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Sahin

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(54) **SYSTEMS, ENVIRONMENT AND METHODS FOR EMOTIONAL RECOGNITION AND SOCIAL INTERACTION COACHING**

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A61B 5/11 (2006.01)
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CPC *A61B 5/165* (2013.01); *A61B 5/0004* (2013.01); *A61B 5/1123* (2013.01); *A61B 5/16* (2013.01); *A61B 5/6803* (2013.01); *A61B 7/04* (2013.01); *G06F 19/00* (2013.01); *G06F 19/3481* (2013.01); *G16H 10/65* (2018.01); *G16H 20/40* (2018.01); *G16H 50/20* (2018.01); *A61B 2560/0242* (2013.01)

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CPC *A61B 5/16*; *A61B 5/004*; *A61B 5/6803*; *A61B 5/1123*; *A61B 7/04*; *A61B 2560/0242*; *G16H 10/65*; *G16H 50/20*; *G06F 19/00*; *G06F 19/3481*
See application file for complete search history.

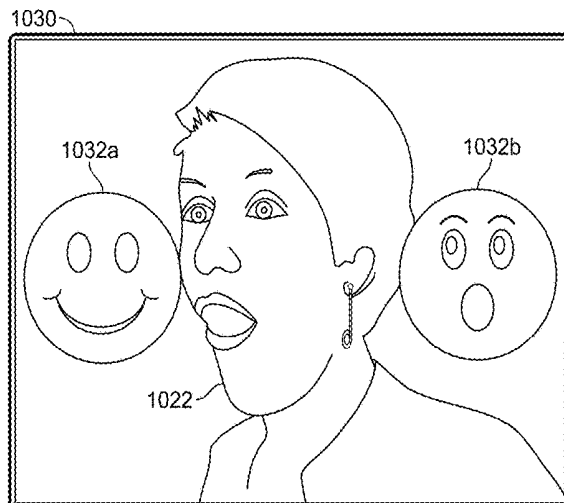
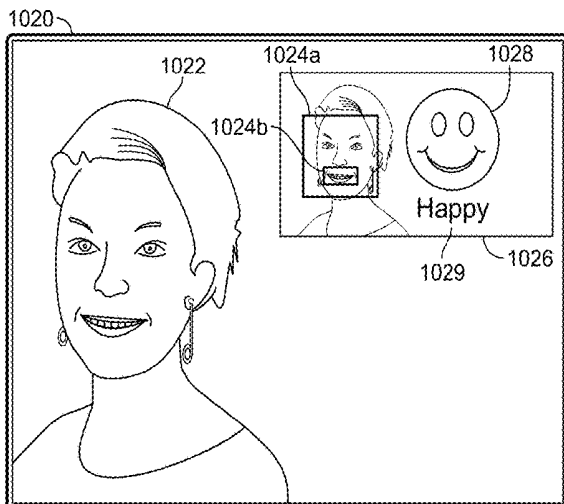
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(57) **ABSTRACT**
The systems, environment, and methods, described herein support evaluation of an individual for ASD while in the home environment. Through data collected by a wearable data collection device donned by the individual, eye contact with the caregiver, verbal interaction, and repetitive verbalizations and motions of the head and body may be tracked and objectively quantified during evaluation. Further, the wearable data collection device may support monitoring of brain activity and other physiology which, in turn, may be analyzed by the systems and environment described herein during evaluation to recognize patterns that predict evaluation outcome and other clinical features. Various software modules and tools supported by the wearable data collection device provide training, ongoing progress tracking, and management solutions for individuals living with ASD.

20 Claims, 23 Drawing Sheets



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G06F 19/00 (2018.01)
G16H 10/65 (2018.01)

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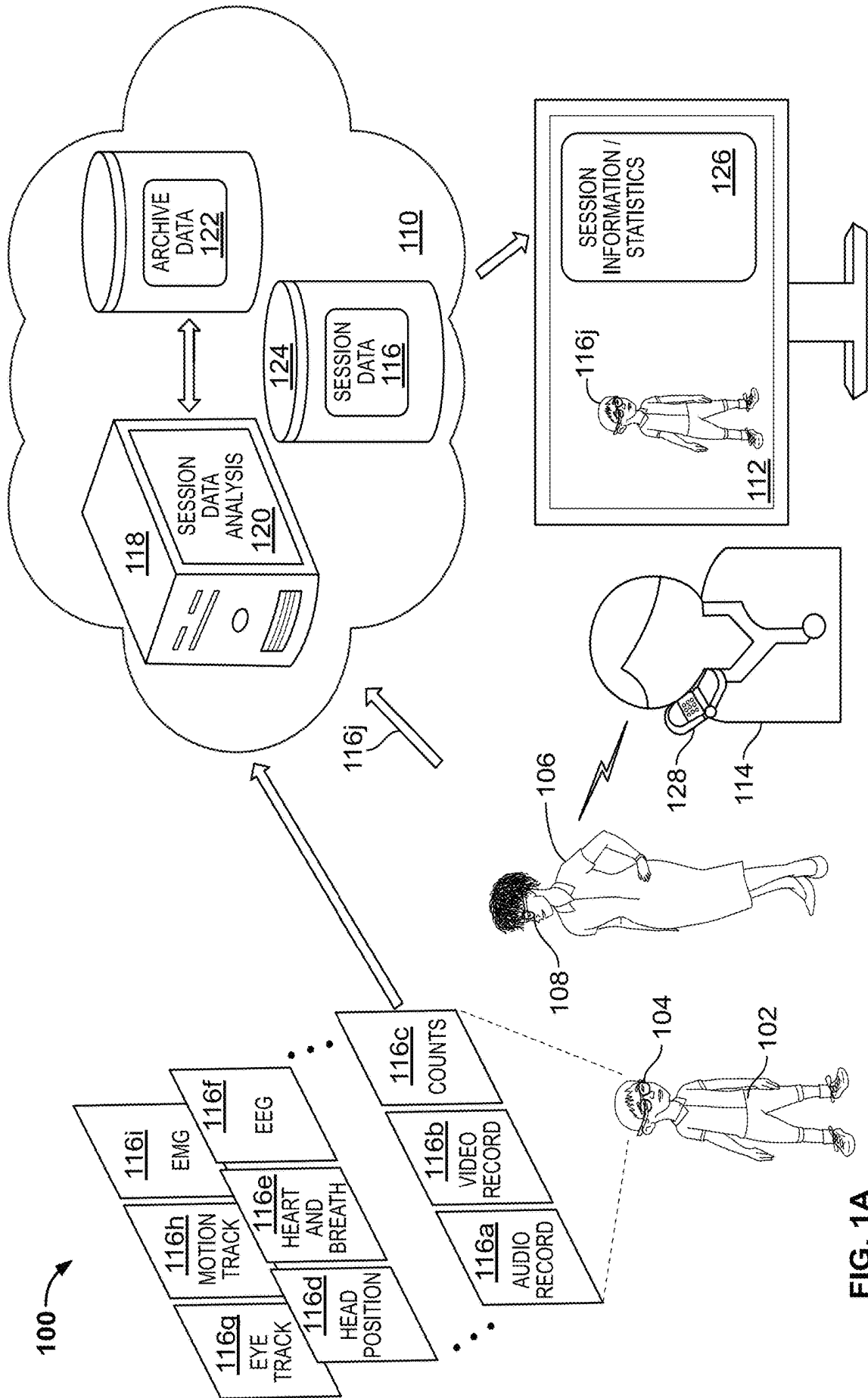


