence in a predictive or interpretational outcome. For example, brain activation of the caudate nucleus in combination with calm voice patterns may increase confidence in a predictor of trust between a subject and a stimulus. Conversely, conflict between brain activity and a surrogate marker may decrease confidence in a predictive or interpretational outcome. For example, a pattern of activation of the insula diagnostic for fear, together with a visual face image showing a smile may decrease the level of confidence that the subject is truly frightened by a stimulus.

[0388] For example, emotion links to cognition, motivation, memory, consciousness, and learning and developmental systems. Affective communication depends on complex, rule-based systems with multiple channels and redundancy built into the exchange system, in order to compensate if one channel fails. Channels can include all five senses: for example, increased heart-rate or sweating may show tension or agitation and can be heard, seen, touched, smelt or tasted. Emotional exchanges may be visible displays of body tension or movement, gestures, posture, facial expressions or use of personal space; or audible displays such as tone of voice, choice of pitch contour, choice of words, speech rate, etc. Humans also use touch, smell, adornment, fashion, architecture, mass media, and consumer products to communicate our emotional state. Universals of emotion that cross cultural boundaries have been identified, and cultural differences have also been identified. For example 'love' is generally categorized as a positive emotion in Western societies, but in certain Eastern cultures there is also a concept for 'sad love.' Accordingly, universal emotional triggers may be used to transcend cultural barriers.

[0389] When communicating with computers, people often treat new media as if they were dealing with real people. They often follow complex social rules for interaction and modify their communication to suit their perceived conversation partner. Much research has focused on the use of facial actions and ways of coding them. Speech recognition systems have also attracted attention as they grow in capability and reliability, and can recognize both verbal messages conveyed by spoken words, and non verbal messages, such as those conveyed by pitch contours.

[0390] System responses and means of expressing emotions also vary. Innovative prototypes are emerging designed to respond indirectly, so the user is relatively unaware of the response: for example by adaptation of material, such as changing pace or simplifying or expanding content. Other systems use text, voice technology, visual agents, or avatars to communicate. See Axelrod et al., "Smoke and Mirrors: Gathering User Requirements for Emerging Affective Systems," 26th Int. Conf. Information Technology Interfaces/TI 2004, Jun. 7-10, 2004, Cavtat, Croatia, pp. 323-328.

[0391] Skin Response

[0392] Mental state may be determined by detection of a skin response associated with a stimulus. One skin response that may correlate with mental state and/or brain activity is galvanic skin response (GSR), also known as electrodermal response (EDR), psychogalvanic reflex (PGR), or skin conductance response (SCR). This is a change in the electrical resistance of the skin. There is a relationship between sympathetic nerve activity and emotional arousal, although one may not be able to identify the specific emotion being elicited. The GSR is highly sensitive to emotions in some people. Fear, anger, startle response, orienting response, and sexual feelings are all among the emotions which may produce similar GSR responses. GSR is typically measured using electrodes to measure skin electrical signals.

[0393] For example, an Ultimate Game study measured skin-conductance responses as a surrogate marker or autonomic index for affective state, and found higher skin conductance activity for unfair offers, and as with insular activation in the brain, this measure discriminated between acceptances and rejections of these offers. See Sanfey, "Social Decision-Making: Insights from Game Theory and Neuroscience," Science, vol. 318, pp. 598-601 (26 Oct. 2007). Other skin responses may include flushing, blushing, goose bumps, sweating, or the like.

[0394] Face Pattern Recognition

[0395] Mental state may also be determined by detection of facial feature changes associated with a stimulus, via pattern recognition, emotion detection software, face recognition software, or the like.

[0396] For example, an emotional social intelligence prosthetic device has been developed that consists of a camera small enough to be pinned to the side of a pair of glasses, connected to a hand-held computer running image recognition software plus association software that can read the emotions these images show. If the wearer seems to be failing to engage his or her listener, the software makes the hand-held computer vibrate. The association software can detect whether someone is agreeing, disagreeing, concentrating, thinking, unsure, or interested, just from a few seconds of video footage. Previous computer programs have detected the six more basic emotional states of happiness, sadness, anger, fear, surprise and disgust. The system can detect a sequence of movements beyond just a single facial expression. The association program is based on a machine-learning algorithm that was trained by showing it more than 100 8-second video clips of actors expressing particular emotions. The software picks out movements of the eyebrows, lips and nose, and tracks head movements such as tilting, nodding, and shaking, which it then associates with the emotion the actor was showing. When presented with fresh video clips, the software gets people's emotions right 90 percent of the time when the clips are of actors, and 64 percent of the time on footage of ordinary people. See "Device warns you if you're boring or irritating," NewScientist http://www.newscientist.com/article/mg19025456.500-device-warns-you-if-youre-boring-or-irritating.html (29 Mar. 2006).

[0397] In another approach, an imager, such as a CCD camera, may observe expressed features of the user. For example, the imager may monitor pupil dilation, eye movement, expression, or a variety of other expressive indicators. Such expressive indicators may indicate a variety of emotional, behavioral, intentional, or other aspects of the user. For example, in one approach, systems have been developed for identifying an emotional behavior of a person based upon selected expressive indicators. Similarly, eye movement and pupil dilation may be correlated to truthfulness, stress, or other user characteristics.

[0398] Eye Movement Analysis

[0399] Eye movement or pupil movement can be tested, for example, by measuring user pupil and/or eye movements, perhaps in relation to items on a display. For example, a user's eye movement to a part of the screen containing an advertisement may be of interest to an advertiser for purposes of advertisement placement or determining advertising noticeability and/or effectiveness within a computerized game world. For example, knowing that a user's eyes have been attracted by an advertisement may be of interest to an advertiser. For example, a merchant may be interested in measuring whether a user notices a virtual world avatar having particular design characteristics. If the user exhibits eye movements toward the avatar on a display, then the merchant may derive a mental state from repeated eye movements vis a vis the avatar, or the merchant may correlate eye movements to the avatar with other physiological activity data such as brain activation data indicating a mental state such as brand preference, approval or reward.

[0400] In another embodiment, a smart camera may be used that can capture images of a user's eyes, process them and issue control commands within a millisecond time frame. Such smart cameras are commercially available (e.g., Hamamatsu's Intelligent Vision System; http:/jp.hamamatsu.com/en/product_info/index.html). Such image capture systems may include dedicated processing elements for each pixel image sensor. Other camera systems may include, for example, a pair of infrared charge coupled device cameras to continuously monitor pupil size and position as a user watches a visual target moving, e.g., forward and backward. This can provide real-time data relating to pupil accommodation relative to objects on a display, which information may be of interest to an entity **170** (e.g., http://jp.hamamatsu.com/en/rd/publication/scientific_american/common/pdf/scientific_0608.pdf).

[0401] Eye movement and/or pupil movement may also be measured by video-based eye trackers. In these systems, a camera focuses on one or both eyes and records eye movement as the viewer looks at a stimulus. Contrast may be used to locate the center of the pupil, and infrared and near-infrared non-collumnated light may be used to create a corneal reflection. The vector between these two features can be used to compute gaze intersection with a surface after a calibration for a subject.

[0402] Two types of eye tracking techniques include bright pupil eye tracking and dark pupil eye tracking. Their difference is based on the location of the illumination source with respect to the optics. If the illumination is coaxial with the optical path, then the eye acts as a retroreflector as the light reflects off the retina, creating a bright pupil effect similar to red eye. If the illumination source is offset from the optical path, then the pupil appears dark.

[0403] Bright Pupil tracking creates greater iris/pupil contrast allowing for more robust eye tracking with all iris pigmentation and greatly reduces interference caused by eyelashes and other obscuring features. It also allows for tracking in lighting conditions ranging from total darkness to very bright light. However, bright pupil techniques are not recommended for tracking outdoors as extraneous IR sources may interfere with monitoring.

[0404] Eye tracking configurations can vary; in some cases the measurement apparatus may be head-mounted, in some cases the head should be stable (e.g., stabilized with a chin rest), and in some cases the eye tracking may be done remotely to automatically track the head during motion. Most eye tracking systems use a sampling rate of at least 30 Hz. Although 50/60 Hz is most common, many video-based eye trackers run at 240, 350 or even 1000/1250 Hz, which is recommended in order to capture the detail of the very rapid eye movements during reading, or during studies of neurology.

[0405] Eye movements are typically divided into fixations, when the eye gaze pauses in a certain position, and saccades, when the eye gaze moves to another position. A series of fixations and saccades is called a scanpath. Most information from the eye is made available during a fixation, not during a saccade. The central one or two degrees of the visual angle (the fovea) provide the bulk of visual information; input from larger eccentricities (the periphery) generally is less informative. Therefore the locations of fixations along a scanpath indicate what information loci on the stimulus were processed during an eye tracking session. On average, fixations last for around 200 milliseconds during the reading of linguistic text, and 350 milliseconds during the viewing of a scene. Preparing a saccade towards a new goal takes around 200 milliseconds.

[0406] Scanpaths are useful for analyzing cognitive intent, interest, and salience. Other biological factors (some as simple as gender) may affect the scanpath as well. Eye tracking in human-computer interaction typically investigates the scanpath for usability purposes, or as a method of input in gaze-contingent displays, also known as gaze-based interfaces.

[0407] There are two primary components to most eye tracking studies: statistical analysis and graphic rendering. These are both based mainly on eye fixations on specific elements. Statistical analyses generally sum the number of eye data observations that fall in a particular region. Commercial software packages may analyze eye tracking and show the relative probability of eye fixation on each feature on an avatar. This allows for a broad analysis of which avatar elements received attention and which ones were ignored. Other behaviors such as blinks, saccades, and cognitive engagement can be reported by commercial software packages. Statistical comparisons can be made to test, for example, competitors, prototypes or subtle changes to an avatar. They can also be used to compare participants in different demographic groups. Statistical analyses may quantify where users look, sometimes directly, and sometimes based on models of higher-order phenomena (e.g., cognitive engagement).

[0408] In addition to statistical analysis, it is often useful to provide visual depictions of eye tracking results. One method is to create a video of an eye tracking testing session with the gaze of a participant superimposed upon it. This allows one to effectively see through the eyes of the consumer during interaction with a target medium. Another method graphically depicts the scanpath of a single participant during a given time interval. Analysis may show each fixation and eye movement of a participant during a search on a virtual shelf display of breakfast cereals, analyzed and rendered with a commercial software package. For example, a different color may represent one second of viewing time, allowing for a determination of the order in which products are seen. Analyses such as these may be used as evidence of specific trends in visual behavior.

[0409] A similar method sums the eye data of multiple participants during a given time interval as a heat map. A heat map may be produced by a commercial software package, and shows the density of eye fixations for several participants superimposed on the original stimulus, for example, an avatar on a magazine cover. Red and orange spots represent areas with high densities of eye fixations. This allows one to examine which regions attract the focus of the viewer.

[0410] Commercial eye tracking applications include web usability, advertising, sponsorship, package design and automotive engineering. Eye tracking studies may presenting a target stimulus to a sample of consumers while an eye tracker is used to record the activity of the eye. Examples of target stimuli may include avatars in the context of websites, television programs, sporting events, films, commercials, magazines, newspapers, packages, shelf displays, consumer systems (ATMs, checkout systems, kiosks), and software. The resulting data can be statistically analyzed and graphically rendered to provide evidence of specific visual patterns. By examining fixations, saccades, pupil dilation, blinks, and a variety of other behaviors, researchers can determine a great deal about the effectiveness of a given avatar in a given medium or associated with a given product.

[0411] A prominent field of eye tracking research is web usability. While traditional usability techniques are often quite powerful in providing information on clicking and scrolling patterns, eye tracking offers the ability to analyze user interaction between the clicks. This provides insight into which features are the most eye-catching, which features cause confusion, and which ones are ignored altogether. Specifically, eye tracking can be used to assess impressions of an avatar in the context of search efficiency, branding, online advertisement, navigation usability, overall design, and/or many other site components. Analyses may target an avatar on a prototype or competitor site in addition to the main client site.

[0412] Eye tracking is commonly used in a variety of different advertising media. Commercials, print ads, online ads, and sponsored programs are all conducive to analysis with eye tracking technology. Analyses may focus on visibility of a target avatar, product, or logo in the context of a magazine, newspaper, website, virtual world, or televised event. This allows researchers to assess in great detail how often a sample of consumers fixates on the target avatar, logo, product, or advertisement. In this way, an advertiser can quantify the success of a given campaign in terms of actual visual attention.

[0413] Eye tracking also provides avatar designers with the opportunity to examine the visual behavior of a consumer while interacting with a target avatar. This may be used to analyze distinctiveness, attractiveness and the tendency of the avatar to be chosen for recognition and/or purchase. Eye tracking can be used while the target avatar is in the prototype stage. Prototype avatars can be are tested against each other and against competitors to examine which specific elements are associated with high visibility and/or appeal.

[0414] Another application of eye tracking research is in the field of automotive design. Eye tracking cameras may be integrated into automobiles to provide the vehicle with the capacity to assess in real-time the visual behavior of the driver. The National Highway Traffic Safety Administration (NHTSA) estimates that drowsiness is the primary causal factor in 100,000 police-reported accidents per year. Another NHTSA study suggests that 80% of collisions occur within three seconds of a distraction. By equipping automobiles with the ability to monitor drowsiness, inattention, and cognitive engagement driving safety could be dramatically enhanced. Lexus® claims to have equipped its LS **460** automobile with the first driver monitor system in 2006, providing a warning if the driver takes his or her eye off the road.