FIG. 1A

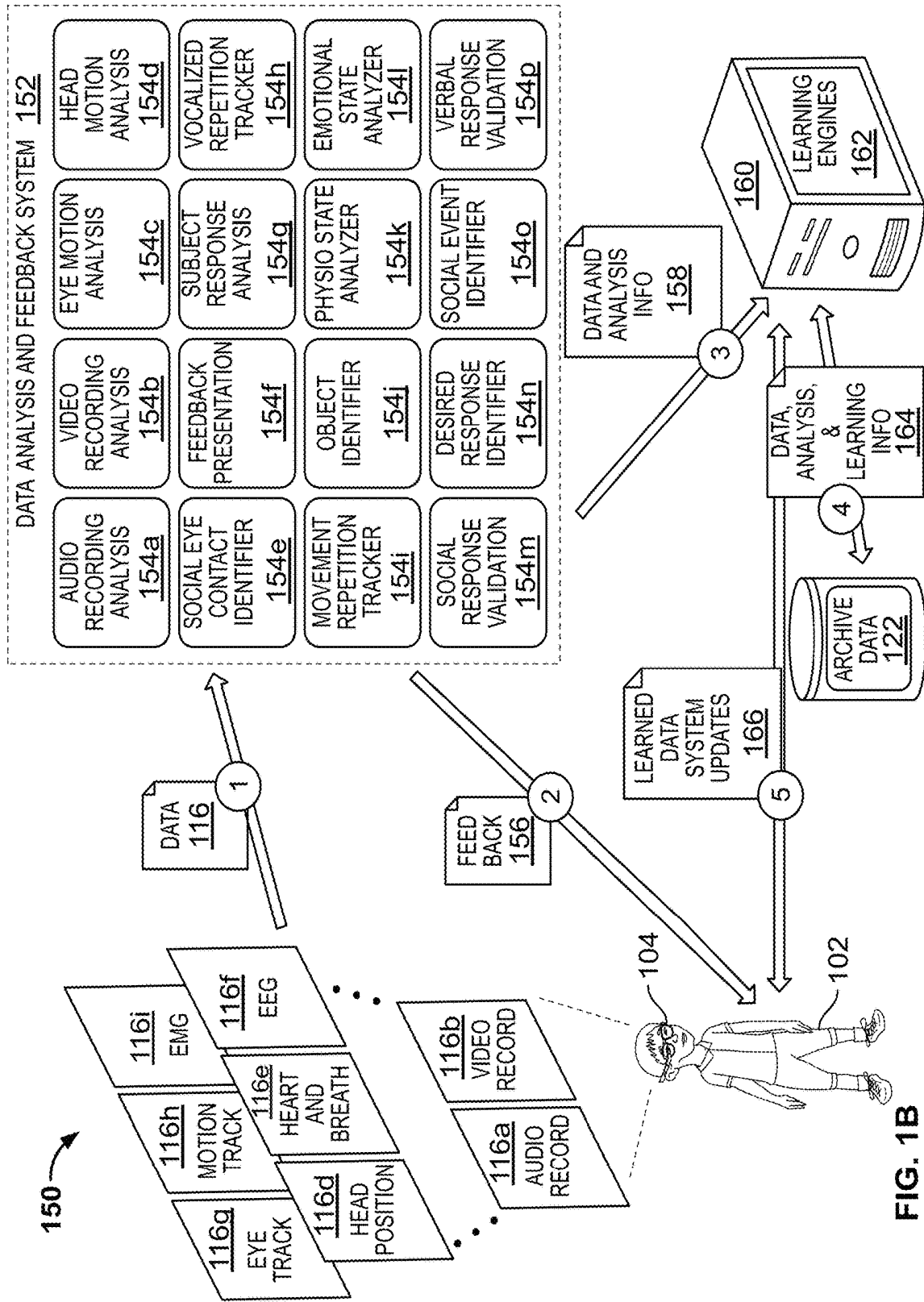


FIG. 1B

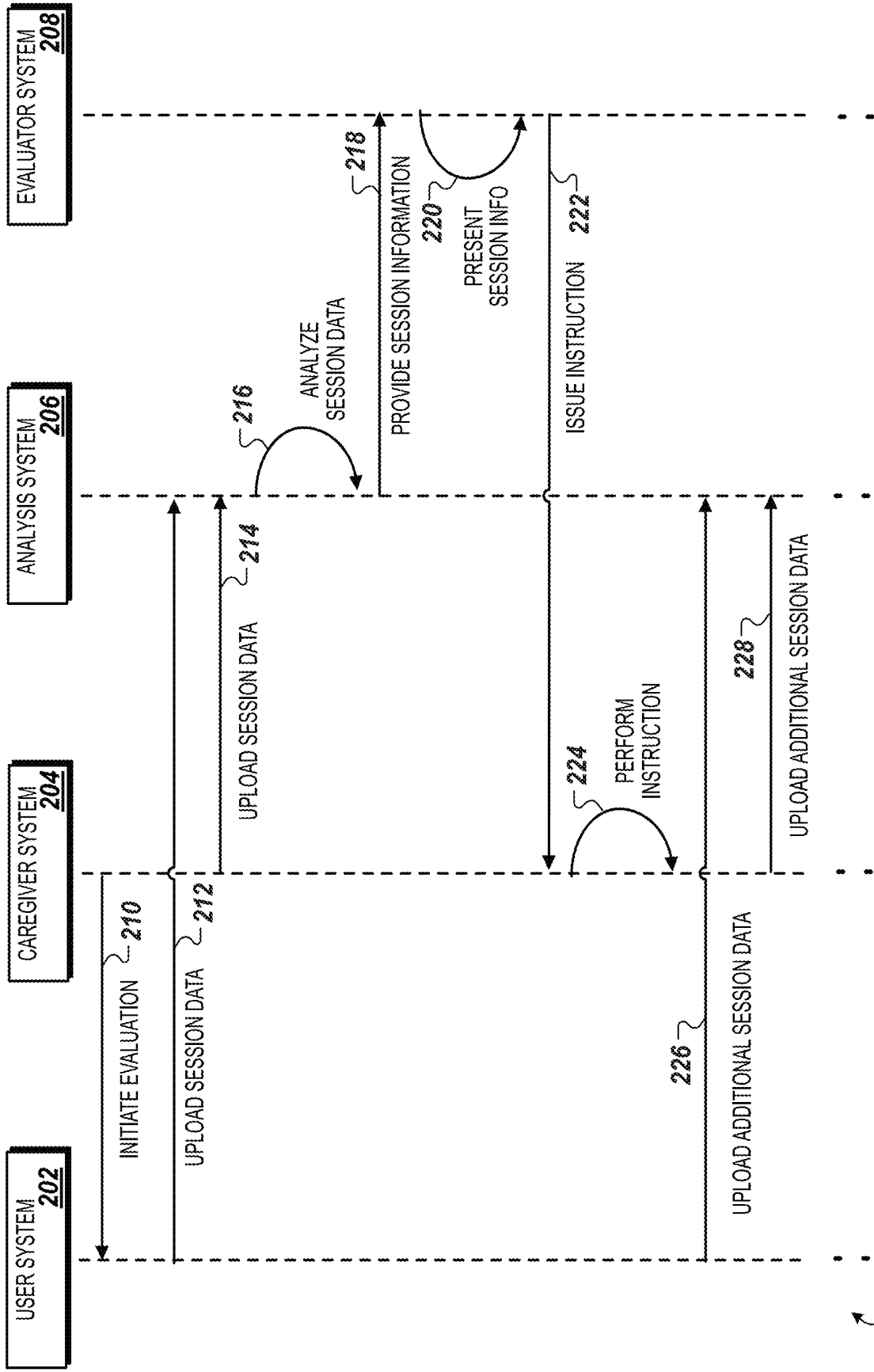


FIG. 2A

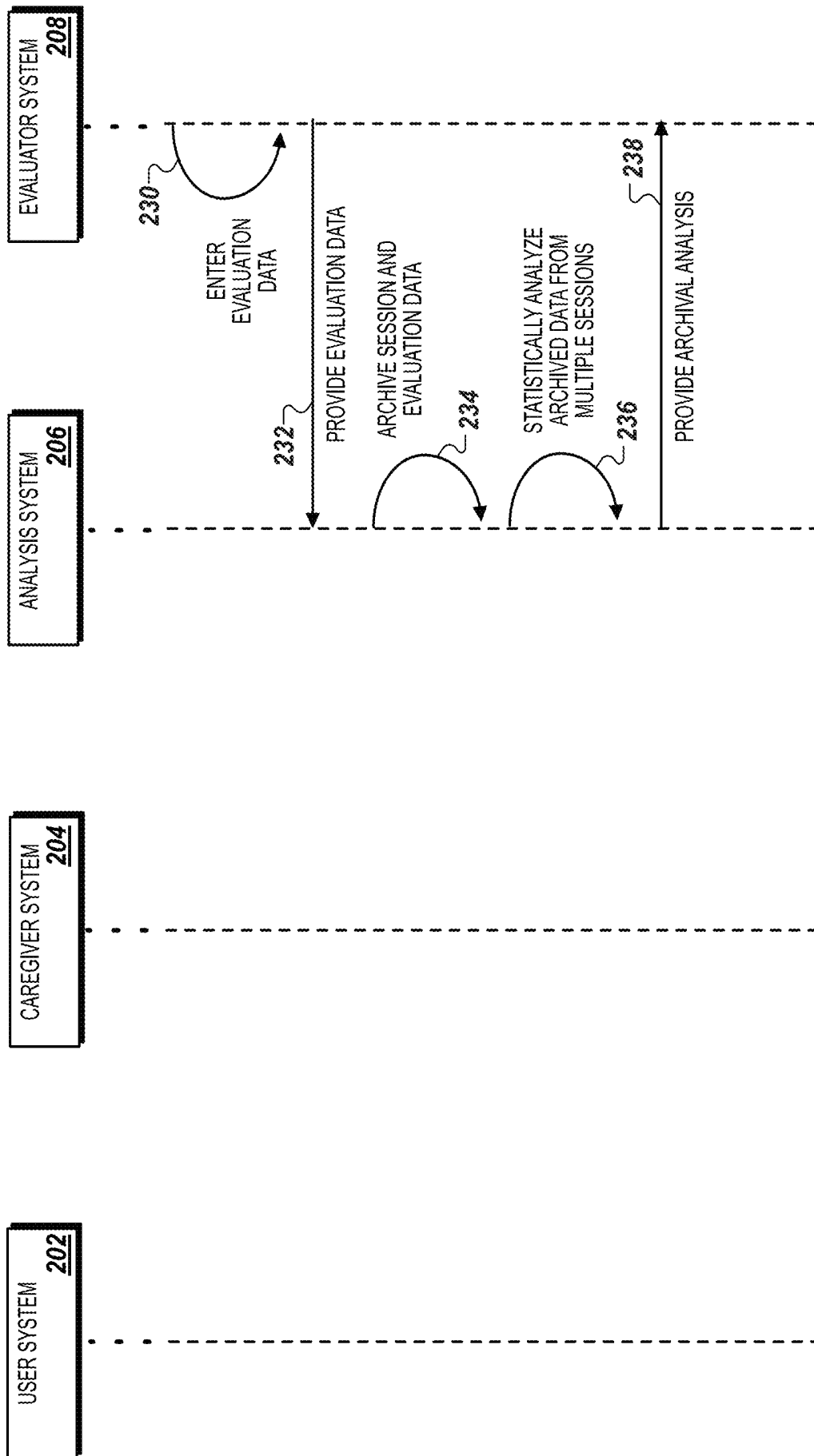


FIG. 2B