[0415] Eye tracking is also used in communication systems for disabled persons, allowing the user to speak, mail, surf the web and so on with only the eyes as tool. Eye control works even when the user has involuntary body movement as a result of cerebral palsy or other disability, and/or when the user wears glasses.

[0416] Eye movement or pupil movement may be gauged from a user's interaction with an application.

[0417] An example of a measure of pupil movement may be an assessment of the size and symmetry of a user's pupils before and after a stimulus, such as light or focal point. In one embodiment, where the user interacts with a head mounted display, the display may include image capturing features that may provide information regarding expressive indicators. Such approaches have been described in scanned-beam display systems such as those found in U.S. Pat. No. 6,560,028.

[0418] Voice Stress Analysis

[0419] Voice stress analysis (VSA) technology records psycho-physiological stress responses that are present in the human voice when a person experiences a psychological stress in response to a stimulus. Psychological stress may be detected as acoustic modifications in the fundamental frequency of a speaker's voice relative to normal frequency modulation of the vocal signal between 8-14 Hz during speech in an emotionally neutral situation. In situations involving a stress response, the 8-14 Hz modulation may decrease as the muscles surrounding the vocal cords contract in response to the reaction.

[0420] VSA typically records an inaudible component of human voice, commonly referred to as the Lippold Tremor. Under normal circumstances, the laryngeal muscles are relaxed, producing recorded voice at approximately 12 Hz. Under stress however, the tensed laryngeal muscles produce voice significantly lower than normal. The higher the stress, the lower down the Hertz scale voice waves are produced. One application for VSA is in the detection of deception.

[0421] Dektor Counterintelligence manufactured the PSE **1000**, an analog machine that was later replaced by the PSE **2000**. The National Institute Of Truth Verification (NITV) then produced and marketed a digital application based on the McQuiston-Ford algorithm. The primary commercial suppliers are Dektor (PSE5128-software); Diogenes (Lantern-software); NITV (CVSA Software); and Baker (Baker-software).

[0422] VSA is distinctly different from LVA (Layered Voice Analysis). LVA is used to measure different components of voice, such as pitch and tone. LVA is available in the form of hand-held devices and software. LVA produces readings such as 'love,' excitement, and fear.

[0423] One example of a commercially available layered voice analysis system is the SENSE system, sold by Nemesysco Ltd (Natania, Israel). SENSE can analyze different layers within the voice, using multiple parameters to analyze each speech segment. SENSE can detect various cognitive states, such as whether a subject is excited, confused, stressed, concentrating, anticipating a response, or unwillingly sharing information. The technology also can provide an in-depth view of the subject's range of emotions, including those relating to love. SENSE technology can be further utilized to identify psychological issues, mental illness, and other behavioral patterns. The LVA technology is the security version of the SENSE technology, adapted to identify the emotional situations a subject is expected to have during formal/security investigations.

[0424] The SENSE technology is made up of 4 sub-processes:

[0425] 1. The vocal waveform is analyzed to measure the presence of local micro-high frequencies, low frequencies, and changes in their presence within a single voice sample.

[0426] 2. A precise frequency spectrum of the vocal input is sampled and analyzed.

[0427] 3. The parameters gathered by the previous steps are used to create a baseline profile for the subject.

[0428] 4. The new voice segments to be tested are compared with the subject's baseline profile, and the analysis is generated.

[0429] This input can be further processed by statistical learning algorithms to predict the probability of a deceptive or fraudulent sentence in a subject's speech. Another layer that is used in certain applications evaluates the conversation as a whole, and produces a final risk or QA value.

[0430] The SENSE technology can detect the following emotional and cognitive states:

[0431] Excitement Level Each of us becomes excited (or depressed) from time to time. SENSE compares the presence of the Micro-High-frequencies of each sample to the basic profile to measure the excitement level in each vocal segment.

[0432] Confusion Level: Is your subject sure about what he or she is saying? SENSE technology measures and compares the tiny delays in a subject's voice to assess how certain he or she is.

[0433] Stress Level Stress may include the body's reaction to a threat, either by fighting the threat, or by fleeing. However, during a spoken conversation neither option may be available. The conflict caused by this dissonance affects the micro-low-frequencies in the voice during speech.

[0434] Thinking Level How much is your subject trying to find answers? Might he or she be "inventing" stories?

[0435] S.O.S.: (Say Or Stop)—Is your subject hesitating to tell you something?

[0436] Concentration Level Extreme concentration might indicate deception.

[0437] Anticipation Level: Is your subject anticipating your responses according to what he or she is telling you?

[0438] Embarrassment Level: Is your subject feeling comfortable, or does he feel some level of embarrassment regarding what he or she is saying?

[0439] Arousal Level What triggers arousal in the subject? Is he or she interested in an object? Aroused by certain visual stimuli?

[0440] Deep Emotions What long-standing emotions does a subject experience? Is he or she "excited" or "uncertain" in general?

[0441] SENSE's "Deep" Technology: Is a subject thinking about a single topic when speaking, or are there several layers to a response (e.g., background issues, something that may be bothering him or her, planning, or the like). SENSE technology can detect brain activity operating at a pre-conscious level.

[0442] The speaking mechanism is one of the most complicated procedures the human body is capable of. First, the brain has to decide what should be said, then air is pushed from the lungs upward to the vocal cords, that must vibrate to produce the main frequency. Now, the vibrated air arrives to the mouth.

[0443] The tongue, the lips, the teeth, and the nose space turns the vibrated air into the sounds that we recognize as phrases. The brain is closely monitoring all these events, and listens to what comes out; if we speak too softly, too loudly, and if it is understandable to a listener. SENSE Technology ignores what your subject is saying, and focuses only on what the brain is broadcasting.

[0444] Humans, unlike other mammals, are capable of predicting or imagining the future. Most people can tell whether or not a certain response will cause them pleasure or pain. Lying is not a feeling, it is a tool. The feeling structure around it will be the one causing us to lie, and understanding the differences is crucial for making an analysis.

[0445] The SENSE technology differentiates among 5 types of lies:

[0446] 1. Jokes—Jokes are not so much lies as they are untruths, used to entertain. No long gain profit or loss will be earned from it, and usually, little or no extra feelings will be involved.

[0447] 2. White Lies—You know you don't want to say the truth, as it may hurt someone else. White lies are lies, but the teller usually experiences little stress or guilt.

[0448] 3. Embarrassment Lies—Same as for white lies, but this time directed internally. Nothing will be lost except the respect of the listener, most likely for the short term.

[0449] 4. Offensive Lies—This is a unique lie, for it's intention is to gain something extra that could not be gained otherwise.

[0450] 5. Defensive Lie—The common lie to protect one's self.

[0451] The SENSE technology is the old "Truster" technology, with several additions and improvements. The old Truster was all about emotions in the context of Truth/Lie; SENSE looks at emotions in general.

[0452] When people get sexually aroused or feel "in love," the pupils get wider, the lips get reddish, the skin of the face gets red. The voice changes too. Increased excitement makes the whole voice higher and more concentrated. The SENSE technology can detect the increased excitement and the associated heightened concentration and anticipation.

[0453] While each of the above described approaches to providing expressive indicators has been described independently, in some approaches, a combination of two or more of the above described approaches may be implemented to provide additional information that may be useful in evaluating user behavior and/or mental state.

[0454] FIG. **12** illustrates an example system **1200** in which embodiments may be implemented. The system **1200** includes a device **1202**. The device **1202** may contain, for example, an application **1206** and a structurally distinct user-health test unit **1204**. In some embodiments the user-health test unit **1204** may be structurally distinct from the device **1202** on which the application **1206** is operable. In such embodiments the user-health test unit **1204** may be implemented, for example, on external device **1260**. Through interaction with application **1206**, user **1210** may generate user data **1216** that may be obtained by device **1202** and/or user-health test unit **1204**. The application **1206** may include, for example, a game **1244**, a communication application **1250**, a security application **1252**, and/or a productivity application **1254**.

[0455] Device **1202** may also include a user-health testing output/brain activity measurement data association module **1270** that can receive output from user-health test unit **1204** and output from brain activity measurement device **1208**, and that can associate one or more data from each.

[0456] The device **1202** may optionally include a data capture module **1212**, a data detection module **1214**, a user input device **1246**, and/or a user monitoring device **1248**. The user-health test unit **1204** may include an alertness or attention test module **1218**, a memory test module **1220**, a speech test module **1222**, a calculation test module **1224**, a neglect or construction test module **1226**, a task sequencing test module **1228**, a visual field test module **1230**, a pupillary reflex or eye movement test module **1232**, a face pattern test module **1234**, a hearing test module **1236**, a voice test module **1238**, a motor skill test module **1240**, or a body movement test module **1242**.

[0457] In FIG. **12**, the device **1202** is illustrated as possibly being included within a system **1200**. Of course, virtually any kind of computing device may be used to implement the user-health test unit **1204** and/or the user-health testing output/brain activity measurement data association module **1270**, such as, for example, a workstation, a desktop computer, a networked computer, a collection of servers and/or databases, or a tablet PC.

[0458] Additionally, not all of the user-health test unit **1204** and/or the user-health testing output/brain activity measurement data association module **1270** need be implemented on a single computing device. For example, the user-health test unit **1204** and/or application **1206** may be implemented and/or operable on a remote computer, while the user interface **1208** and/or user data **1216** are implemented and/or stored on a local computer. Further, aspects of the user-health test unit **1204** and/or the user-health testing output/brain activity measurement data association module **1270** may be implemented in different combinations and implementations than that shown in FIG. **12**. For example, functionality of the user interface **1208** may be incorporated into the user-health test unit **1204**. The user-health test unit **1204** and/or the user-health testing output/brain activity measurement data association module **1270** may perform simple data relay functions and/or complex data analysis, including, for example, fuzzy logic and/or traditional logic steps. Further, many methods of searching databases and/or establishing data associations known in the art may be used, including, for example, unsupervised pattern discovery methods, coincidence detection methods, and/or entity relationship modeling. In some embodiments, the user-health test unit **1204** may process user data **1216** according to health profiles available as updates through a network.

[0459] The user data **1216** may be stored in virtually any type of memory that is able to store and/or provide access to information in, for example, a one-to-many, many-to-one, and/or many-to-many relationship. Such a memory may include, for example, a relational database and/or an object-oriented database, examples of which are provided in more detail herein.

[0460] FIG. **13** illustrates certain alternative embodiments of the system **1200** of FIG. **12**. In FIG. **13**, the user **1210** may use the user interface **1208** to interact through a network **1302** with the application **1206** operable on a device **1202**. A user-health test unit **1204** may be implemented on the device **1202**, or on another device within the system **1200** but separate from the device **1202**. The device **1202** may be in communication over a network **1302** with a network destination **1306** and/or healthcare provider **1310**, which may interact with the device **1202** and/or the user-health test unit **1204** through, for example, a user interface **1308**. Of course, it should be understood that there may be many users other than the specifically-illustrated user **1210**, for example, each with access to a local instance of the application **1206**. System **1200** may include a user-health testing output/brain activity measurement data association module **1314** that can associate output from user-health test unit **1204** with data from brain activity measurement device **1312**.

[0461] In this way, the user **1210**, who may be using a device that is connected through a network **1302** with the system **1200** (e.g., in an office, outdoors and/or in a public environment), may generate user data **1216** and brain activity measurement data as if the user **1210** were interacting locally with the device **1202** on which the application **1206** is locally operable.

[0462] As referenced herein, the user-health test unit **1204** and/or user-health testing output/brain activity measurement data association module **1314** may be used to perform various data querying, association, and/or recall techniques with respect to the user data **1216**, in order to associate at least one user-health test function output with brain activity measurement data. For example, where the user data **1216** and/or brain activity measurement data is organized, keyed to, and/or otherwise accessible using one or more reference health condition attributes or profiles, various Boolean, statistical, and/or semi-boolean searching techniques may be performed to associate user-health test unit output with brain activity measurement device output.

[0463] Many examples of databases and database structures may be used in connection with the user-health test unit **1204** and/or user-health testing output/brain activity measurement data association module **1314**. Such examples include hierarchical models (in which data is organized in a tree and/or parent-child node structure), network models (based on set theory, and in which multi-parent structures per child node are supported), or object/relational models (combining the relational model with the object-oriented model).

[0464] Still other examples include various types of eXtensible Mark-up Language (XML) databases. For example, a database may be included that holds data in some format other than XML, but that is associated with an XML interface for accessing the database using XML. As another example, a database may store XML data directly. Additionally, or alternatively, virtually any semi-structured database may be used, so that context may be provided to/associated with stored data elements (either encoded with the data elements, or encoded externally to the data elements), so that data storage and/or access may be facilitated.

[0465] Such databases, and/or other memory storage techniques, may be written and/or implemented using various programming or coding languages. For example, object-oriented database management systems may be written in programming languages such as, for example, C++ or Java. Relational and/or object/relational models may make use of database languages, such as, for example, the structured query language (SQL), which may be used, for example, for interactive queries for information and/or for gathering and/or compiling data from the relational database(s).

[0466] For example, SQL or SQL-like operations over one or more of reference health condition may be performed, or Boolean operations using a reference health condition may be performed. For example, weighted Boolean operations may be performed in which different weights or priorities are assigned to one or more of the reference health conditions, perhaps relative to one another. For example, a number-weighted, exclusive-OR operation may be performed to request specific weightings of desired (or undesired) health reference data to be included or excluded.

[0467] FIG. **14** illustrates an operational flow **1400** representing example operations related to computational user-health testing. In FIG. **14** and in following figures that include various examples of operational flows, discussion and explanation may be provided with respect to the above-described system environments of FIGS. **12-13**, and/or with respect to other examples and contexts. However, it should be understood that the operational flows may be executed in a number of other environment and contexts, and/or in modified versions of FIGS. **12-13**. Also, although the various operational flows are presented in the sequence(s) illustrated, it should be understood that the various operations may be performed in other orders than those which are illustrated, or may be performed concurrently.

[0468] After a start operation, operation **1410** shows accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application. The user-health test function may be implemented on a device **1202** within a system **1200**. The user-health test function may be carried out by a user-health test unit **1204** resident on device **1202**. System **1200** may also include application **1206** that is operable on device **1202**. For example, a user-health test function may be implemented as a user-health test unit **1204** residing on an external device **1260**, which user-health test unit **1204** communicates with via a network **170**, for example, with the at least one device **1202**. In this example, the user-health test function may be implemented in the at least one device **1202** by virtue of its communication over the network **170**, and the user-health test function optionally may be structurally distinct from at least one application **1206** operable on the at least one device **1202**. The at least one application **1206** may reside on the at least one device **1202**, or the at least one application **1206** may not reside on the at least one device **1202** but instead be operable on the at least one device **1202** from a remote location, for example, through a network or other link. One example of a user-health test function is a memory test function within a game application requiring a recognition response to a previously-encountered object, sound, and/or avatar in the game.

[0469] Operation **1420** depicts accepting brain activity measurement data proximate to the interaction. For example, a user-health testing output/brain activity measurement data association module **1270** may obtain user brain activity measurement data from, for example, brain activity measurement device **1208** proximate to an interaction between a user and at least one application. For example, user-health testing output/brain activity measurement data association module **1270** may obtain user hippocampus activity data proximate to an interaction between the user and the at least one application requiring long-term memory function and/or spatial navigation function.

[0470] It should be understood that there is no preferred order regarding operation **1410** and operation **1420**. For example, it makes no difference to the herein claimed subject matter which is accepted first, the brain activity measurement data or the user-health test function output. They may also be accepted at substantially the same time.

[0471] Operation **1430** depicts associating the at least one user-health test function output with the brain activity measurement data. For example, user-health testing output/brain activity measurement data association module **1314** can associate output from user-health test unit **1204** with data from brain activity measurement device **1312**. For example, an alertness or attention test module **1218** may provide output to user-health testing output/brain activity measurement data association module **1314** based on an interaction between a user and a social networking website. Concurrently or at another time, brain activity measurement device **1208** may provide measurements of parietal cortex activity to the user-health testing output/brain activity measurement data association module **1314**. Accordingly, the user-health testing output/brain activity measurement data association module **1314** can associate attention test output with brain activity measurement device output, especially that corresponding to regions of the brain associated with attention, e.g., the parietal cortex.

[0472] Operation **1440** depicts presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may present the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data. In some circumstances, user-health test function output may be susceptible to multiple interpretations. For example, a user's inability to move a cursor on a display to click on a target may implicate one or more of a motor skill impairment, an attention deficit, a cognitive impairment, and/or a visual impairment, to name a few. By presenting brain activity measurement data with the user-health test function output, an identification of a specific problem may be facilitated. For example, brain activity measurement data signifying a memory defect may suggest that output of a speech test module **1222** indicating a speech deficit may instead be a memory problem, perhaps calling for operation of a memory test module **1220** to test this hypothesis. This may also be accompanied by brain activity measurement data indicating normal functioning of the speech areas of the brain.

[0473] In another example, the user-health testing output/brain activity measurement data association module **1314** can provide associated user-health test function output and brain activity measurement data to a computer connected by a network to the device **1202** or to at least one memory.

[0474] In this regard, it should be understood that a data signal may first be encoded and/or represented in digital form (i.e., as digital data), prior to the assignment to at least one memory. For example, a digitally-encoded representation of user eye movement data may be stored in a local memory, or may be transmitted for storage in a remote memory.

[0475] Thus, an operation may be performed relating either to a local or remote storage of the digital data, or to another type of transmission of the digital data. Of course, as discussed herein, operations also may be performed relating to accessing, querying, processing, associating, recalling, or otherwise obtaining the digital data from a memory, including, for example, receiving a transmission of the digital data from a remote memory. Accordingly, such operation(s) may involve elements including at least an operator (e.g., either human or computer) directing the operation, a transmitting computer, and/or a receiving computer.

[0476] FIG. **15** illustrates alternative embodiments of the example operational flow **1400** of FIG. **14**. FIG. **15** illustrates example embodiments where the accepting operation **1410** may include at least one additional operation. Additional operations may include operations **1500**, **1502**, **1504**, and/or operation **1506**.

[0477] Operation **1500** depicts accepting at least one personal computing device output as the at least one user-health test function output. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one personal computing device output as the at least one user-health test function output. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may receive output of a user-health test function implemented on a laptop and/or desktop computer of user **1210**. In another embodiment, a device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept an output from a mobile computing device having a user-health test unit **1204**, such as a cell phone or pda, as the at least one user-health test function output.

[0478] Operation **1502** depicts accepting at least one alertness or attention test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one alertness or attention test function output at least partly based on an interaction between at least one user and at least one device-operable application. In one embodiment, for example, an alertness or attention test module **1218** may be implemented in the at least one device **1202** that can receive user data **1216** from an interaction between the user **1210** and the at least one application **1206**, the at least one application **1206** being operable on the at least one device **1202**. Such an alertness or attention test module **1218** may produce output based on user data **1216** from data capture module **112** and/or data detection module **114**.

[0479] Alertness or attention user attributes are indicators of a user's mental status. An example of an alertness test function may be a measure of reaction time as one objective manifestation. Examples of attention test functions may include ability to focus on simple tasks, ability to spell the word "world" forward and backward, or reciting a numerical sequence forward and backward as objective manifestations of an alertness problem. An alertness or attention test module **1218** and/or user-health test unit **1204** may require a user to enter a password backward as an alertness test function. Alternatively, a user may be prompted to perform an executive function as a predicate to launching an application such as a word processing program. For example, an alertness test function could be activated by a user command to open a word processing program, requiring performance of, for example, a spelling task as a preliminary step in launching the word processing program. Also, writing ability may be tested by requiring the user to write their name or write a sentence on a device, perhaps with a stylus on a touchscreen.

[0480] Reduced level of alertness or attention can indicate the following possible conditions where an acute reduction in alertness or attention is detected: stroke involving the reticular activating system, stroke involving the bilateral or unilateral thalamus, metabolic abnormalities such as hyper or hypoglycemia, toxic effects due to substance overdose (for example, benzodiazepines, or other toxins such as alcohol). Reduced level of alertness and attention can indicate the following possible conditions where a subacute or chronic reduction in alertness or attention is detected: dementia (caused by, for example, Alzheimer's disease, vascular dementia, Parkinson's disease, Huntingdon's disease, Creutzfeldt-Jakob disease, Pick disease, head injury, infection, normal pressure hydrocephalus, brain tumor, exposure to toxin (for example, lead or other heavy metals), metabolic disorders, hormone disorders, hypoxia, drug reactions, drug overuse, drug abuse, encephalitis (caused by, for example, enteroviruses, herpes viruses, or arboviruses), or mood disorders (for example, bipolar disorder, cyclothymic disorder, depression, depressive disorder NOS (not otherwise specified), dysthymic disorder, postpartum depression, or seasonal affective disorder)).

[0481] Operation **1504** depicts accepting at least one memory test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one memory test function output at least partly based on an interaction between at least one user and at least one device-operable application. Memory test function output may be provided by memory test module **1220**, which may receive user data **1216** from data capture module **112** and/or data detection module **114**.

[0482] A user's memory attributes are indicators of a user's mental status. An example of a memory test function may be a measure of a user's short-term ability to recall items presented, for example, in a story, or after a short period of time. Another example of a memory test function may be a measure of a user's long-term memory, for example their ability to remember basic personal information such as birthdays, place of birth, or names of relatives. Another example of a memory test function may be a memory test module **1220** and/or user-health test unit **1204** prompting a user to change and enter a password with a specified frequency during internet browser use. A memory test function involving changes to a password that is required to access an internet server can challenge a user's memory according to a fixed or variable schedule.

[0483] Difficulty with recall after about 1 to 5 minutes may indicate damage to the limbic memory structures located in the medial temporal lobes and medial diencephalon of the brain, or damage to the fornix. Dysfunction of these structures characteristically causes anterograde amnesia, meaning difficulty remembering new facts and events occurring after lesion onset. Reduced short-term memory function can also indicate the following conditions: head injury, Alzheimer's disease, Herpes virus infection, seizure, emotional shock or hysteria, alcohol-related brain damage, barbiturate or heroin use, general anaesthetic effects, electroconvulsive therapy effects, stroke, transient ischemic attack (i.e., a "mini-stroke"), complication of brain surgery. Reduced long-term memory function can indicate the following conditions: Alzheimer's disease, alcohol-related brain damage, complication of brain surgery, depressive pseudodementia, adverse drug reactions (e.g., to benzodiazepines, anti-ulcer drugs, analgesics, anti-hypertensives, diabetes drugs, beta-blockers, anti-Parkinson's disease drugs, anti-emetics, anti-psychotics, or certain drug combinations, such as haloperidol and methyldopa combination therapy), multi-infarct dementia, or head injury.

[0484] Operation **1506** depicts accepting at least one speech test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one speech test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, speech test module **1222** can produce output at least partly based on user data **1216** from data capture module **112** and/or data detection module **114**.

[0485] User speech attributes are indicators of a user's mental status. An example of a speech test function may be a measure of a user's fluency or ability to produce spontaneous speech, including phrase length, rate of speech, abundance of spontaneous speech, tonal modulation, or whether paraphasic errors (e.g., inappropriately substituted words or syllables), neologisms (e.g., nonexistent words), or errors in grammar are present. Another example of a speech test function is a program that can measure the number of words spoken by a user during a video conference. The number of words per interaction or per unit time could be measured. A marked decrease in the number of words spoken could indicate a speech problem.

[0486] Another example of a speech test function may be a measure of a user's comprehension of spoken language, including whether a user **110** can understand simple questions and commands, or grammatical structure. For example, a user **1210** could be tested by a speech test module **1222** and/or user-health test unit **1204** asking the question "Mike was shot by John. Is John dead?" An inappropriate response may indicate a speech center defect. Alternatively a user-health test unit **1204** and/or speech test module **1222** may require a user to say a code or phrase and repeat it several times. Speech defects may become apparent if the user has difficulty repeating the code or phrase during, for example, a videoconference setup or while using speech recognition software.

[0487] Another example of a speech test function may be a measure of a user's ability to name simple everyday objects (e.g., pen, watch, tie) and also more difficult objects (e.g., fingernail, belt buckle, stethoscope). A speech test function may, for example, require the naming of an object prior to or during the interaction of a user **1210** with an application **1206**, as a time-based or event-based checkpoint. For example, a user **1210** may be prompted by the user-health test unit **1204** and/or the speech test module **1222** to say "armadillo" after being shown a picture of an armadillo, prior to or during the user's interaction with, for example, a word processing or email program. A test requiring the naming of parts of objects is often more difficult for users with speech comprehension impairment. Another speech test gauges a user's ability to repeat single words and sentences (e.g., "no if's and's or but's"). A further example of a speech test measures a user's ability to read single words, a brief written passage, or the front page of the newspaper aloud followed by a test for comprehension.

[0488] Difficulty with speech or reading/writing ability may indicate, for example, lesions in the dominant (usually left) frontal lobe, including Broca's area (output area); the left temporal and parietal lobes, including Wernicke's area (input area); subcortical white matter and gray matter structures, including thalamus and caudate nucleus; as well as the non-dominant hemisphere. Typical diagnostic conditions may include, for example, stroke, head trauma, dementia, multiple sclerosis, Parkinson's disease, Landau-Kleffner syndrome (a rare syndrome of acquired epileptic aphasia).

[0489] FIG. **16** illustrates alternative embodiments of the example operational flow **1400** of FIG. **14**. FIG. **16** illustrates example embodiments where the accepting operation **1410** may include at least one additional operation. Additional operations may include operations **1600**, **1602**, **1604**, and/or operation **1606**.

[0490] Operation **1600** depicts accepting at least one calculation test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one calculation test function output at least partly based on an interaction between at least one user and at least one device-operable application. Calculation test module **1224** can produce output at least partly based on user data **1216** via a data capture module **112** and/or data detection module **114**.

[0491] A user's calculation attributes are indicators of a user's mental status. An example of a calculation test function may be a measure of a user's ability to do simple math such as addition or subtraction, for example. A calculation test module **1224** and/or user-health test unit **1204** may prompt a user **1210** to solve an arithmetic problem in the context of interacting with application **1206**, or alternatively, in the context of using the device in between periods of interacting with the application **1206**. For example, a user may be prompted to enter the number of items and/or gold pieces collected during a segment of gameplay in the context of playing a game. In this and other contexts, user interaction with a device's operating system or other system function may also constitute user interaction with an application **1206**. Difficulty in completing calculation tests may be indicative of stroke (e.g., embolic, thrombotic, or due to vasculitis), dominant parietal lesion, or brain tumor (e.g., glioma or meningioma). When a calculation ability deficiency is found with defects in user ability to distinguish right and left body parts (right-left confusion), ability to name and identify each finger (finger agnosia), and ability to write their name and a sentence, Gerstman's syndrome, a lesion in the dominant parietal lobe of the brain, may be present.

[0492] Operation **1602** depicts accepting at least one neglect or construction test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one neglect or construction test function output at least partly based on an interaction between at least one user and at least one device-operable application. Neglect or construction test module **1226** may produce output at least partly based on user data **1216** via a data capture module **112** and/or data detection module **114**.