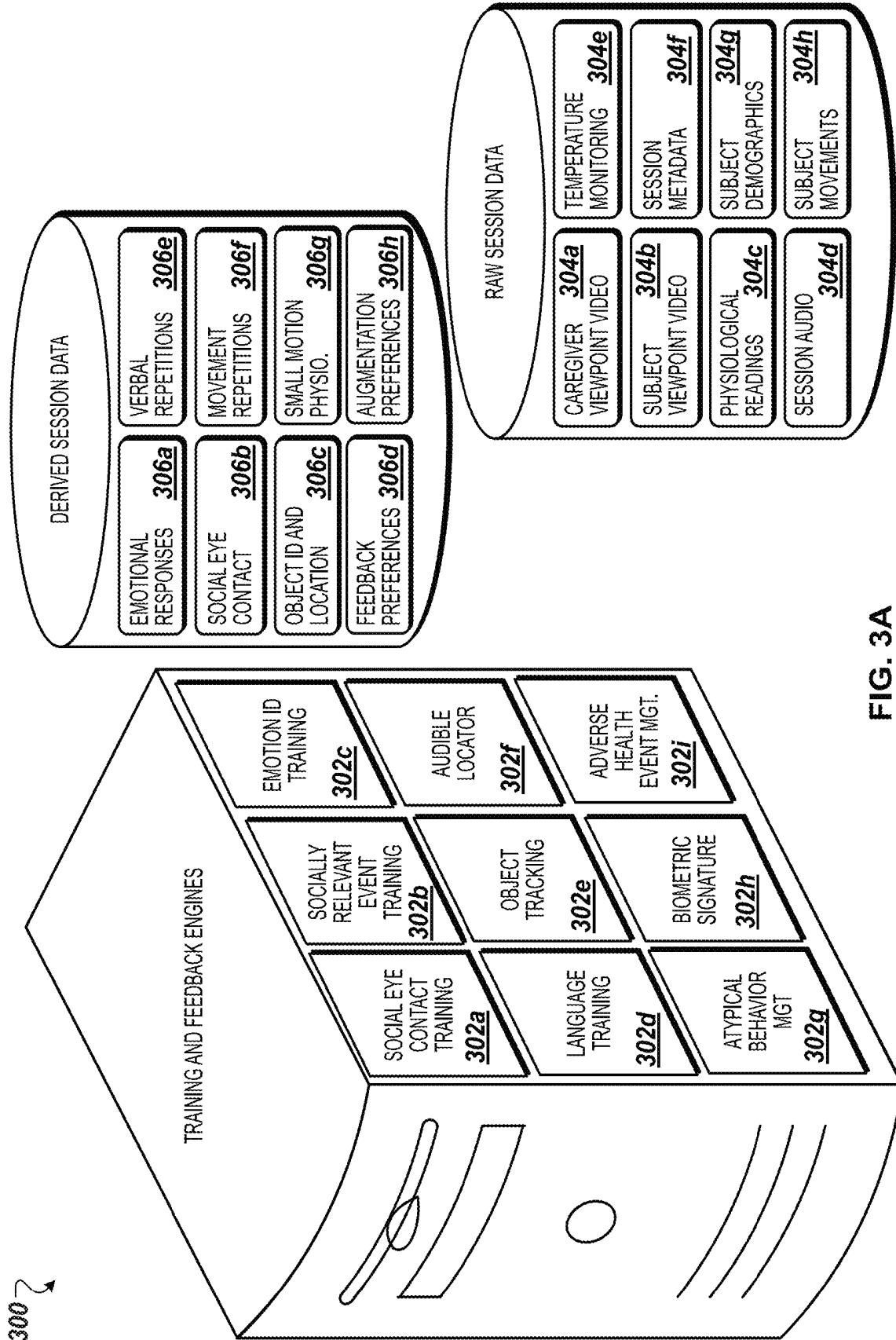


FIG. 3A

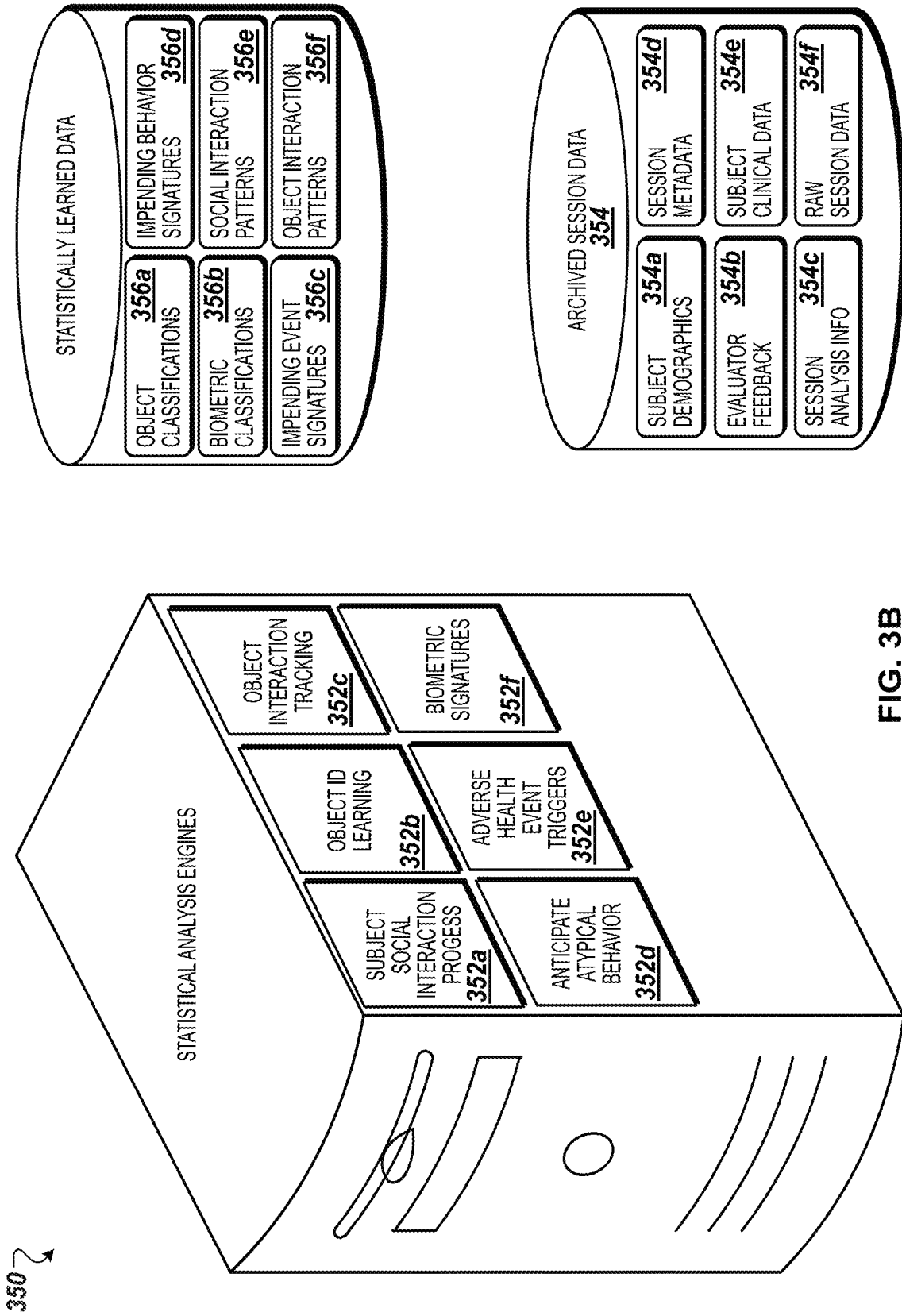


FIG. 3B

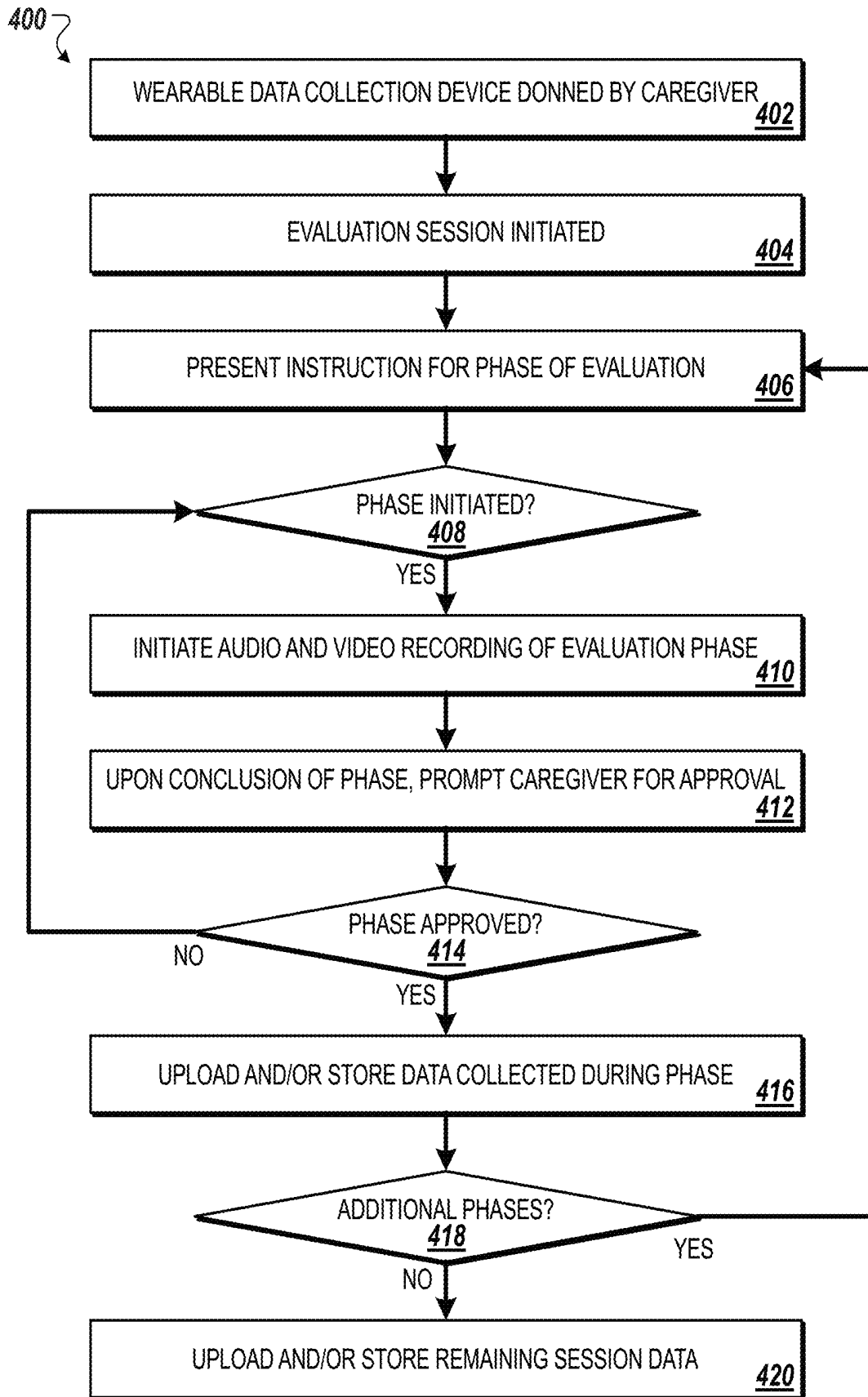


FIG. 4

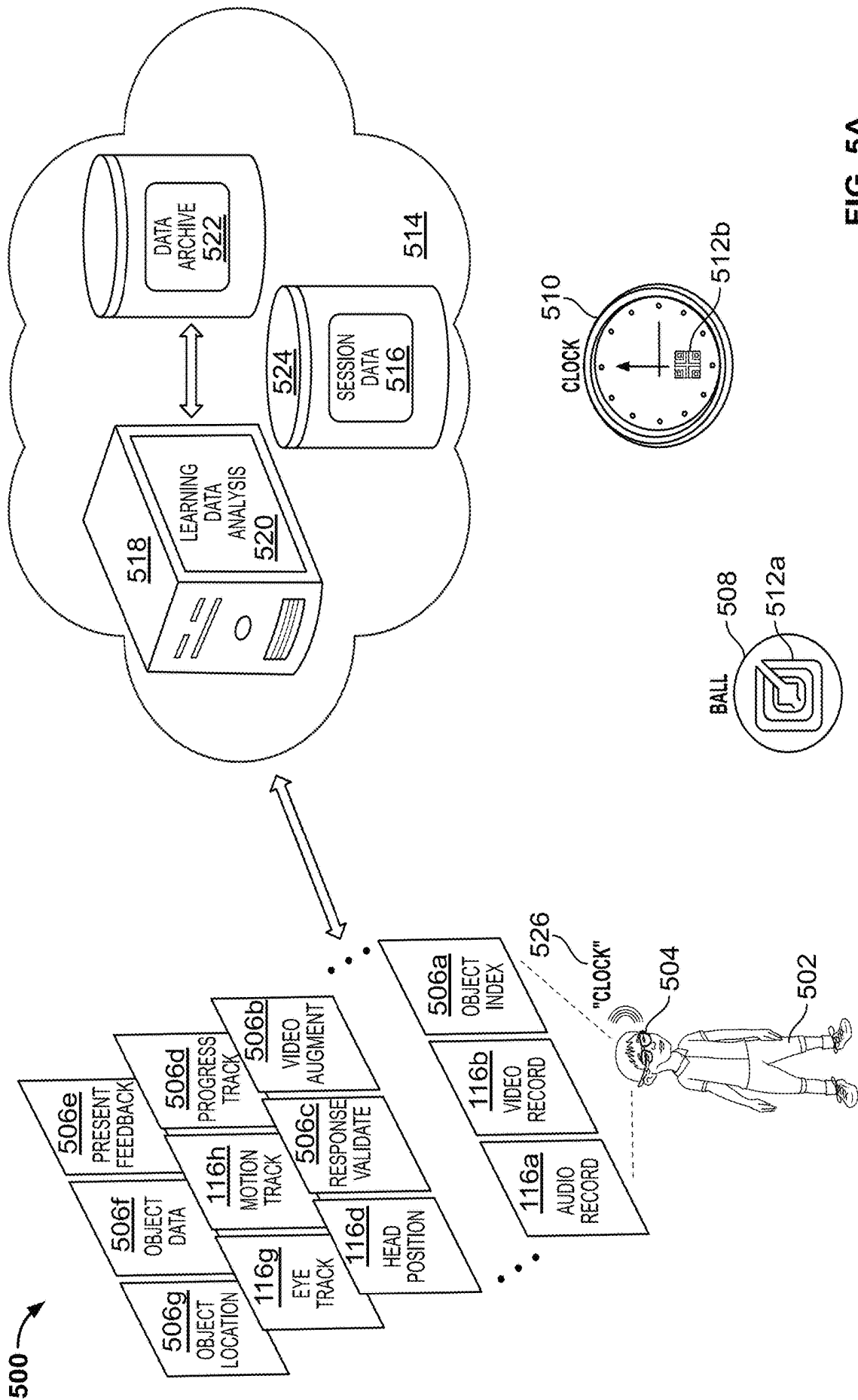