[0493] Neglect or construction user attributes are indicators of a user's mental status. Neglect may include a neurological condition involving a deficit in attention to an area of space, often one side of the body or the other. A construction defect may include a deficit in a user's ability to draw complex figures or manipulate blocks or other objects in space as a result of neglect or other visuospatial impairment.

[0494] Hemineglect may include an abnormality in attention to one side of the universe that is not due to a primary sensory or motor disturbance. In sensory neglect, users ignore visual, somatosensory, or auditory stimuli on the affected side, despite intact primary sensation. This can often be demonstrated by testing for extinction on double simultaneous stimulation. Thus, a neglect or construction test module **1226** and/or user-health test unit **1204** may present a stimulus on one or both sides of a display for a user **1210** to click on. A user with hemineglect may detect the stimulus on the affected side when presented alone, but when stimuli are presented simultaneously on both sides, only the stimulus on the unaffected side may be detected. In motor neglect, normal strength may be present, however, the user often does not move the affected limb unless attention is strongly directed toward it.

[0495] An example of a neglect test function may be a measure of a user's awareness of events occurring on one side of the user or the other. A user could be asked, "Do you see anything on the left side of the screen?" Users with anosognosia (i.e., unawareness of a disability) may be strikingly unaware of severe deficits on the affected side. For example, some people with acute stroke who are completely paralyzed on the left side believe there is nothing wrong and may even be perplexed about why they are in the hospital. Alternatively, a neglect or construction test module **1226** and/or user-health test unit **1204** may present a drawing task to a user in the context of an application **1206** that involves similar activities. A construction test involves prompting a user to draw complex figures or to manipulate objects in space. Difficulty in completing such a test may be a result of neglect or other visuospatial impairment.

[0496] Another neglect test function is a test of a user's ability to acknowledge a series of objects on a display that span a center point on the display. For example, a user may be prompted to click on each of 5 hash marks present in a horizontal line across the midline of a display. If the user has a neglect problem, she may only detect and accordingly click on the hash marks on one side of the display, neglecting the others.

[0497] Hemineglect is most common in lesions of the right (nondominant) parietal lobe, causing users to neglect the left side. Left-sided neglect can also occasionally be seen in right frontal lesions, right thalamic or basal ganglia lesions, and, rarely, in lesions of the right midbrain. Hemineglect or difficulty with construction tasks may be indicative of stroke (e.g., embolic, thrombotic, or due to vasculitis), or brain tumor (e.g., glioma or meningioma).

[0498] Operation **1604** depicts accepting at least one task sequencing test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one task sequencing test function output at least partly based on an interaction between at least one user and at least one device-operable application. Task sequencing test module **128** may produce output at least partly based on user data **1216** from data capture module **112** and/or data detection module **114**.

[0499] A user's task sequencing attributes are indicators of a user's mental status. An example of a task sequencing test function may be a measure of a user's perseveration. For example, a task sequencing test module **1228** and/or user-health test unit **1204** may ask a user to continue drawing a silhouette pattern of alternating triangles and squares (i.e., a written alternating sequencing task) for a time period. In users with perseveration problems, the user may get stuck on one shape and keep drawing triangles. Another common finding is motor impersistence, a form of distractibility in which users only briefly sustain a motor action in response to a command such as "raise your arms" or "Look to the right." Ability to suppress inappropriate behaviors can be tested by the auditory "Go-No-Go" test, in which the user moves a finger in response to one sound, but must keep it still in response to two sounds. Alternatively, a task sequencing test module **1228** and/or user-health test unit **1204** may prompt a user to perform a multi-step function in the context of an application **1206**, for example. For example, a game may prompt a user to enter a character's name, equip an item from an inventory, an click on a certain direction of travel, in that order. Difficulty completing this task may indicate, for example, a frontal lobe defect associated with dementia.

[0500] Decreased ability to perform sequencing tasks may be indicative of stroke (e.g., embolic, thrombotic, or due to vasculitis), brain tumor (e.g., glioma or meningioma), or dementia (caused by, for example, Alzheimer's disease, vascular dementia, Parkinson's disease, Huntingdon's disease, Creutzfeldt-Jakob disease, Pick disease, head injury, infection (e.g., meningitis, encephalitis, HIV, or syphilis), normal pressure hydrocephalus, brain tumor, exposure to toxin (for example, lead or other heavy metals), metabolic disorders, hormone disorders, hypoxia (caused by, e.g., emphysema, pneumonia, or congestive heart failure), drug reactions (e.g., anti-cholinergic side effects, drug overuse, drug abuse (e.g., cocaine or heroin).

[0501] Operation **1606** depicts accepting at least one visual field test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one visual field test function output at least partly based on an interaction between at least one user and at least one device-operable application. Visual field test module **1230** may produce output at least partly based on user data **1216** via a data capture module **112** and/or data detection module **114**.

[0502] An example of a visual field test function may be a measure of a user's gross visual acuity, for example using a Snellen eye chart or visual equivalent on a display. Alternatively, a campimeter may be used to conduct a visual field test. A visual field test module **1230** and/or user-health test unit **1204** can prompt a user to activate a portion of a display when the user can detect an object entering their field of view from a peripheral location relative to a fixed point of focus, either with both eyes or with one eye covered at a time. Such testing could be done in the context of, for example, new email alerts that require clicking and that appear in various locations on a display. Based upon the location of decreased visual field, the defect can be localized, for example in a quadrant system. A pre-chiasmatic lesion results in ipsilateral eye blindness. A chiasmatic lesion can result in bi-temporal hemianopsia (i.e., tunnel vision). Post-chiasmatic lesions proximal to the geniculate ganglion can result in left or right homonymous hemianopsia. Lesions distal to the geniculate ganglion can result in upper or lower homonymous quadrantanopsia.

[0503] Visual field defects may indicate optic nerve conditions such as pre-chiasmatic lesions, which include fractures of the sphenoid bone (e.g., transecting the optic nerve), retinal tumors, or masses compressing the optic nerve. Such conditions may result in unilateral blindness and unilaterally unreactive pupil (although the pupil may react to light applied to the contralateral eye). Bi-temporal hemianopsia can be caused by glaucoma, pituitary adenoma, craniopharyngioma or saccular Berry aneurysm at the optic chiasm. Post-chiasmatic lesions are associated with homonymous hemianopsia or quadrantanopsia depending on the location of the lesion.

[0504] FIG. **17** illustrates alternative embodiments of the example operational flow **1400** of FIG. **14**. FIG. **17** illustrates example embodiments where the accepting operation **1410** may include at least one additional operation. Additional operations may include operations **1700**, **1702**, **1704**, and/or operation **1706**.

[0505] Operation **514** depicts accepting at least one pupillary reflex test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one pupillary reflex test function output at least partly based on an interaction between at least one user and at least one device-operable application. Pupillary reflex or eye movement test module **1232** may produce output at least partly based on user data **1216** from data capture module **112** and/or data detection module **114**.

[0506] An example of a pupillary reflex test function may be a measure of a user's pupils when exposed to light or objects at various distances. A pupillary reflex or eye movement test module **1232** and/or user-health test unit **1204** may assess the size and symmetry of a user's pupils before and after a stimulus, such as light or focal point. Anisocoria (i.e., unequal pupils) of up to 0.5 mm is fairly common, and is benign provided pupillary reaction to light is normal. Pupillary reflex can be tested in a darkened room by shining light in one pupil and observing any constriction of the ipsilateral pupil (direct reflex) or the contralateral pupil (contralateral reflex). If abnormality is found with light reaction, pupillary accommodation can be tested by having the user focus on an object at a distance, then focus on the object at about 10 cm from the nose. Pupils should converge and constrict at close focus.

[0507] Pupillary abnormalities may be a result of either optic nerve or oculomotor nerve lesions. An optic nerve lesion (e.g., blind eye) will not react to direct light and will not elicit a consensual pupillary constriction, but will constrict if light is shown in the opposite eye. A Horner's syndrome lesion (sympathetic chain lesion) can also present as a pupillary abnormality. In Horner's syndrome, the affected pupil is smaller but constricts to both light and near vision and may be associated with ptosis and anhydrosis. In an oculomotor nerve lesion, the affected pupil is fixed and dilated and may be associated with ptosis and lateral deviation (due to unopposed action of the abducens nerve). Small pupils that do not react to light but do constrict with near vision (i.e., accommodate but do not react to light) can be seen in central nervous system syphilis ("Argyll Robertson pupil").

[0508] Pupillary reflex deficiencies may indicate damage to the oculomotor nerve in basilar skull fracture or uncal herniation as a result of increased intracranial pressure. Masses or tumors in the cavernous sinus, syphilis, or aneurysm may also lead to compression of the oculomotor nerve. Injury to the oculomotor nerve may result in ptosis, inferolateral displacement of the ipsilateral eye (which can present as diplopia or strabismus), or mydriasis.

[0509] An example of an eye movement test function may be a pupillary reflex or eye movement test module **1232** and/or user-health test unit **1204** measurement of a user's ability to follow a target on a display with her eyes throughout a 360° range. Such testing may be done in the context of a user playing a game or participating in a videoconference. In such examples, user data **1216** may be obtained through a camera in place as a user monitoring device **1248** that can monitor the eye movements of the user during interaction with the application **1206**.

[0510] Testing of the trochlear nerve or the abducens nerve for damage may involve measurement of extraocular movements. The trochlear nerve performs intorsion, depression, and abduction of the eye. A trochlear nerve lesion may present as extorsion of the ipsilateral eye and worsened diplopia when looking down. Damage to the abducens nerve may result in a decreased ability to abduct the eye.

[0511] Abnormalities in eye movement may indicate fracture of the sphenoid wing, intracranial hemorrhage, neoplasm, or aneurysm. Such insults may present as extorsion of the ipsilateral eye. Individuals with this condition complain of worsened diplopia with attempted downgaze, but improved diplopia with head tilted to the contralateral side. Injury to the abducens nerve may be caused by aneurysm, a mass in the cavernous sinus, or a fracture of the skull base. Such insults may result in extraocular palsy defined by medial deviation of the ipsilateral eye. Users with this condition may present with diplopia that improves when the contralateral eye is abducted.

[0512] Nystagmus is a rapid involuntary rhythmic eye movement, with the eyes moving quickly in one direction (quick phase), and then slowly in the other direction (slow phase). The direction of nystagmus is defined by the direction of its quick phase (e.g., right nystagmus is due to a right-moving quick phase). Nystagmus may occur in the vertical or horizontal directions, or in a semicircular movement. Terminology includes downbeat nystagmus, upbeat nystagmus, seesaw nystagmus, periodic alternating nystagmus, and pendular nystagmus. There are other similar alterations in periodic eye movements (saccadic oscillations) such as opsoclonus or ocular flutter. One can think of nystagmus as the combination of a slow adjusting eye movement (slow phase) as would be seen with the vestibulo-ocular reflex, followed by a quick saccade (quick phase) when the eye has reached the limit of its rotation.

[0513] In medicine, the clinical importance of nystagmus is that it indicates that the user's spatial sensory system perceives rotation and is rotating the eyes to adjust. Thus it depends on the coordination of activities between two major physiological systems: the vision and the vestibular apparatus (which controls posture and balance). This may be physiological (i.e., normal) or pathological.

[0514] Vestibular nystagmus may be central or peripheral. Important differentiating features between central and peripheral nystagmus include the following: peripheral nystagmus is unidirectional with the fast phase opposite the lesion; central nystagmus may be unidirectional or bidirectional; purely vertical or torsional nystagmus suggests a central location; central vestibular nystagmus is not dampened or inhibited by visual fixation; tinnitus or deafness often is present in peripheral vestibular nystagmus, but it usually is absent in central vestibular nystagmus. According to Alexander's law, the nystagmus associated with peripheral lesions becomes more pronounced with gaze toward the side of the fast-beating component; with central nystagmus, the direction of the fast component is directed toward the side of gaze (e.g., left-beating in left gaze, right-beating in right gaze, and up-beating in upgaze).

[0515] Downbeat nystagmus is defined as nystagmus with the fast phase beating in a downward direction. The nystagmus usually is of maximal intensity when the eyes are deviated temporally and slightly inferiorly. With the eyes in this position, the nystagmus is directed obliquely downward. In most users, removal of fixation (e.g., by Frenzel goggles) does not influence slow phase velocity to a considerable extent, however, the frequency of saccades may diminish.

[0516] The presence of downbeat nystagmus is highly suggestive of disorders of the cranio-cervical junction (e.g., Arnold-Chiari malformation). This condition also may occur with bilateral lesions of the cerebellar flocculus and bilateral lesions of the medial longitudinal fasciculus, which carries optokinetic input from the posterior semicircular canals to the third nerve nuclei. It may also occur when the tone within pathways from the anterior semicircular canals is relatively higher than the tone within the posterior semicircular canals. Under such circumstances, the relatively unopposed neural activity from the anterior semicircular canals causes a slow upward pursuit movement of the eyes with a fast, corrective downward saccade. Additional causes include demyelination (e.g., as a result of multiple sclerosis), microvascular disease with vertebrobasilar insufficiency, brain stem encephalitis, tumors at the foramen magnum (e.g., meningioma, or cerebellar hemangioma), trauma, drugs (e.g., alcohol, lithium, or anti-seizure medications), nutritional imbalances (e.g., Wernicke encephalopathy, parenteral feeding, magnesium deficiency), or heat stroke.

[0517] Upbeat nystagmus is defined as nystagmus with the fast phase beating in an upward direction. Daroff and Troost described two distinct types. The first type consists of a large amplitude nystagmus that increases in intensity with upward gaze. This type is suggestive of a lesion of the anterior vermis of the cerebellum. The second type consists of a small amplitude nystagmus that decreases in intensity with upward gaze and increases in intensity with downward gaze. This type is suggestive of lesions of the medulla, including the perihypoglossal nuclei, the adjacent medial vestibular nucleus, and the nucleus intercalatus (structures important in gaze-holding). Upbeat nystagmus may also be an indication of benign paroxysmal positional vertigo.

[0518] Torsional (rotary) nystagmus refers to a rotary movement of the globe about its anteroposterior axis. Torsional nystagmus is accentuated on lateral gaze. Most nystagmus resulting from dysfunction of the vestibular system has a torsional component superimposed on a horizontal or vertical nystagmus. This condition occurs with lesions of the anterior and posterior semicircular canals on the same side (e.g., lateral medullary syndrome or Wallenberg syndrome). Lesions of the lateral medulla may produce a torsional nystagmus with the fast phase directed away from the side of the lesion. This type of nystagmus can be accentuated by otolithic stimulation by placing the user on their side with the intact side down (e.g., if the lesion is on the left, the nystagmus is accentuated when the user is placed on his right side).

[0519] This condition may occur when the tone within the pathways of the posterior semicircular canals is relatively higher than the tone within the anterior semicircular canals, and it can occur from lesions of the ventral tegmental tract or the brachium conjunctivum, which carry optokinetic input from the anterior semicircular canals to the third nerve nuclei.

[0520] Pendular nystagmus is a multivectorial nystagmus (i.e., horizontal, vertical, circular, and elliptical) with an equal velocity in each direction that may reflect brain stem or cerebellar dysfunction. Often, there is marked asymmetry and dissociation between the eyes. The amplitude of the nystagmus may vary in different positions of gaze. Causes of pendular nystagmus may include demyelinating disease, monocular or binocular visual deprivation, oculapalatal myoclonus, internuclear opthalmoplegia, or brain stem or cerebellar dysfunction.

[0521] Horizontal nystagmus is a well-recognized finding in patients with a unilateral disease of the cerebral hemispheres, especially with large, posterior lesions. It often is of low amplitude. Such patients show a constant velocity drift of the eyes toward the intact hemisphere with fast saccade directed toward the side of the lesion.

[0522] Seesaw nystagmus is a pendular oscillation that consists of elevation and intorsion of one eye and depression and extorsion of the fellow eye that alternates every half cycle. This striking and unusual form of nystagmus may be seen in patients with chiasmal lesions, suggesting loss of the crossed visual inputs from the decussating fibers of the optic nerve at the level of the chiasm as the cause or lesions in the rostral midbrain. This type of nystagmus is not affected by otolithic stimulation. Seesaw nystagmus may also be caused by parasellar lesions or visual loss secondary to retinitis pigmentosa.

[0523] Gaze-evoked nystagmus is produced by the attempted maintenance of an extreme eye position. It is the most common form of nystagmus. Gaze-evoked nystagmus is due to a deficient eye position signal in the neural integrator network. Thus, the eyes cannot be maintained at an eccentric orbital position and are pulled back toward primary position by the elastic forces of the orbital fascia. Then, corrective saccade moves the eyes back toward the eccentric position in the orbit.

[0524] Gaze-evoked nystagmus may be caused by structural lesions that involve the neural integrator network, which is dispersed between the vestibulocerebellum, the medulla (e.g., the region of the nucleus prepositus hypoglossi and adjacent medial vestibular nucleus "NPH/MVN"), and the interstitial nucleus of Cajal ("INC"). Patients recovering from a gaze palsy go through a period where they are able to gaze in the direction of the previous palsy, but they are unable to sustain gaze in that direction; therefore, the eyes drift slowly back toward primary position followed by a corrective saccade. When this is repeated, a gaze-evoked or gaze-paretic nystagmus results.

[0525] Gaze-evoked nystagmus often is encountered in healthy users; in which case, it is called end-point nystagmus. End-point nystagmus usually can be differentiated from gaze-evoked nystagmus caused by disease, in that the former has lower intensity and, more importantly, is not associated with other ocular motor abnormalities. Gaze-evoked nystagmus also may be caused by alcohol or drugs including anti-convulsants (e.g., phenobarbital, phenytoin, or carbamazepine) at therapeutic dosages.

[0526] Spasmus nutans is a rare condition with the clinical triad of nystagmus, head nodding, and torticollis. Onset is from age 3-15 months with disappearance by 3 or 4 years. Rarely, it may be present to age 5-6 years. The nystagmus typically consists of small-amplitude, high frequency oscillations and usually is bilateral, but it can be monocular, asymmetric, and variable in different positions of gaze. Spasmus nutans occurs in otherwise healthy children. Chiasmal, suprachiasmal, or third ventricle gliomas may cause a condition that mimics spasmus nutans.

[0527] Periodic alternating nystagmus is a conjugate, horizontal jerk nystagmus with the fast phase beating in one direction for a period of approximately 1-2 minutes. The nystagmus has an intervening neutral phase lasting 10-20 seconds; the nystagmus begins to beat in the opposite direction for 1-2 minutes; then the process repeats itself. The mechanism may be disruption of the vestibulo-ocular tracts at the pontomedullary junction. Causes of periodic alternating nystagmus may include Arnold-Chiari malformation, demyelinating disease, spinocerebellar degeneration, lesions of the vestibular nuclei, head trauma, encephalitis, syphilis, posterior fossa tumors, or binocular visual deprivation (e.g., ocular media opacities).

[0528] Abducting nystagmus of internuclear opthalmoplegia ("INO") is nystagmus in the abducting eye contralateral to a medial longitudinal fasciculus ("MLF") lesion.

[0529] Operation **1702** depicts accepting at least one face pattern test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one face pattern test function output at least partly based on an interaction between at least one user and at least one device-operable application. Face pattern test module **1234** may produce output at leas partly based on user data **1216** from data capture module **112** and/or data detection module **114**.

[0530] An example of a face pattern test function may be a face pattern test module **1234** and/or user-health test unit **1204** that can compare a user's face while at rest, specifically looking for nasolabial fold flattening or drooping of the corner of the mouth, with the user's face while moving certain facial features. The user may be asked to raise her eyebrows, wrinkle her forehead, show her teeth, puff out her cheeks, or close her eyes tight. Such testing may done via facial pattern recognition software used in conjunction with, for example, a videoconferencing application. Any weakness or asymmetry may indicate a lesion in the facial nerve. In general, a peripheral lesion of the facial nerve may affect the upper and lower face while a central lesion may only affect the lower face.

[0531] Abnormalities in facial expression or pattern may indicate a petrous fracture. Peripheral facial nerve injury may also be due to compression, tumor, or aneurysm. Bell's Palsy is thought to be caused by idiopathic inflammation of the facial nerve within the facial canal. A peripheral facial nerve lesion involves muscles of both the upper and lower face and can involve loss of taste sensation from the anterior ⅔ of the tongue (via the chorda tympani). A central facial nerve palsy due to tumor or hemorrhage results in sparing of upper and frontal orbicularis occuli due to crossed innervation. Spared ability to raise eyebrows and wrinkle the forehead helps differentiate a peripheral palsy from a central process. This also may indicate stroke or multiple sclerosis.

[0532] Operation **1704** depicts accepting at least one hearing test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one hearing test function output at least partly based on an interaction between at least one user and at least one device-operable application. Such a hearing test module **1236** may produce output at least partly based on user data **1216** from data capture module **112** and/or data detection module **114**.

[0533] An example of a hearing test function may be a hearing test module **1236** and/or user-health test unit **1204** conducting a gross hearing assessment of a user's ability to hear sounds. This can be done by simply presenting sounds to the user or determining if the user can hear sounds presented to each of the ears. For example, a hearing test module **1236** and/or user-health test unit **1204** may vary volume settings or sound frequency on a user's device **1202** or within an application **1206** over time to test user hearing. Alternatively, a hearing test module **1236** and/or user-health test unit **1204** in a mobile phone device may carry out various hearing test functions.

[0534] Petrous fractures that involve the vestibulocochlear nerve may result in hearing loss, vertigo, or nystagmus (frequently positional) immediately after the injury. Severe middle ear infection can cause similar symptoms but have a more gradual onset. Acoustic neuroma is associated with gradual ipsilateral hearing loss. Due to the close proximity of the vestibulocochlear nerve with the facial nerve, acoustic neuromas often present with involvement of the facial nerve. Neurofibromatosis type II is associated with bilateral acoustic neuromas. Vertigo may be associated with anything that compresses the vestibulocochlear nerve including vascular abnormalities, inflammation, or neoplasm.

[0535] Operation **1706** depicts accepting at least one voice test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/of user-health testing output/brain activity measurement data association module **1270** may accept at least one voice test function output at least partly based on an interaction between at least one user and at least one device-operable application. Voice test module **1238** may produce output at least partly based on user data **116** from data capture module **112** and/or data detection module **114**.

[0536] An example of a voice test function may be a measure of symmetrical elevation of the palate when the user says "aah," or a test of the gag reflex. In an ipsilateral lesion of the vagus nerve, the uvula deviates towards the affected side. As a result of its innervation (through the recurrent laryngeal nerve) to the vocal cords, hoarseness may develop as a symptom of vagus nerve injury. A voice test module **1238** and/or user-health test unit **1204** may monitor user voice frequency or volume data during, for example, gaming, videoconferencing, speech recognition software use, or mobile phone use. Injury to the recurrent laryngeal nerve can occur with lesions in the neck or apical chest. The most common lesions are tumors in the neck or apical chest. Cancers may include lung cancer, esophageal cancer, or squamous cell cancer.

[0537] Other voice test functions may involve first observing the tongue (while in floor of mouth) for fasciculations. If present, fasciculations may indicate peripheral hypoglossal nerve dysfunction. Next, the user may be prompted to protrude the tongue and move it in all directions. When protruded, the tongue will deviate toward the side of a lesion (as the unaffected muscles push the tongue more than the weaker side). Gross symptoms of pathology may result in garbled sound in speech (as if there were marbles in the user's mouth). Damage to the hypoglossal nerve affecting voice/speech may indicate neoplasm, aneurysm, or other external compression, and may result in protrusion of the tongue away from side of the lesion for an upper motor neuron process and toward the side of the lesion for a lower motor neuron process. Accordingly, a voice test module **138** and/or user-health test unit **104** may assess a user's ability to make simple sounds or to say words, for example, consistently with an established voice pattern for the user.

[0538] FIG. **18** illustrates alternative embodiments of the example operational flow **1410** of FIG. **14**. FIG. **18** illustrates example embodiments where the accepting operation **1410** may include at least one additional operation. Additional operations may include operation **1800**, **1802**, **1804**, and/or operation **1806**.

[0539] Operation **1800** depicts accepting at least one motor skill test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one motor skill test function output at least partly based on an interaction between at least one user and at least one device-operable application. Motor skill test module **1240** may produce output at least partly based on user data **116** from data capture module **112** and/or data detection module **114**.

[0540] An example of a motor skill test function may be a measure of a user's ability to perform a physical task, or a measure of tremor in a body part (i.e., a rhythmic, involuntary, or oscillating movement of a body part occurring in isolation or as part of a clinical syndrome). A motor skill test module **1240** and/or user-health test unit **1204** may measure, for example, a user's ability to traverse a path on a display in straight line with a pointing device, to type a certain sequence of characters without error, or to type a certain number of characters without repetition. For example, a wobbling cursor on a display may indicate ataxia in the user, or a wobbling cursor while the user is asked to maintain the cursor on a fixed point on a display may indicate early Parkinson's disease symptoms. Alternatively, a user may be prompted to switch tasks, for example, to alternately type some characters using a keyboard and click on some target with a mouse. If a user has a motor skill deficiency, she may have difficulty stopping one task and starting the other task.

[0541] In clinical practice, characterization of tremor is important for etiologic consideration and treatment. Common types of tremor include resting tremor, postural tremor, action or kinetic tremor, task-specific tremor, or intention or terminal tremor. Resting tremor occurs when a body part is at complete rest against gravity. Tremor amplitude tends to decrease with voluntary activity. Causes of resting tremor may include Parkinson's disease, Parkinson-plus syndromes (e.g., multiple system atrophy, progressive supranuclear palsy, or corticobasal degeneration), Wilson's disease, drug-induced Parkinsonism (e.g., neuroleptics, Reglan, or phenthiazines), or long-standing essential tremor.

[0542] Postural tremor occurs during maintenance of a position against gravity and increases with action. Action or kinetic tremor occurs during voluntary movement. Examples of postural and action tremors may include essential tremor (primarily postural), metabolic disorders (e.g., thyrotoxicosis, pheochromocytoma, or hypoglycemia), drug-induced parkinsonism (e.g., lithium, amiodarone, or beta-adrenergic agonists), toxins (e.g., alcohol withdrawal, heavy metals), neuropathic tremor (e.g., neuropathy).

[0543] Task-specific tremor emerges during specific activity. An example of this type is primary writing tremor. Intention or terminal tremor manifests as a marked increase in tremor amplitude during a terminal portion of targeted movement. Examples of intention tremor include cerebellar tremor and multiple sclerosis tremor.

[0544] Operation **1802** depicts accepting at least one body movement test function output at least partly based on an interaction between at least one user and at least one device-operable application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one body movement test function output at least partly based on an interaction between at least one user and at least one device-operable application. Body movement test module **1242** may produce output at least partly based on user data **1216** from data capture module **112** and/or data detection module **114**.