FIG. 5A

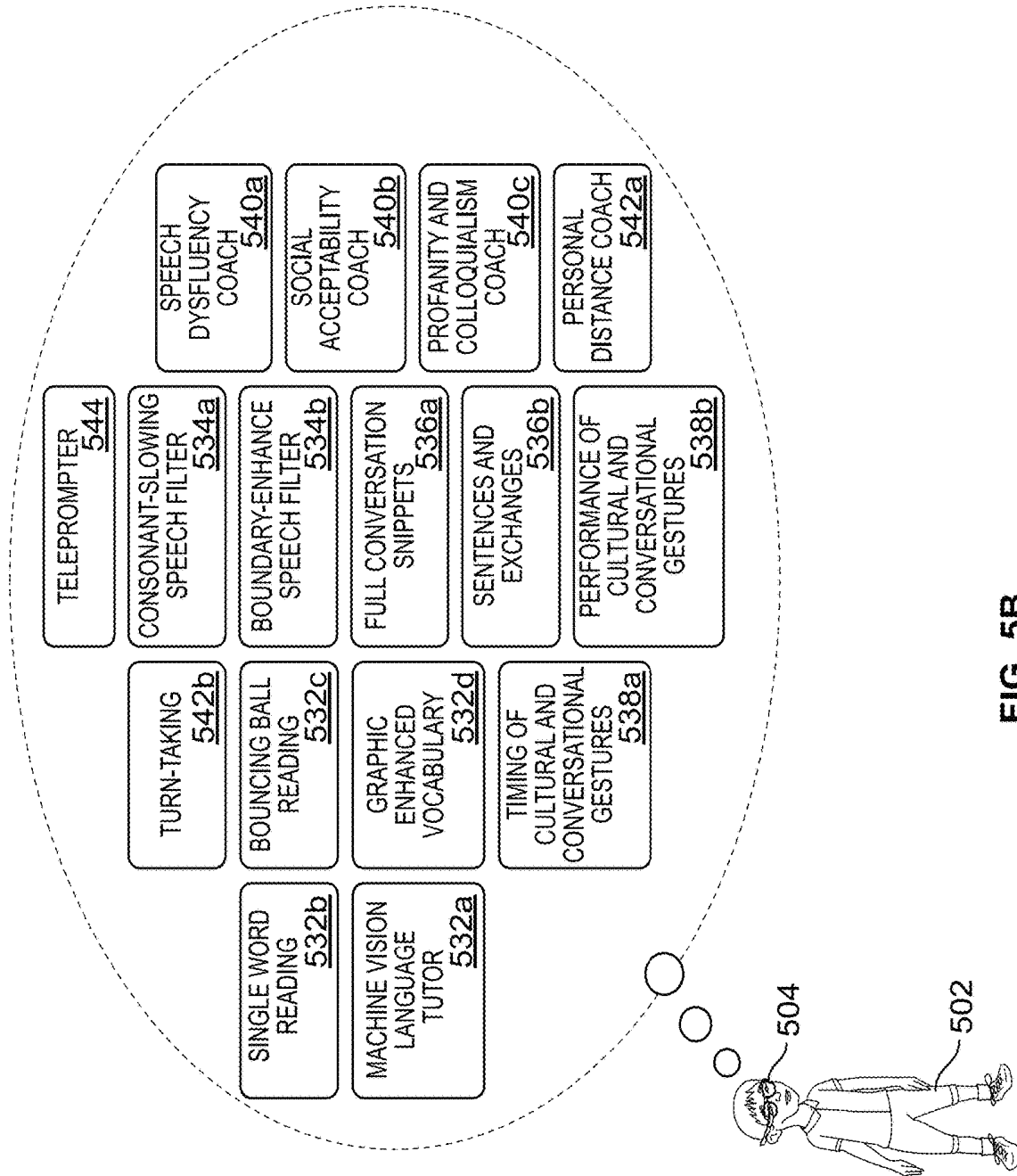


FIG. 5B

550

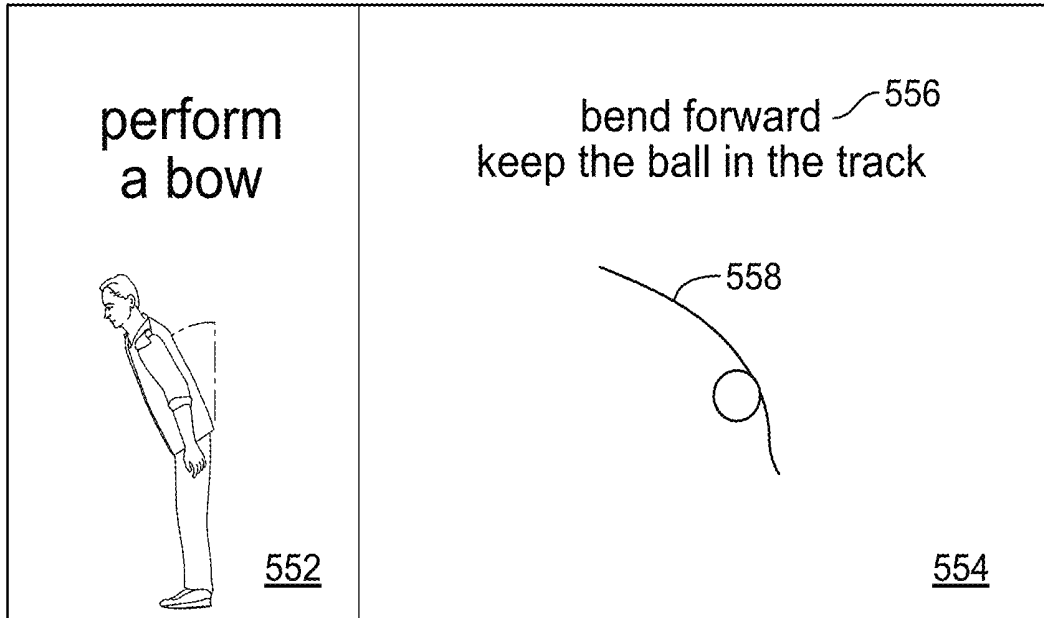


FIG. 5C

560

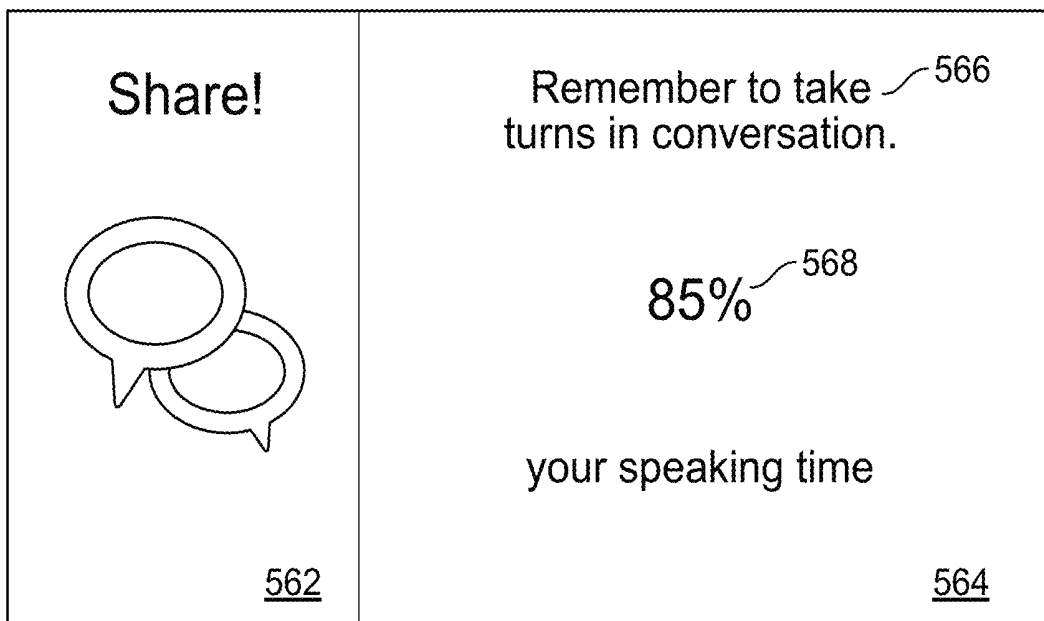