[0545] An example of a body movement test function may be first observing the user for atrophy or fasciculation in the trapezius muscles, shoulder drooping, or displacement of the scapula. A body movement test module **1242** and/or user-health test unit **1204** may then instruct the user to turn the head and shrug shoulders against resistance. Weakness in turning the head in one direction may indicate a problem in the contralateral spinal accessory nerve, while weakness in shoulder shrug may indicate an ipsilateral spinal accessory nerve lesion. Ipsilateral paralysis of the sternocleidomastoid and trapezius muscles due to neoplasm, aneurysm, or radical neck surgery also may indicate damage to the spinal accessory nerve. A body movement test module **1242** and/or user-health test unit **1204** may perform gait analysis, for example, in the context of a security system surveillance application involving video monitoring of the user.

[0546] Cerebellar disorders can disrupt body coordination or gait while leaving other motor functions relatively intact. The term ataxia is often used to describe the abnormal movements seen in coordination disorders. In ataxia, there are medium- to large-amplitude involuntary movements with an irregular oscillatory quality superimposed on and interfering with the normal smooth trajectory of movement. Overshoot is also commonly seen as part of ataxic movements and is sometimes referred to as "past pointing" when target-oriented movements are being discussed. Another feature of coordination disorders is dysdiadochokinesia (i.e., abnormal alternating movements). Cerebellar lesions can cause different kinds of coordination problems depending on their location. One important distinction is between truncal ataxia and appendicular ataxia. Appendicular ataxia affects movements of the extremities and is usually caused by lesions of the cerebellar hemispheres and associated pathways. Truncal ataxia affects the proximal musculature, especially that involved in gait stability, and is caused by midline damage to the cerebellar vermis and associated pathways.

[0547] Fine movements of the hands and feet also may be tested by a body movement test module **1242** and/or user-health test unit **1204**. Rapid alternating movements, such as wiping one palm alternately with the palm and dorsum of the other hand, may be tested as well. A common test of coordination is the finger-nose-finger test, in which the user is asked to alternately touch their nose and an examiner's finger as quickly as possible. Ataxia may be revealed if the examiner's finger is held at the extreme of the user's reach, and if the examiner's finger is occasionally moved suddenly to a different location. Overshoot may be measured by having the user raise both arms suddenly from their lap to a specified level in the air. In addition, pressure can be applied to the user's outstretched arms and then suddenly released. To test the accuracy of movements in a way that requires very little strength, a user can be prompted to repeatedly touch a line drawn on the crease of the user's thumb with the tip of their forefinger; alternatively, a body movement test module **1242** and/or user-health test unit **1204** may prompt a user to repeatedly touch an object on a touchscreen display.

[0548] Normal performance of motor tasks depends on the integrated functioning of multiple sensory and motor subsystems. These include position sense pathways, lower motor neurons, upper motor neurons, the basal ganglia, and the cerebellum. Thus, in order to convincingly demonstrate that abnormalities are due to a cerebellar lesion, one should first test for normal joint position sense, strength, and reflexes and confirm the absence of involuntary movements caused by basal ganglia lesions. As discussed above, appendicular ataxia is usually caused by lesions of the cerebellar hemispheres and associated pathways, while truncal ataxia is often caused by damage to the midline cerebellar vermis and associated pathways.

[0549] Another body movement test is the Romberg test, which may indicate a problem in the vestibular or proprioception system. A user is asked to stand with feet together (touching each other). Then the user is prompted to close their eyes. If a problem is present, the user may begin to sway or fall. With the eyes open, three sensory systems provide input to the cerebellum to maintain truncal stability. These are vision, proprioception, and vestibular sense. If there is a mild lesion in the vestibular or proprioception systems, the user is usually able to compensate with the eyes open. When the user closes their eyes, however, visual input is removed and instability can be brought out. If there is a more severe proprioceptive or vestibular lesion, or if there is a midline cerebellar lesion causing truncal instability, the user will be unable to maintain this position even with their eyes open.

[0550] Operation **1804** depicts accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable game. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable game **1244**. User-health test unit **1204** can produce output at least partly based on user data **1216** from an interaction between user **1210** and game **1244**, the game **1244** being operable on the at least one device **1202**. Such a game **1244** may generate user data **1216** via user input device **1246** and/or user monitoring device **1248**. Examples of a user input device **1246** may include a text entry device such as a keyboard, a pointing device such as a mouse, a touchscreen, or the like. Examples of a user monitoring device **1248** may include a microphone, a photography device, a video device, or the like.

[0551] Examples of a game **1244** may include a computer game such as, for example, solitaire, puzzle games, role-playing games, first-person shooting games, strategy games, sports games, racing games, adventure games, or the like. Such games may be played offline or through a network (e.g., online games).

[0552] Operation **1806** depicts accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable communication application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable communication application **1250**. The user-health test unit **1204** can produce output at least partly based on user data **1216** from an interaction between user **1210** and communication application **1250**. Such a communication application **1250** may generate user data **1216** via user input device **1246** and/or user monitoring device **1248**.

[0553] Examples of a communication application **1250** may include various forms of one-way or two-way information transfer, typically to, from, between, or among devices. Some examples of communications applications include: an email program, a telephony application, a videocommunications function, an internet or other network messaging program, a cell phone communication application, or the like. Such a communication application may operate via text, voice, video, or other means of communication, combinations of these, and/or other means of communication.

[0554] FIG. **19** illustrates alternative embodiments of the example operational flow **1410** of FIG. **14**. FIG. **19** illustrates example embodiments where the accepting operation **1410** may include at least one additional operation. Additional operations may include operation **1900** and/or operation **1902**.

[0555] Operation **1900** depicts accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable security application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable security application. User-health test unit **1204** can produce output at least partly based on user data **1216** from an interaction between user **1210** and security application **1252**. Such a security application **1252** may generate user data **1216** via user input device **1246** and/or user monitoring device **1248**.

[0556] Examples of a security application **1252** may include a password entry program, a code entry system, a biometric identification application, a video monitoring system, or the like.

[0557] Operation **1902** depicts accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable productivity application. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable productivity application **1254** operable on the at least one device **1202**. User-health test unit **1204** can produce output at least partly based on user data **1216** from an interaction between user **1210** and the productivity application **1254**. Such a productivity application **1254** may generate user data **1216** via user input device **1246** and/or user monitoring device **1248**.

[0558] Examples of a productivity application **1254** may include a word processing program, a spreadsheet program, business software, or the like.

[0559] FIG. **20** illustrates alternative embodiments of the example operational flow **1400** of FIG. **14**. FIG. **20** illustrates example embodiments where the accepting operation **1420** may include at least one additional operation. Additional operations may include operation **2000**, **2002**, **2004**, and/or operation **2006**.

[0560] Operation **2000** depicts accepting electrical brain activity measurement data proximate to the interaction. For example, device **1202** and/or user-health testing output/brain activity measurement data association module, **1270** may accept electrical brain activity measurement data proximate to the interaction from brain activity measurement device **1208**. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may accept electrical signals representing brain activity from a non-invasive electroencephalography headset such as that sold by Emotiv Systems, Inc. In another example, magnetoencephalography may be used to generate brain activity measurement data based on electrical activity in the brain.

[0561] Such electrical brain activity measurement data may be collected at a time proximate to analysis of a user-health attribute or to collection of user-health data, for example, reaction time data such as, for example, the speed of a user **1210**'s response to a prompting icon on a display, for example by clicking with a mouse or other pointing device or by some other response mode. For example, within a game situation a user may be prompted to click on a target as a test of alertness or awareness. Data may be collected once or many times for this task. A multiplicity of data points indicating a change in reaction time may be indicative of a change in alertness, awareness, neglect, construction, memory, hearing, or other user-health attribute as discussed above.

[0562] Operation **2002** depicts accepting brain blood oxygen level data proximate to the interaction. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept brain blood oxygen level data proximate to the interaction from brain activity measurement device **1208**. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may accept brain blood oxygen level data from a functional near infra-red headset. In another example, functional magnetic resonance imaging may be used to generate brain blood oxygen level data.

[0563] Such brain blood oxygen level data may be collected at a time proximate to generation of user-health test function output and/or collection of user-health data, for example, user movement data, which may include data from a pointing device when a user is prompted to activate or click a specific area on a display to test, for example, visual field range or motor skill function. Another example is brain blood oxygen level data collection at a time proximate to collection of visual data of a user's body, for example during a videoconference, wherein changes in facial movement, limb movement, or other body movements are detectable, as discussed above.

[0564] Operation **2004** depicts accepting brain glucose metabolism or brain blood flow data proximate to the interaction. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept brain glucose metabolism or brain blood flow data proximate to the interaction. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may accept brain blood glucose metabolism data in the form of positron emission tomography output data. In another example, functional magnetic resonance imaging may be used to generate brain blood flow data.

[0565] Such brain glucose metabolism or brain blood flow data may be collected at a time proximate to generation of user-health test function output and/or collection of user-health data, for example, user cognitive function data such as data from a text or number input device and/or user monitoring device when a user is prompted to, for example, spell, write, speak, or calculate in order to test, for example, alertness, ability to calculate, speech, motor skill function, or the like, as discussed above.

[0566] Operation **2006** depicts accepting ventromedial prefrontal cortex data proximate to the interaction. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept ventromedial prefrontal cortex data proximate to the interaction. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may accept ventromedial prefrontal cortex data from a brain activity measurement made at a time proximate to an interaction of the user with a brand-name consumer product. In this example, measured activation of the ventromedial prefrontal cortex may indicate a brand preference. The ventromedial prefrontal cortex activation may be measured at or near a time when the user is interacting with various brands of consumer goods, for example. User-health data from the interaction may be at least partly based on, for example, user memory function data, which may include data from a text or number input device or user monitoring device when a user is prompted to, for example, spell, write, speak, or calculate in order to test, for example, short-term memory, long-term memory, or the like, as discussed above.

[0567] FIG. **21** illustrates alternative embodiments of the example operational flow **1400** of FIG. **14**. FIG. **21** illustrates example embodiments where the accepting operation **1420** may include at least one additional operation. Additional operations may include operation **2100**, **2102**, **2104**, and/or operation **2106**.

[0568] Operation **2100** depicts accepting at least one of frontopolar cortex data, prefrontal cortex data, ventral striatum data, orbitofrontal prefrontal cortex data, amygdala data, or nucleus accumbens data proximate to the interaction. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one of frontopolar cortex data, prefrontal cortex data, ventral striatum data, orbitofrontal prefrontal cortex data, amygdala data, or nucleus accumbens data proximate to the interaction. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may accept nucleus accumbens activation data proximate to, for example, a voice or speech interaction of a user with a web page, object in a virtual world, object in an email, or the like. Nucleus accumbens activation, as discussed above, may signify object preference. An example of user voice or speech data may include data from a speech or voice input device or user monitoring device, such as a telephonic device or a video communication device with sound receiving/transmission capability, for example when a user task requires, for example, speaking, singing, or other vocalization, as discussed above.

[0569] Operation **2102** depicts accepting at least one of dorsolateral prefrontal cortex data, posterior parietal cortex data, occipital cortex data, or left premotor area data proximate to the interaction. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one of dorsolateral prefrontal cortex data, posterior parietal cortex data, occipital cortex data, or left premotor area data proximate to the interaction. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may accept posterior parietal cortex activation data proximate to, for example, an eye movement interaction of a user with a web page, object in a game, virtual world object, object in an email, or the like. Posterior parietal cortex activation, as discussed above, may signify visuospatial attention. An example of user eye movement data may include data from a user monitoring device, such as a video communication device, for example, when a user task requires tracking objects on a display, reading, or during resting states between activities in an application, as discussed above. A further example includes pupillary reflex data from the user at rest or during an activity required by an application or user-health test function.

[0570] Operation **2104** depicts accepting at least one of inferior precuneus data, posterior cingulate data, right parietal cortex data, right superior frontal gyrus data, or right supramarginal gyrus data proximate to the interaction. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one of inferior precuneus data, posterior cingulate data, right parietal cortex data, right superior frontal gyrus data, or right supramarginal gyrus data proximate to the interaction. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may accept inferior precuneus activation data proximate to, for example, an interaction of a user with a virtual shopping experience. Inferior precuneus activation, as discussed above, may signify preference for a visual image. A virtual shopping interaction may provide user data relevant to cognitive, memory, or motor skill function impairment, or the like, as discussed above. Other examples of an interaction may include internet usage data including, for example, data from a user's offline interaction with internet content obtained while online.

[0571] Operation **2106** depicts accepting at least one of insula data, lateral orbital frontal cortex data, or amygdala data proximate to the interaction. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may accept at least one of insula data, lateral orbital frontal cortex data, or amygdala data proximate to the interaction. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may accept amygdala activation data proximate to, for example, an interaction of a user with a video communications device. Amygdala activation, as discussed above, may signify emotion, fear, and/or reward. Conversely, inhibition of the amygdala may correlate with increased risk-taking behavior. In one example, user image data proximate to amygdala activity measurement may include data from a user's video capture device, monitoring device, such as a video communication device, for example, when a user inputs a photograph or video when using an application, or when a user's image is captured when communicating via a photography or video-based application. Other examples of user image data may include biometric data such as facial pattern data, eye scanning data, or the like. Such user image data may indicate, for example, alertness, attention, motor skill function impairment, or the like, as discussed above. In one embodiment, a face expression indicating fear may be proximate to an amygdala activation measurement.

[0572] FIG. **22** illustrates alternative embodiments of the example operational flow **1400** of FIG. **14**. FIG. **22** illustrates example embodiments where the associating operation **1430** may include at least one additional operation. Additional operations may include operation **2200**, **2202**, and/or operation **2204**.

[0573] Operation **2200** depicts associating at least one attention test function output and at least one of prefrontal activity measurement data or parietal activity measurement data. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may associate at least one attention test function output and at least one of prefrontal activity measurement data or parietal activity measurement data. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may associate prefrontal activity measurement data with attention test function output such as, for example, a fast reaction time in responding to an image appearing on a display. In this example, prefrontal activation indicating sustained attention may reinforce the output of the user-health test function indicating attention with respect to, for example, an image on a website. In another embodiment, a lack of prefrontal activity may be associated with a user-health test function output indicating an attention deficit, and may reinforce such a conclusion. In another embodiment, attention test function output indicating attention to, for example, a particular object in a virtual world, for example, an automobile design may be associated with a proximate brain activity measurement indicating activation of brain areas involved in attention and/or preference.

[0574] Operation **2202** depicts associating at least one face pattern test function output and nucleus accumbens activation data. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may associate at least one face pattern test function output and nucleus accumbens activation data. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may associate nucleus accumbens activation with output of a face pattern test function indicating positive emotions proximate to an interaction of the user with a particular attribute of a device-operable application, e.g., an avatar, a product, a message, a sound, or the like.

[0575] Operation **2204** depicts associating at least one body movement test function output and motor cortex data. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may associate at least one body movement test function output and motor cortex data. In one embodiment, user-health testing output/brain activity measurement data association module **1270** may associate motor cortex activity measurement data with body movement test function output such as, for example, an image of a user moving one or more body parts when prompted. In this example, a comparison of motor cortex activation with, for example, output of the user-health test function indicating a body movement impairment may be useful in diagnosing a neurological basis or other basis for a disorder (e.g., a non-neurological basis). Accordingly, in another embodiment, body movement test function output indicating a body movement problem may be associated with ostensibly normal motor cortex readings, indicating that the impairment may be local, perhaps a local neuromuscular defect.

[0576] FIG. **23** illustrates alternative embodiments of the example operational flow **1400** of FIG. **14**. FIG. **23** illustrates example embodiments where the presenting operation **1440** may include at least one additional operation. Additional operations may include operation **2300**, **2302**, and/or operation **2304**.

[0577] Operation **2300** depicts presenting at least one attention test function output and at least one of prefrontal activity measurement data or parietal activity measurement data at least partly based on associating the at least one attention test function output with the at least one of prefrontal activity measurement data or parietal activity measurement data. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may present at least one attention test function output and at least one of prefrontal activity measurement data or parietal activity measurement data at least partly based on associating the at least one attention test function output with the at least one of prefrontal activity measurement data or parietal activity measurement data. In some circumstances, user-health test function output may be susceptible to multiple interpretations. For example, a user's inability to move a cursor on a display to click on a target may implicate one or more of motor skill impairment, attention deficit, memory impairment, cognitive impairment, and/or visual impairment, to name a few. By presenting brain activity measurement data with the user-health test function output, an identification of a specific problem may be facilitated. In this example, brain activity measurement data indicating an unexpected lack of activation in the attention areas of the brain such as the prefrontal cortex and/or parietal areas may signify an attention deficit to the exclusion of other explanations. This may be particularly true where brain activity measurement data for other areas of the brain, such as motor areas, memory areas, cognitive areas, and/or vision areas, show expected or normal activity.

[0578] Operation **2302** depicts presenting at least one face pattern test function output and fusiform face area data at least partly based on associating the at least one face pattern test function output with the fusiform face area data. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may present at least one face pattern test function output and fusiform face area data at least partly based on associating the at least one face pattern test function output with the fusiform face area data. As discussed above, user-health test function output may be susceptible to multiple interpretations. For example, a change in a user's facial expression may implicate one or more of attentional stimulation, memory stimulation, cognitive stimulation, and/or visual stimulation, to name a few. By presenting brain activity measurement data with the user-health test function output, an identification of a specific source or cause of the output may be identified. In this example, brain activity measurement data indicating activation in the face recognition areas of the brain such as the fusiform face area may signify that a change in the face pattern of the user may be due to recognition of a face on a display, for example, perhaps to the exclusion of other explanations. This may be particularly true where brain activity measurement data for other areas of the brain show expected or normal activity.

[0579] Operation **2304** depicts presenting at least one body movement test function output and motor cortex data at least partly based on associating the at least one body movement test function output with the motor cortex data. For example, device **1202** and/or user-health testing output/brain activity measurement data association module **1270** may present at least one body movement test function output and motor cortex data at least partly based on associating the at least one body movement test function output with the motor cortex data. As discussed above, user-health test function output may be susceptible to multiple interpretations. For example, a change in a user's body movement may implicate one or more of attentional stimulation, cognitive stimulation, motor skill impairment, and/or a change in brain chemistry, to name a few. By presenting brain activity measurement data with the user-health test function output, an identification of a specific source or cause of the output may be identified. In this example, brain activity measurement data indicating anomalous activation in the areas of the brain controlling motor function, such as the motor cortex, may signify that a change in the body movement of the user may be due to, for example, stroke-induced damage to the motor cortex, perhaps to the exclusion of other explanations. This may be particularly true where brain activity measurement data for other areas of the brain show expected or normal activity. In another example, user-health test function output indicating a changed pattern of body movement may be presented with a brain activity measurement data signature that indicates a mood disorder, such as depression. Such psychiatric disorders may be detected based on brain activity measurement data. For example, depression has been linked to increased brain activity in the circuit consisting of the orbitofrontal cortex, thalamus, anterior cingulate, and ventral striatum.

[0580] Also, user-health test output may suggest the incidence of a psychiatric disorder in a user. For example, it has been shown that depressed people move in a mathematically different way from other people. See "Something in the way he moves," Economist, 27 Sep. 2007. Accordingly, a user-health test unit **1204** may mathematically analyze the body movement of a user in order to identify depression or other mood disorders, for example. Coupled with brain activity measurement data indicative of depression, such data may be particularly informative to a health care provider or parent, for example.

[0581] As a further example, a task within a video game may be employed as as user-health test function. For example, navigating a virtual town in the game Duke Nukem has been used as a test for depression. Depressed people found significantly fewer locations than did health control participants, and the more depressed the person, the worse they did. See "Video game may help detect depression," New Scientist, p. 18, 10 Mar. 2007.

[0582] FIG. **24** illustrates a partial view of an example computer program product **2400** that includes a computer program **2404** for executing a computer process on a computing device. An embodiment of the example computer program product **2400** is provided using a signal bearing medium **2402**, and may include one or more instructions for accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application; one or more instructions for accepting brain activity measurement data proximate to the interaction; one or more instructions for associating the at least one user-health test function output with the brain activity measurement data; and one or more instructions for presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data. The one or more instructions may be, for example, computer executable and/or logic-implemented instructions. In one implementation, the signal-bearing medium **2402** may include a computer-readable medium **2406**. In one implementation, the signal bearing medium **2402** may include a recordable medium **2408**. In one implementation, the signal bearing medium **2402** may include a communications medium **2410**.

[0583] FIG. **25** illustrates an example system **2500** in which embodiments may be implemented. The system **2500** includes a computing system environment. The system **2500** also illustrates the user **110** using a device **2504**, which is optionally shown as being in communication with a computing device **2502** by way of an optional coupling **2506**. The optional coupling **2506** may represent a local, wide-area, or peer-to-peer network, or may represent a bus that is internal to a computing device (e.g., in example embodiments in which the computing device **2502** is contained in whole or in part within the device **2504**). A storage medium **2508** may be any computer storage media.

[0584] The computing device **2502** includes computer-executable instructions **2510** that when executed on the computing device **2502** cause the computing device **2502** to (a) accept at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application; (b) accept brain activity measurement data proximate to the interaction; (c) associate the at least one user-health test function output with the brain activity measurement data; and (d) present the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data. As referenced above and as shown in FIG. **25**, in some examples, the computing device **2502** may optionally be contained in whole or in part within the device **2504**.

[0585] In FIG. **25**, then, the system **2500** includes at least one computing device (e.g., **2502** and/or **2504**). The computer-executable instructions **2510** may be executed on one or more of the at least one computing device. For example, the computing device **2502** may implement the computer-executable instructions **2510** and output a result to (and/or receive data from) the computing device **2504**. Since the computing device **2502** may be wholly or partially contained within the computing device **2504**, the device **2504** also may be said to execute some or all of the computer-executable instructions **2510**, in order to be caused to perform or implement, for example, various ones of the techniques described herein, or other techniques.

[0586] The device **2504** may include, for example, a portable computing device, workstation, or desktop computing device. In another example, the computing device **2502** is operable to communicate with the device **2504** associated with the user **110** to receive information about the input from the user **110** for performing data access and data processing and presenting an output of a user-health test function and brain activity measurement data.

[0587] Although a user **110** is shown/described herein as a single illustrated figure, those skilled in the art will appreciate that a user **110** may be representative of a human user, a robotic user (e.g., computational entity), and/or substantially any combination thereof (e.g., a user may be assisted by one or more robotic agents). In addition, a user **110**, as set forth herein, although shown as a single entity may in fact be composed of two or more entities. Those skilled in the art will appreciate that, in general, the same may be said of "sender" and/or other entity-oriented terms as such terms are used herein.

[0588] One skilled in the art will recognize that the herein described components (e.g., steps), devices, and objects and the discussion accompanying them are used as examples for the sake of conceptual clarity and that various configuration modifications are within the skill of those in the art. Consequently, as used herein, the specific exemplars set forth and the accompanying discussion are intended to be representative of their more general classes. In general, use of any specific exemplar herein is also intended to be representative of its class, and the non-inclusion of such specific components (e.g., steps), devices, and objects herein should not be taken as indicating that limitation is desired.

[0589] Those skilled in the art will appreciate that the foregoing specific exemplary processes and/or devices and/or technologies are representative of more general processes and/or devices and/or technologies taught elsewhere herein, such as in the claims filed herewith and/or elsewhere in the present application.

[0590] Those having skill in the art will recognize that the state of the art has progressed to the point where there is little distinction left between hardware, software, and/or firmware implementations of aspects of systems; the use of hardware, software, and/or firmware is generally (but not always, in that in certain contexts the choice between hardware and software can become significant) a design choice representing cost vs. efficiency tradeoffs. Those having skill in the art will appreciate that there are various vehicles by which processes and/or systems and/or other technologies described herein can be effected (e.g., hardware, software, and/or firmware), and that the preferred vehicle will vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle; alternatively, if flexibility is paramount, the implementer may opt for a mainly software implementation; or, yet again alternatively, the implementer may opt for some combination of hardware, software, and/or firmware. Hence, there are several possible vehicles by which the processes and/or devices and/or other technologies described herein may be effected, none of which is inherently superior to the other in that any vehicle to be utilized is a choice dependent upon the context in which the vehicle will be deployed and the specific concerns (e.g., speed, flexibility, or predictability) of the implementer, any of which may vary. Those skilled in the art will recognize that optical aspects of implementations will typically employ optically-oriented hardware, software, and or firmware.

[0591] In some implementations described herein, logic and similar implementations may include software or other control structures suitable to operation. Electronic circuitry, for example, may manifest one or more paths of electrical current constructed and arranged to implement various logic functions as described herein. In some implementations, one or more media are configured to bear a device-detectable implementation if such media hold or transmit a special-purpose device instruction set operable to perform as described herein. In some variants, for example, this may manifest as an update or other modification of existing software or firmware, or of gate arrays or other programmable hardware, such as by performing a reception of or a transmission of one or more instructions in relation to one or more operations described herein. Alternatively or additionally, in some variants, an implementation may include special-purpose hardware, software, firmware components, and/or general-purpose components executing or otherwise invoking special-purpose components. Specifications or other implementations may be transmitted by one or more instances of tangible transmission media as described herein, optionally by packet transmission or otherwise by passing through distributed media at various times.

[0592] Alternatively or additionally, implementations may include executing a special-purpose instruction sequence or otherwise invoking circuitry for enabling, triggering, coordinating, requesting, or otherwise causing one or more occurrences of any functional operations described above. In some variants, operational or other logical descriptions herein may be expressed directly as source code and compiled or otherwise invoked as an executable instruction sequence. In some contexts, for example, C++ or other code sequences can be compiled directly or otherwise implemented in high-level descriptor languages (e.g., a logic-synthesizable language, a hardware description language, a hardware design simulation, and/or other such similar mode(s) of expression). Alternatively or additionally, some or all of the logical expression may be manifested as a Verilog-type hardware description or other circuitry model before physical implementation in hardware, especially for basic operations or timing-critical applications. Those skilled in the art will recognize how to obtain, configure, and optimize suitable transmission or computational elements, material supplies, actuators, or other common structures in light of these teachings.

[0593] The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In one embodiment, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), or other integrated formats. However, those skilled in the art will recognize that some aspects of the embodiments disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein are capable of being distributed as a program product in a variety of forms, and that an illustrative embodiment of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a floppy disk, a hard disk drive, a Compact Disc (CD), a Digital Video Disk (DVD), a digital tape, a computer memory, etc.; and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link (e.g., transmitter, receiver, transmission logic, reception logic, etc.), etc.).

[0594] In a general sense, those skilled in the art will recognize that the various aspects described herein which can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, and/or any combination thereof can be viewed as being composed of various types of "electrical circuitry." Consequently, as used herein "electrical circuitry" includes, but is not limited to, electrical circuitry having at least one discrete electrical circuit, electrical circuitry having at least one integrated circuit, electrical circuitry having at least one application specific integrated circuit, electrical circuitry forming a general purpose computing device configured by a computer program (e.g., a general purpose computer configured by a computer program which at least partially carries out processes and/or devices described herein, or a microprocessor configured by a computer program which at least partially carries out processes and/or devices described herein), electrical circuitry forming a memory device (e.g., forms of memory (e.g., random access, flash, read only, etc.)), and/or electrical circuitry forming a communications device (e.g., a modem, communications switch, optical-electrical equipment, etc.). Those having skill in the art will recognize that the subject matter described herein may be implemented in an analog or digital fashion or some combination thereof.