FIG. 5D

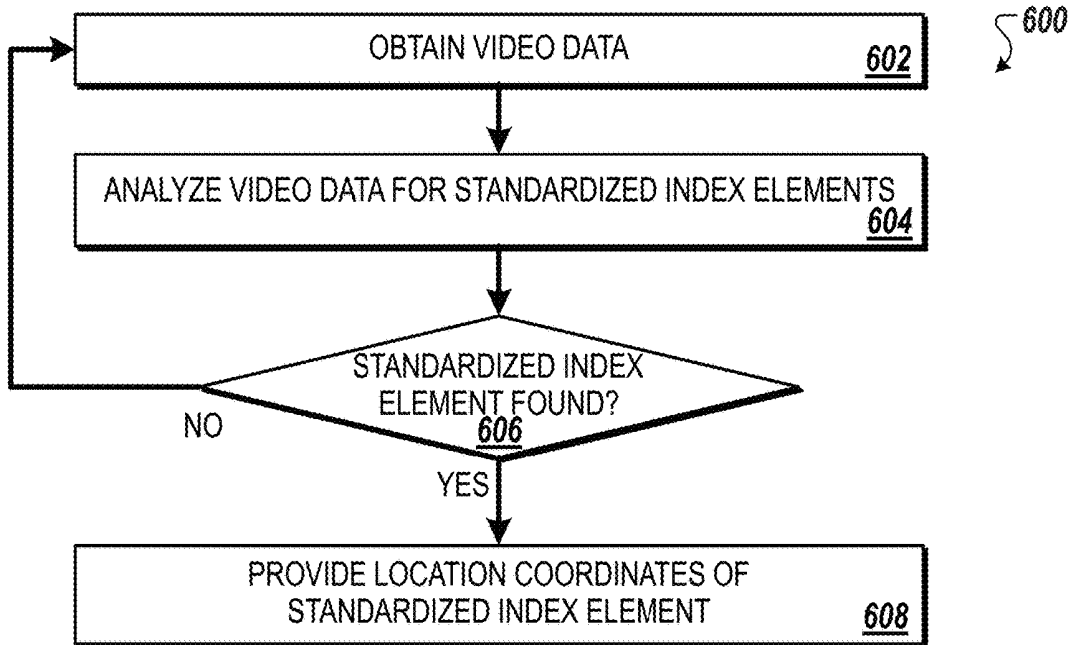


FIG. 6A

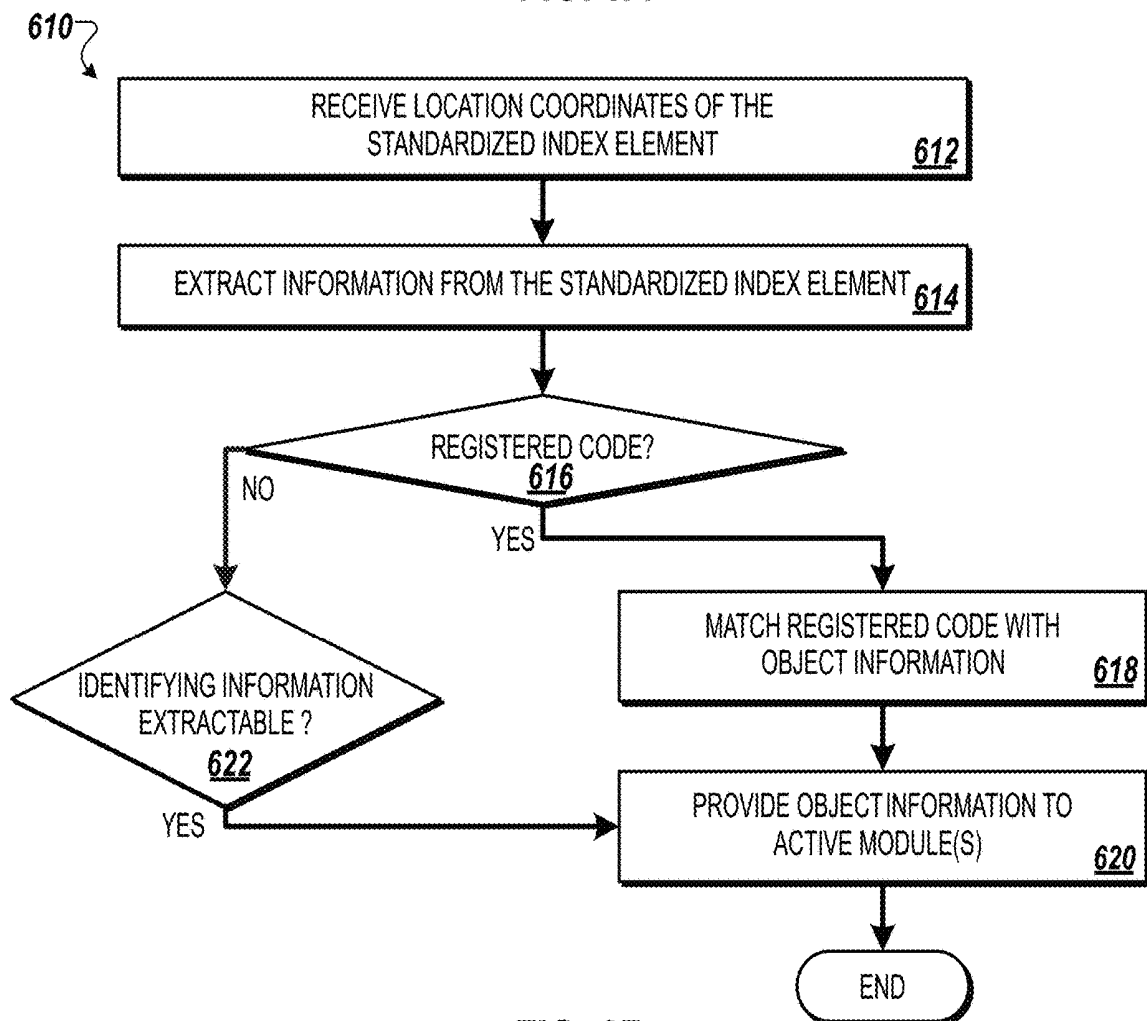


FIG. 6B

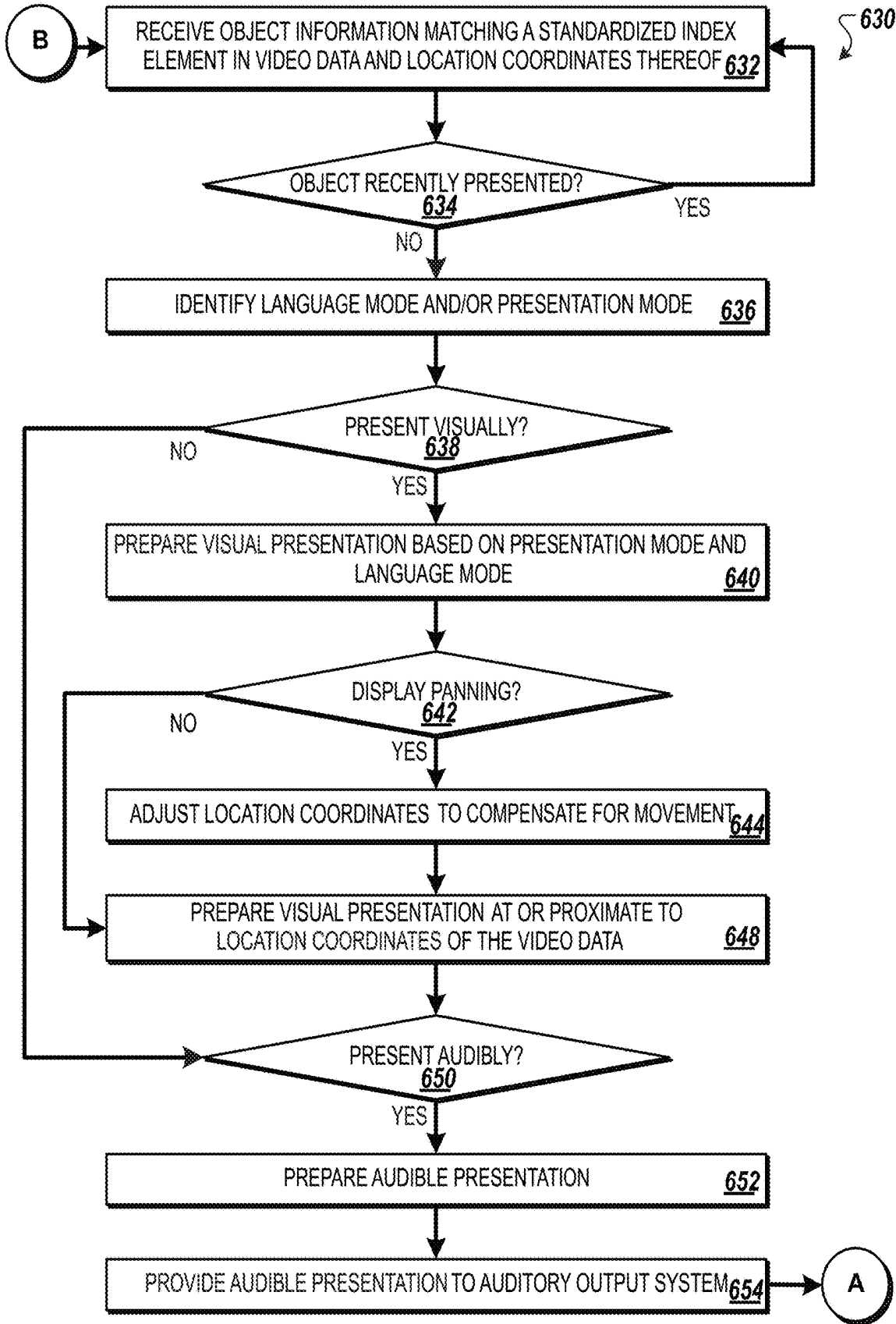


FIG. 6C

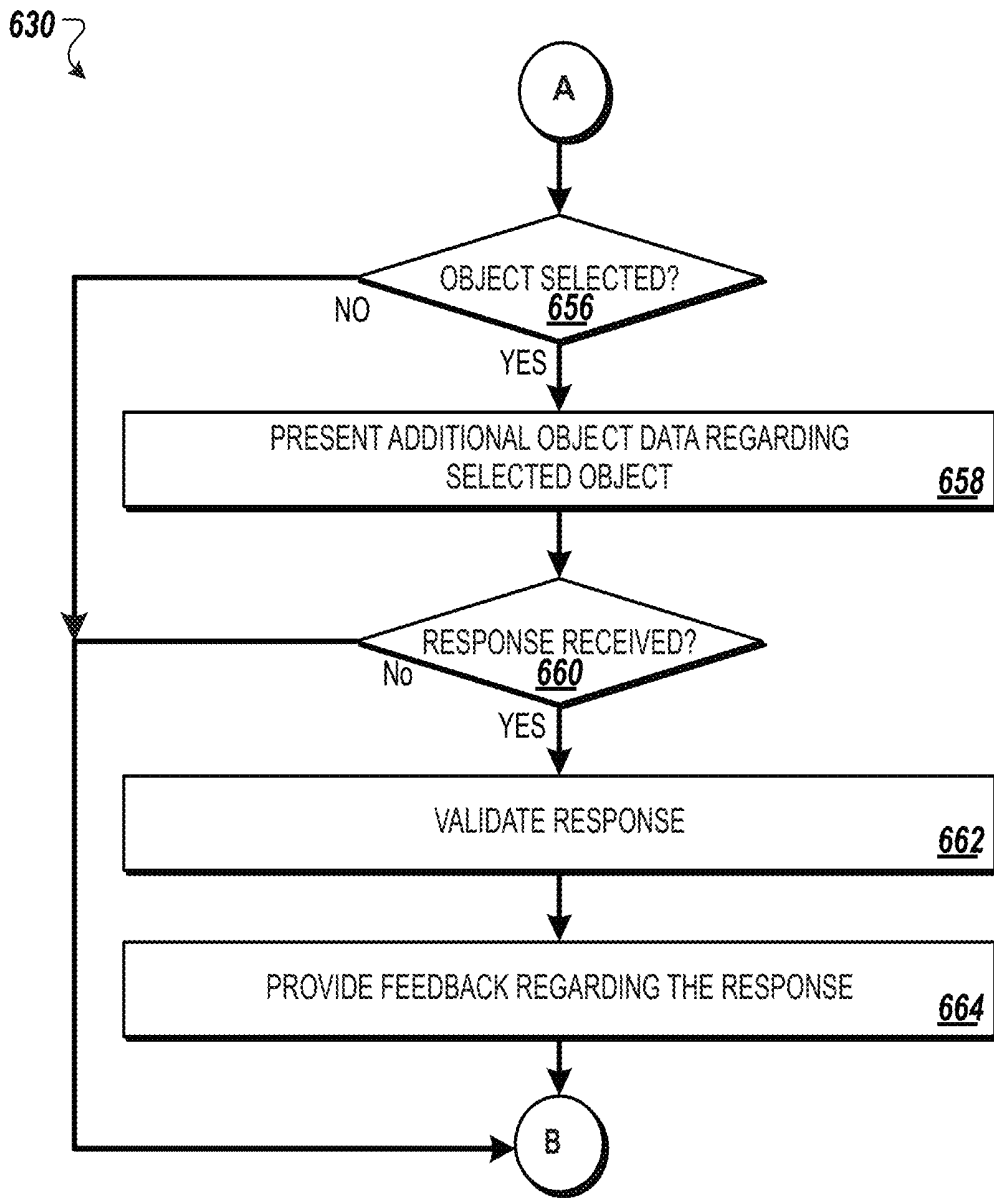


FIG. 6D

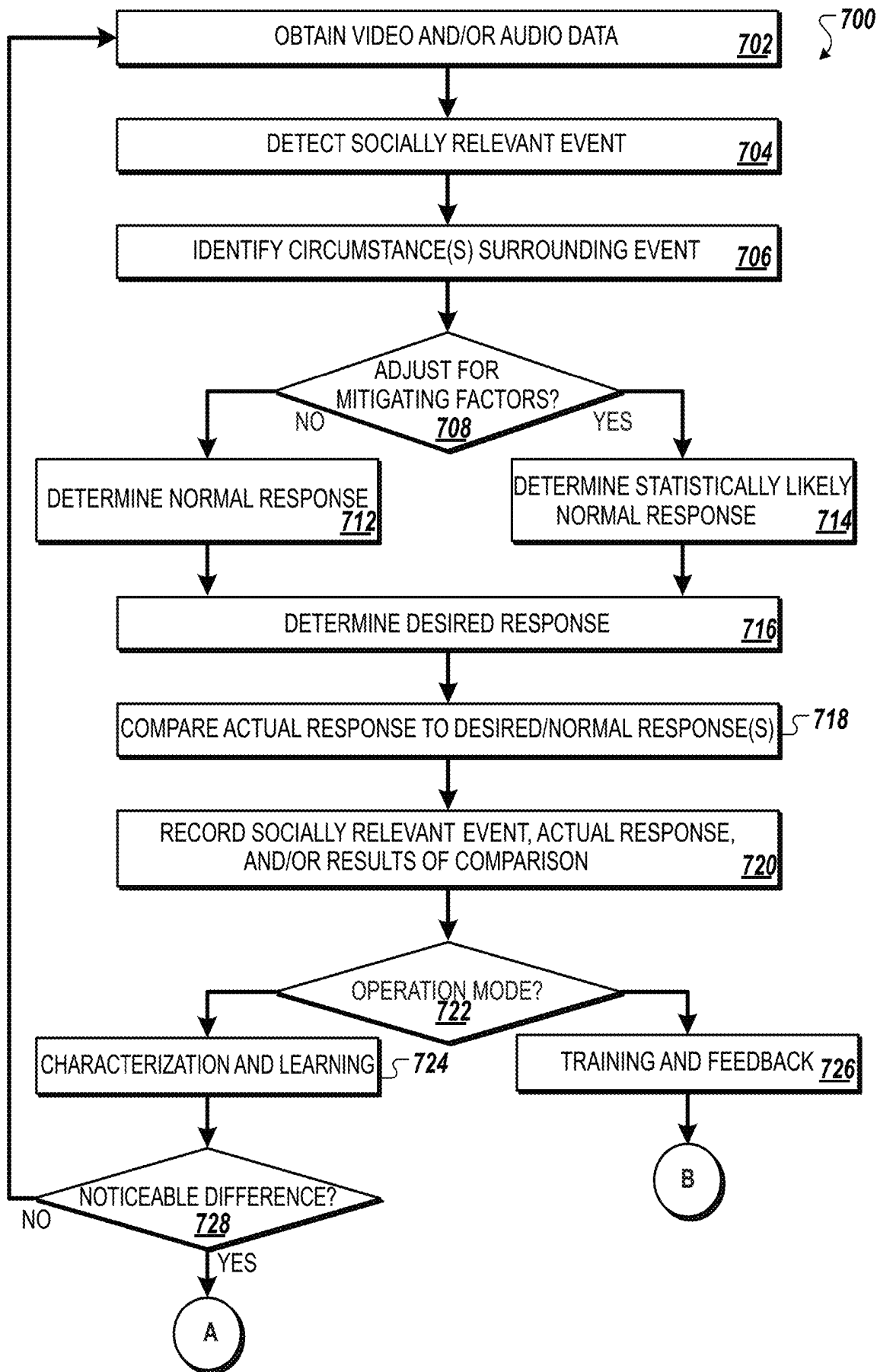


FIG. 7A

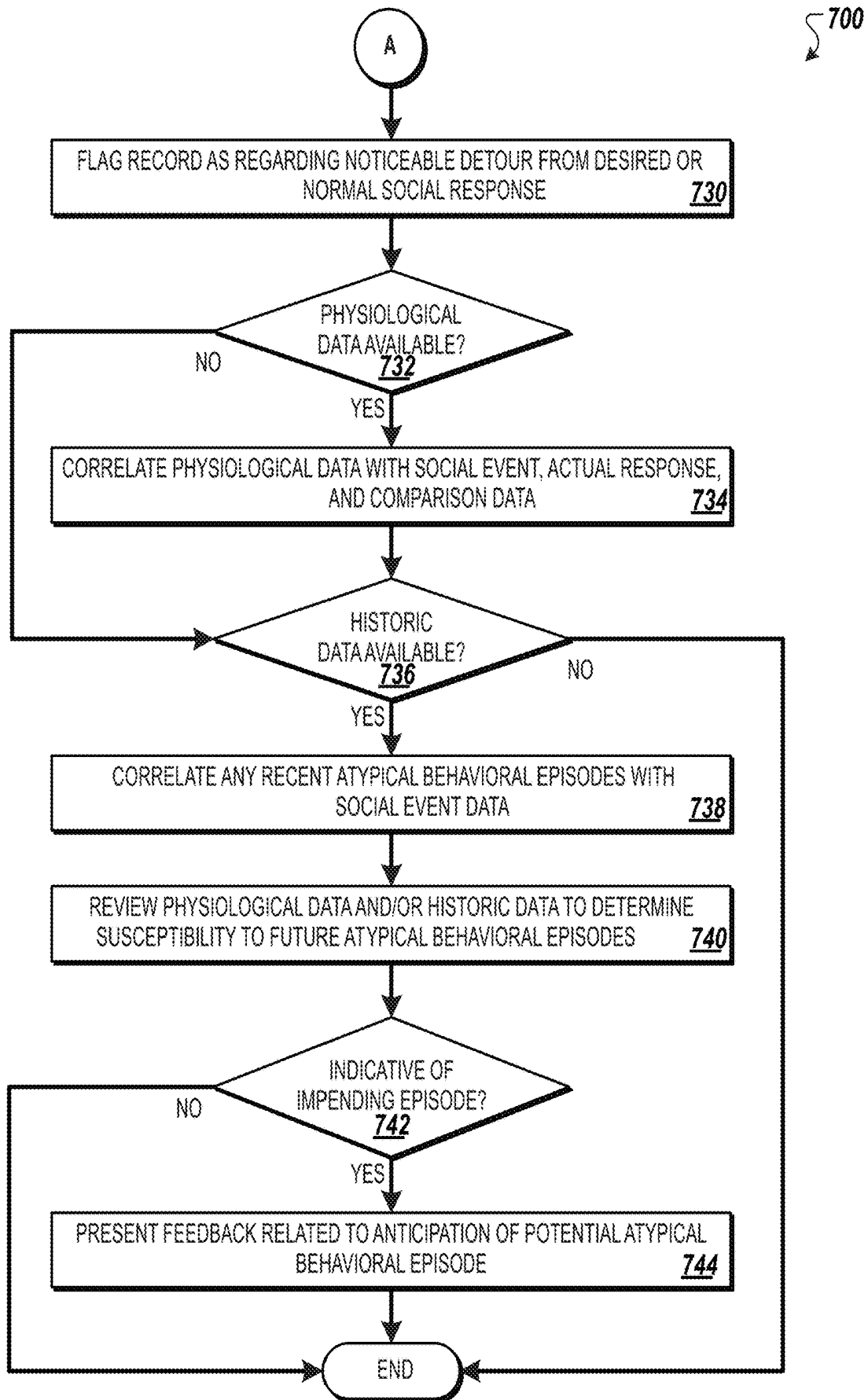


FIG. 7B

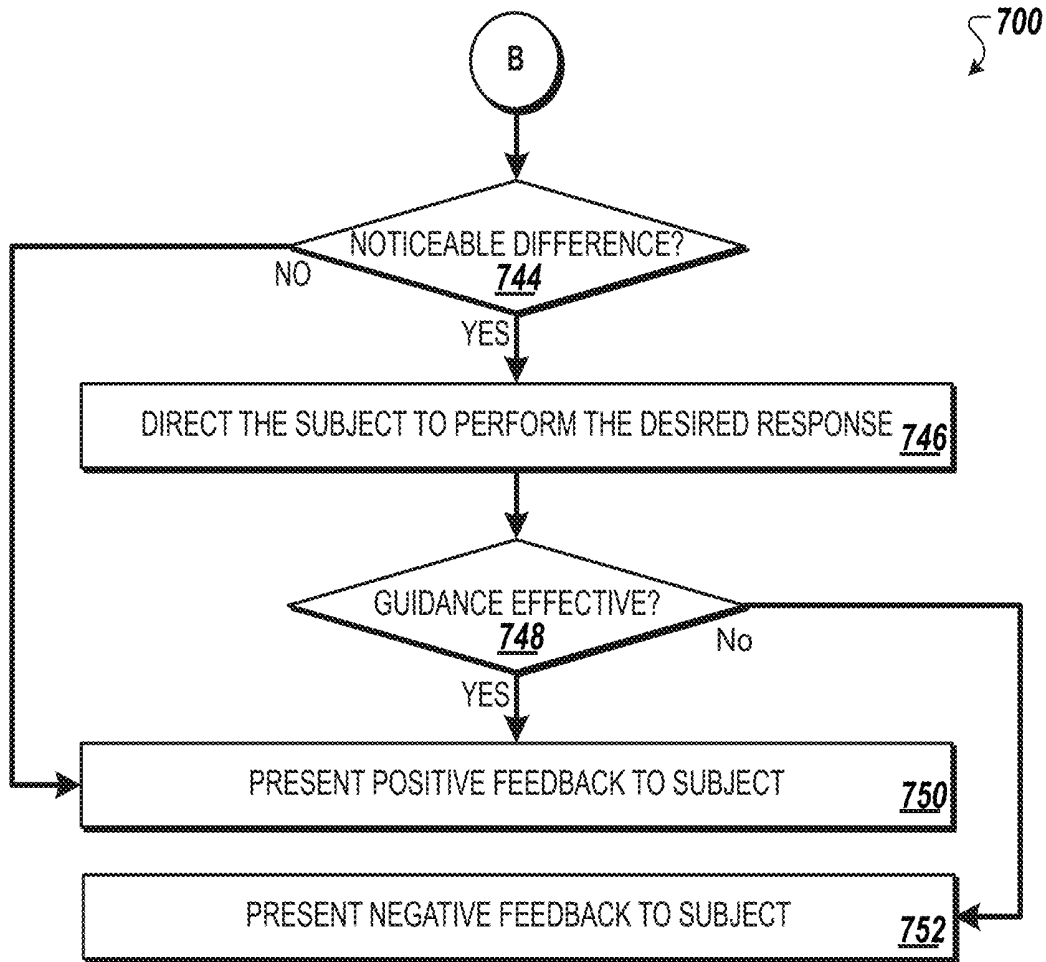