[0595] Those skilled in the art will recognize that at least a portion of the devices and/or processes described herein can be integrated into an image processing system. Those having skill in the art will recognize that a typical image processing system generally includes one or more of a system unit housing, a video display device, memory such as volatile or non-volatile memory, processors such as microprocessors or digital signal processors, computational entities such as operating systems, drivers, applications programs, one or more interaction devices (e.g., a touch pad, a touch screen, an antenna, etc.), control systems including feedback loops and control motors (e.g., feedback for sensing lens position and/or velocity; control motors for moving/distorting lenses to give desired focuses). An image processing system may be implemented utilizing suitable commercially available components, such as those typically found in digital still systems and/or digital motion systems.

[0596] Those skilled in the art will recognize that at least a portion of the devices and/or processes described herein can be integrated into a data processing system. Those having skill in the art will recognize that a data processing system generally includes one or more of a system unit housing, a video display device, memory such as volatile or non-volatile memory, processors such as microprocessors or digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices (e.g., a touch pad, a touch screen, an antenna, etc.), and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity; control motors for moving and/or adjusting components and/or quantities). A data processing system may be implemented utilizing suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

[0597] Those skilled in the art will recognize that at least a portion of the devices and/or processes described herein can be integrated into a mote system. Those having skill in the art will recognize that a typical mote system generally includes one or more memories such as volatile or non-volatile memories, processors such as microprocessors or digital signal processors, computational entities such as operating systems, user interfaces, drivers, sensors, actuators, applications programs, one or more interaction devices (e.g., an antenna USB ports, acoustic ports, etc.), control systems including feedback loops and control motors (e.g., feedback for sensing or estimating position and/or velocity; control motors for moving and/or adjusting components and/or quantities). A mote system may be implemented utilizing suitable components, such as those found in mote computing/communication systems. Specific examples of such components entail such as Intel Corporation's and/or Crossbow Corporation's mote components and supporting hardware, software, and/or firmware.

[0598] Those skilled in the art will recognize that it is common within the art to implement devices and/or processes and/or systems, and thereafter use engineering and/or other practices to integrate such implemented devices and/or processes and/or systems into more comprehensive devices and/or processes and/or systems. That is, at least a portion of the devices and/or processes and/or systems described herein can be integrated into other devices and/or processes and/or systems via a reasonable amount of experimentation. Those having skill in the art will recognize that examples of such other devices and/or processes and/or systems might include—as appropriate to context and application—all or part of devices and/or processes and/or systems of (a) an air conveyance (e.g., an airplane, rocket, helicopter, etc.), (b) a ground conveyance (e.g., a car, truck, locomotive, tank, armored personnel carrier, etc.), (c) a building (e.g., a home, warehouse, office, etc.), (d) an appliance (e.g., a refrigerator, a washing machine, a dryer, etc.), (e) a communications system (e.g., a networked system, a telephone system, a Voice over IP system, etc.), (f) a business entity (e.g., an Internet Service Provider (ISP) entity such as Comcast Cable, Qwest, Southwestern Bell, etc.), or (g) a wired/wireless services entity (e.g., Sprint, Cingular, Nextel, etc.), etc.

[0599] In certain cases, use of a system or method may occur in a territory even if components are located outside the territory. For example, in a distributed computing context, use of a distributed computing system may occur in a territory even though parts of the system may be located outside of the territory (e.g., relay, server, processor, signal-bearing medium, transmitting computer, receiving computer, etc. located outside the territory).

[0600] A sale of a system or method may likewise occur in a territory even if components of the system or method are located and/or used outside the territory.

[0601] Further, implementation of at least part of a system for performing a method in one territory does not preclude use of the system in another territory.

[0602] All of the above U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications and non-patent publications referred to in this specification and/or listed in any Application Data Sheet are incorporated herein by reference, to the extent not inconsistent herewith.

[0603] One skilled in the art will recognize that the herein described components (e.g., operations), devices, objects, and the discussion accompanying them are used as examples for the sake of conceptual clarity and that various configuration modifications are contemplated. Consequently, as used herein, the specific exemplars set forth and the accompanying discussion are intended to be representative of their more general classes. In general, use of any specific exemplar is intended to be representative of its class, and the non-inclusion of specific components (e.g., operations), devices, and objects should not be taken limiting.

[0604] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations are not expressly set forth herein for sake of clarity.

[0605] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely exemplary, and that in fact many other architectures may be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected", or "operably coupled," to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably couplable," to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components, and/or wirelessly interactable, and/or wirelessly interacting components, and/or logically interacting, and/or logically interactable components.

[0606] In some instances, one or more components may be referred to herein as "configured to," "configurable to," "operable/operative to," "adapted/adaptable," "able to," "conformable/conformed to," etc. Those skilled in the art will recognize that "configured to" can generally encompass active-state components and/or inactive-state components and/or standby-state components, unless context requires otherwise.

[0607] While particular aspects of the present subject matter described herein have been shown and described, it will be apparent to those skilled in the art that, based upon the teachings herein, changes and modifications may be made without departing from the subject matter described herein and its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as are within the true spirit and scope of the subject matter described herein. It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to claims containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that typically a disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms unless context dictates otherwise. For example, the phrase "A or B" will be typically understood to include the possibilities of "A" or "B" or "A and B."

[0608] With respect to the appended claims, those skilled in the art will appreciate that recited operations therein may generally be performed in any order. Also, although various operational flows are presented in a sequence(s), it should be understood that the various operations may be performed in other orders than those which are illustrated, or may be performed concurrently. Examples of such alternate orderings may include overlapping, interleaved, interrupted, reordered, incremental, preparatory, supplemental, simultaneous, reverse, or other variant orderings, unless context dictates otherwise. Furthermore, terms like "responsive to," "related to," or other past-tense adjectives are generally not intended to exclude such variants, unless context dictates otherwise.

What is claimed is:

1. A method comprising:

accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application;

accepting brain activity measurement data proximate to the interaction;

associating the at least one user-health test function output with the brain activity measurement data; and

presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data.

2. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one personal computing device output as the at least one user-health test function output.

3. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one alertness or attention test function output at least partly based on an interaction between at least one user and at least one device-operable application.

4. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one memory test function output at least partly based on an interaction between at least one user and at least one device-operable application.

5. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one speech test function output at least partly based on an interaction between at least one user and at least one device-operable application.

6. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one calculation test function output at least partly based on an interaction between at least one user and at least one device-operable application.

7. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one neglect or construction test function output at least partly based on an interaction between at least one user and at least one device-operable application.

8. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one task sequencing test function output at least partly based on an interaction between at least one user and at least one device-operable application.

9. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one visual field test function output at least partly based on an interaction between at least one user and at least one device-operable application.

10. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one pupillary reflex test function output at least partly based on an interaction between at least one user and at least one device-operable application.

11. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one face pattern test function output at least partly based on an interaction between at least one user and at least one device-operable application.

12. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one hearing test function output at least partly based on an interaction between at least one user and at least one device-operable application.

13. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one voice test function output at least partly based on an interaction between at least one user and at least one device-operable application.

14. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one motor skill test function output at least partly based on an interaction between at least one user and at least one device-operable application.

15. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one body movement test function output at least partly based on an interaction between at least one user and at least one device-operable application.

16. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable game.

17. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable communication application.

18. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable security application.

19. The method of claim **1** wherein the accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application comprises:

accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable productivity application.

20. The method of claim **1** wherein the accepting brain activity measurement data proximate to the interaction comprises:

accepting electrical brain activity measurement data proximate to the interaction.

21. The method of claim **1** wherein the accepting brain activity measurement data proximate to the interaction comprises:

accepting brain blood oxygen level data proximate to the interaction.

22. The method of claim **1** wherein the accepting brain activity measurement data proximate to the interaction comprises:

accepting brain glucose metabolism or brain blood flow data proximate to the interaction.

23. The method of claim **1** wherein the accepting brain activity measurement data proximate to the interaction comprises:

accepting ventromedial prefrontal cortex data proximate to the interaction.

24. The method of claim **1** wherein the accepting brain activity measurement data proximate to the interaction comprises:

accepting at least one of frontopolar cortex data, prefrontal cortex data, ventral striatum data, orbitofrontal prefrontal cortex data, amygdala data, or nucleus accumbens data proximate to the interaction.

25. The method of claim **1** wherein the accepting brain activity measurement data proximate to the interaction comprises:

accepting at least one of dorsolateral prefrontal cortex data, posterior parietal cortex data, occipital cortex data, or left premotor area data proximate to the interaction.

26. The method of claim **1** wherein the accepting brain activity measurement data proximate to the interaction comprises:

accepting at least one of inferior precuneus data, posterior cingulate data, right parietal cortex data, right superior frontal gyrus data, or right supramarginal gyrus data proximate to the interaction.

27. The method of claim **1** wherein the accepting brain activity measurement data proximate to the interaction comprises:

accepting at least one of insula data, lateral orbital frontal cortex data, or amygdala data proximate to the interaction.

28. The method of claim **1** wherein the associating the at least one user-health test function output with the brain activity measurement data comprises:

associating at least one attention test function output and at least one of prefrontal activity measurement data or parietal activity measurement data.

29. The method of claim **1** wherein the associating the at least one user-health test function output with the brain activity measurement data comprises:

associating at least one face pattern test function output and nucleus accumbens activation data.

30. The method of claim **1** wherein the associating the at least one user-health test function output with the brain activity measurement data comprises:

associating at least one body movement test function output and motor cortex data.

31. The method of claim **1** wherein the presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data comprises:

presenting at least one attention test function output and at least one of prefrontal activity measurement data or parietal activity measurement data at least partly based on associating the at least one attention test function output with the at least one of prefrontal activity measurement data or parietal activity measurement data.

32. The method of claim **1** wherein the presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data comprises:

presenting at least one face pattern test function output and fusiform face area data at least partly based on associating the at least one face pattern test function output with the fusiform face area data.

33. The method of claim **1** wherein the presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data comprises:

presenting at least one body movement test function output and motor cortex data at least partly based on associating the at least one body movement test function output with the motor cortex data.

34-66. (canceled)

67. A computer program product comprising:

a signal-bearing medium bearing

(a) one or more instructions for accepting at least one user-health test function output at least partly based on an interaction between at least one user and at least one device-operable application;

(b) one or more instructions for accepting brain activity measurement data proximate to the interaction;

(c) one or more instructions for associating the at least one user-health test function output with the brain activity measurement data; and

(d) one or more instructions for presenting the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data.

68. The computer program product of claim **67**, wherein the signal-bearing medium includes a computer-readable medium.

69. The computer program product of claim **67**, wherein the signal-bearing medium includes a recordable medium.

70. The computer program product of claim **67**, wherein the signal-bearing medium includes a communications medium.

71. A system comprising:

a computing device; and

instructions that when executed on the computing device cause the computing device to

(a) accept at least one user-health test function output at least one partly based on an interaction between at least one user and at least one device-operable application;

(b) accept brain activity measurement data proximate to the interaction;

(c) associate the at least one user-health test function output with the brain activity measurement data; and

(d) present the at least one user-health test function output and the brain activity measurement data at least partly based on the associating the at least one user-health test function output with the brain activity measurement data.

72. The system of claim **71** wherein the computing device comprises:

one or more of a personal digital assistant (PDA), a personal entertainment device, a mobile phone, a laptop computer, a tablet personal computer, a networked computer, a computing system comprised of a cluster of processors, a computing system comprised of a cluster of servers, a workstation computer, and/or a desktop computer.

73. The system of claim **71** wherein the computing device is operable to associate the at least one user-health test function output with the brain activity measurement data and present the user-health test function output and the brain activity measurement data at least partly based on data from at least one memory.

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专利名称(译)	计算用户健康测试		
公开(公告)号	US20080287821A1	公开(公告)日	2008-11-20
申请号	US12/151742	申请日	2008-05-07
[标]申请(专利权)人(译)	特拉华州的SEARETE负债CORP		
申请(专利权)人(译)	SEARETE有限责任公司，特拉华州的有限责任公司		
当前申请(专利权)人(译)	SEARETE有限责任公司，特拉华州的有限责任公司		
[标]发明人	JUNG EDWARD K Y LEUTHARDT ERIC C LEVIEN ROYCE A LORD ROBERT W MALAMUD MARK A		
发明人	JUNG, EDWARD K.Y. LEUTHARDT, ERIC C. LEVIEN, ROYCE A. LORD, ROBERT W. MALAMUD, MARK A.		
IPC分类号	A61B5/12 A61B5/00 A61B5/0476 A61B5/11		
CPC分类号	G06F19/3406 G06F19/3418 G06F19/363 G16H10/20 G16H40/63 G16H40/67		
外部链接	Espacenet USPTO		

摘要(译)

描述了至少部分地基于至少一个用户和至少一个设备可操作应用之间的交互来执行接受至少一个用户健康测试功能输出的方法，装置，计算机程序产品，设备和系统;接受接近交互的大脑活动测量数据;将至少一个用户健康测试功能输出与大脑活动测量数据相关联;并且至少部分地基于将所述至少一个用户健康测试功能输出与所述大脑活动测量数据相关联来呈现所述至少一个用户健康测试功能输出和所述大脑活动测量数据。