FIG. 7C



FIG. 7D

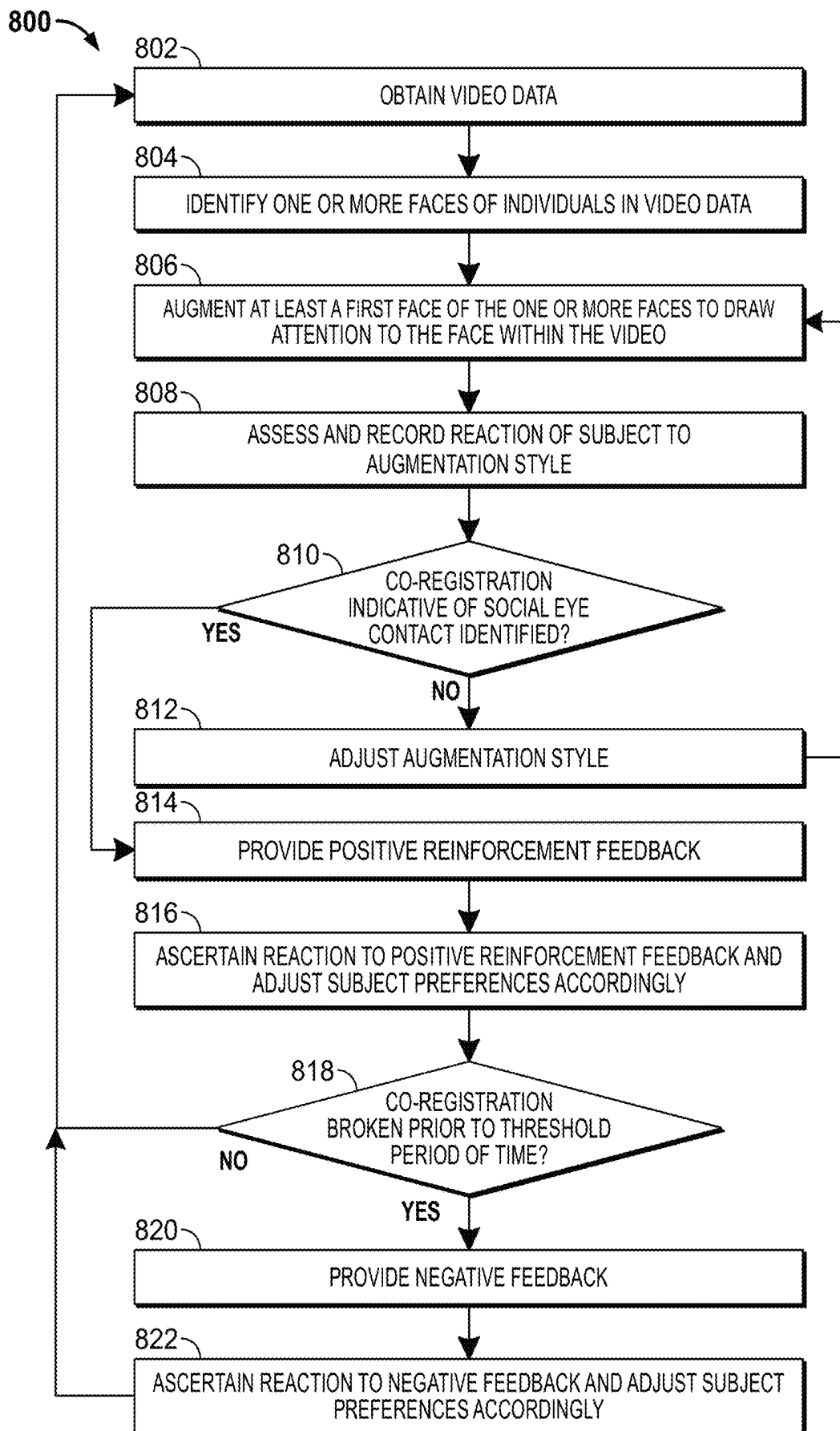


FIG. 8

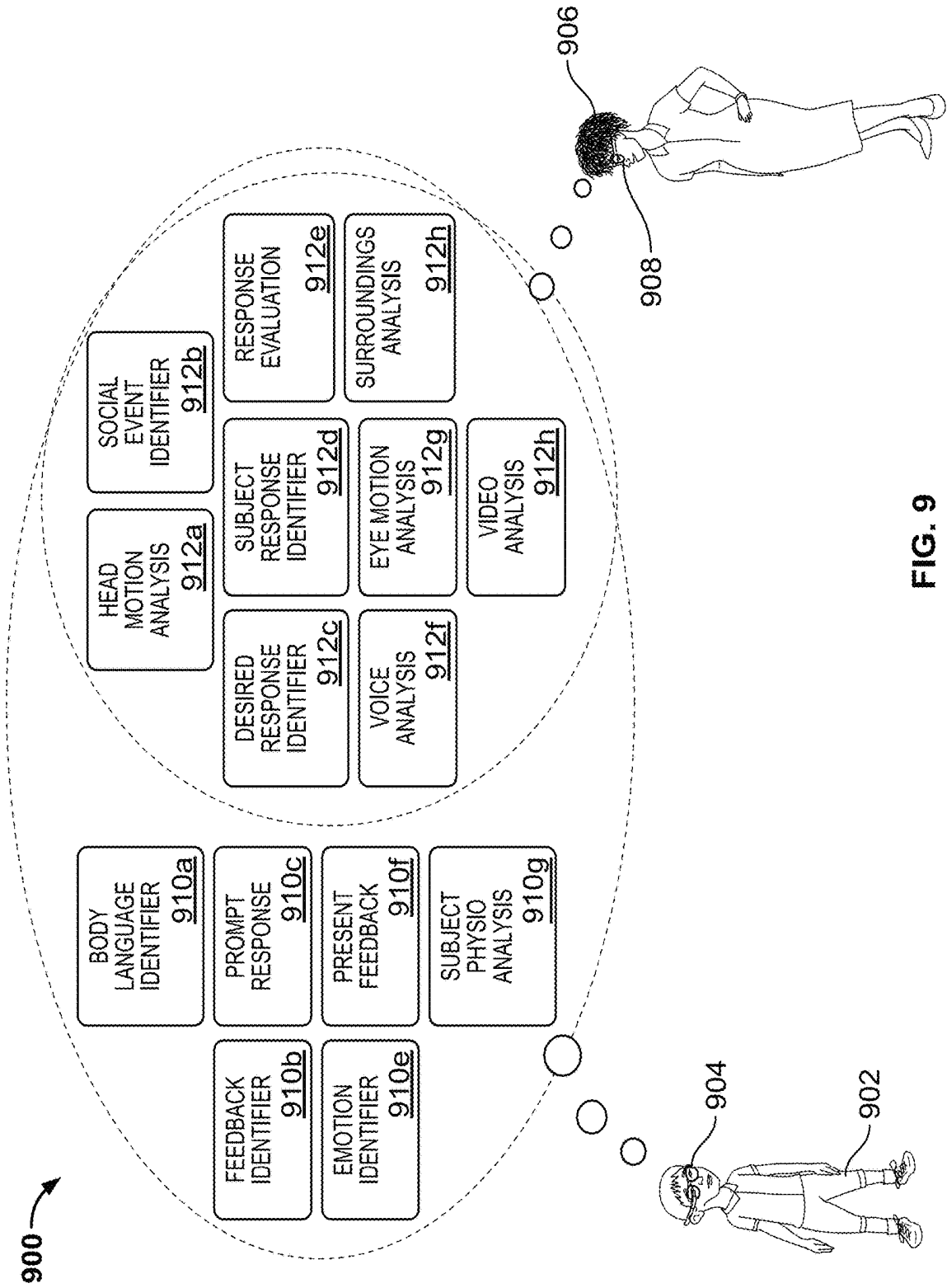


FIG. 9

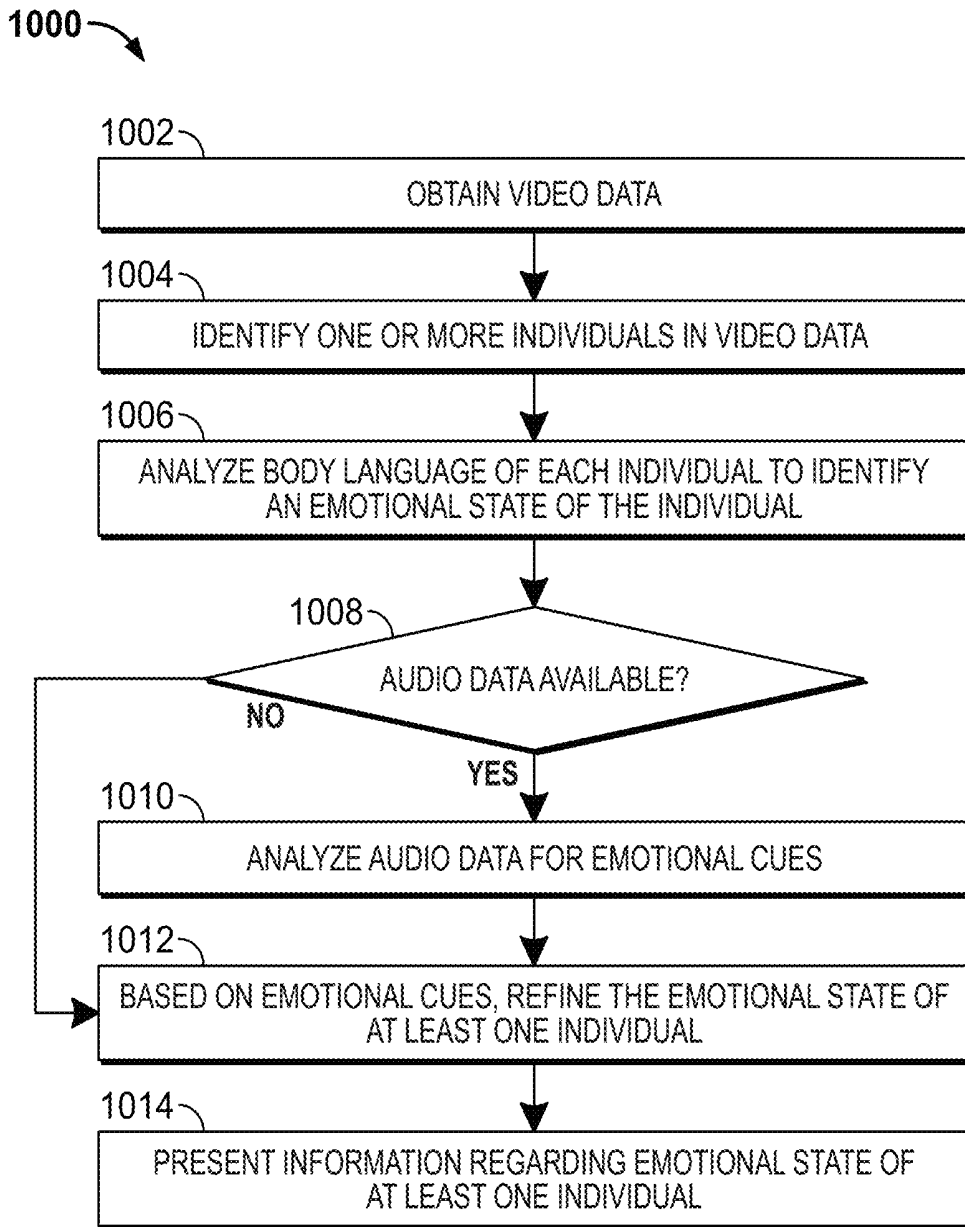


FIG. 10A

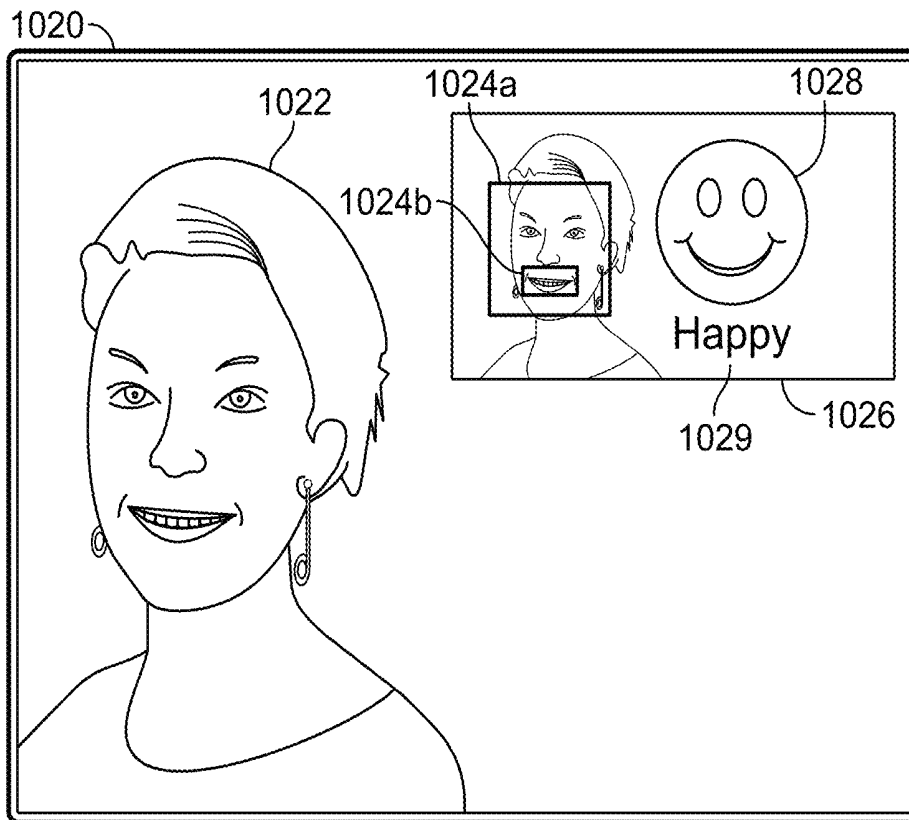


FIG. 10B

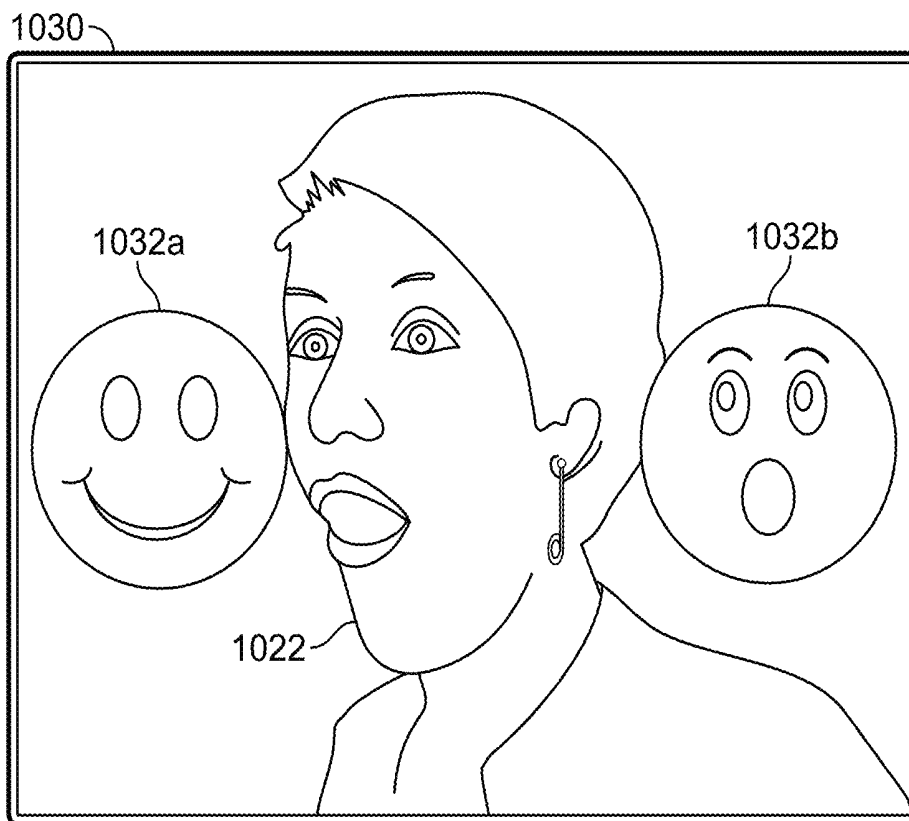


FIG. 10C

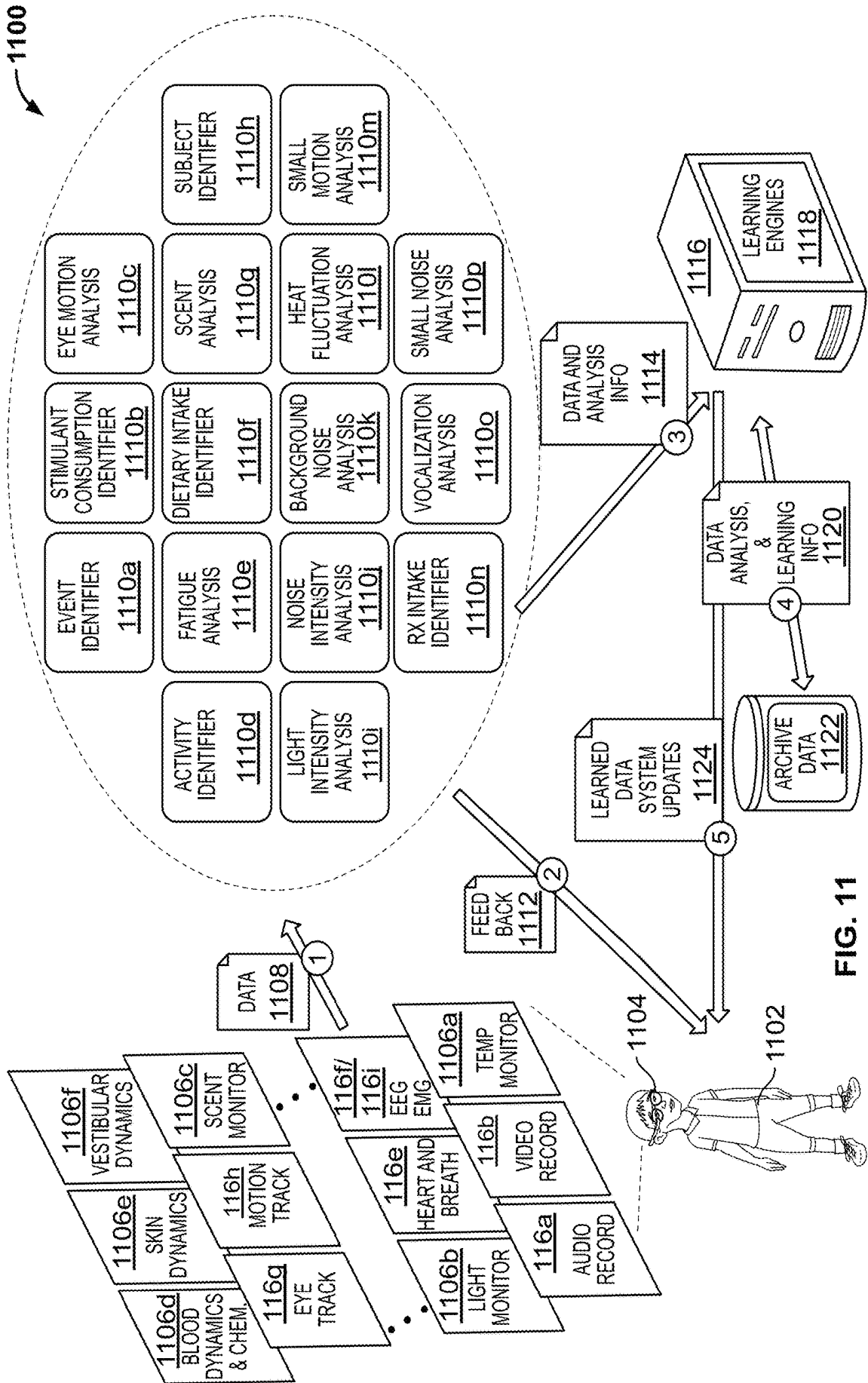


FIG. 11

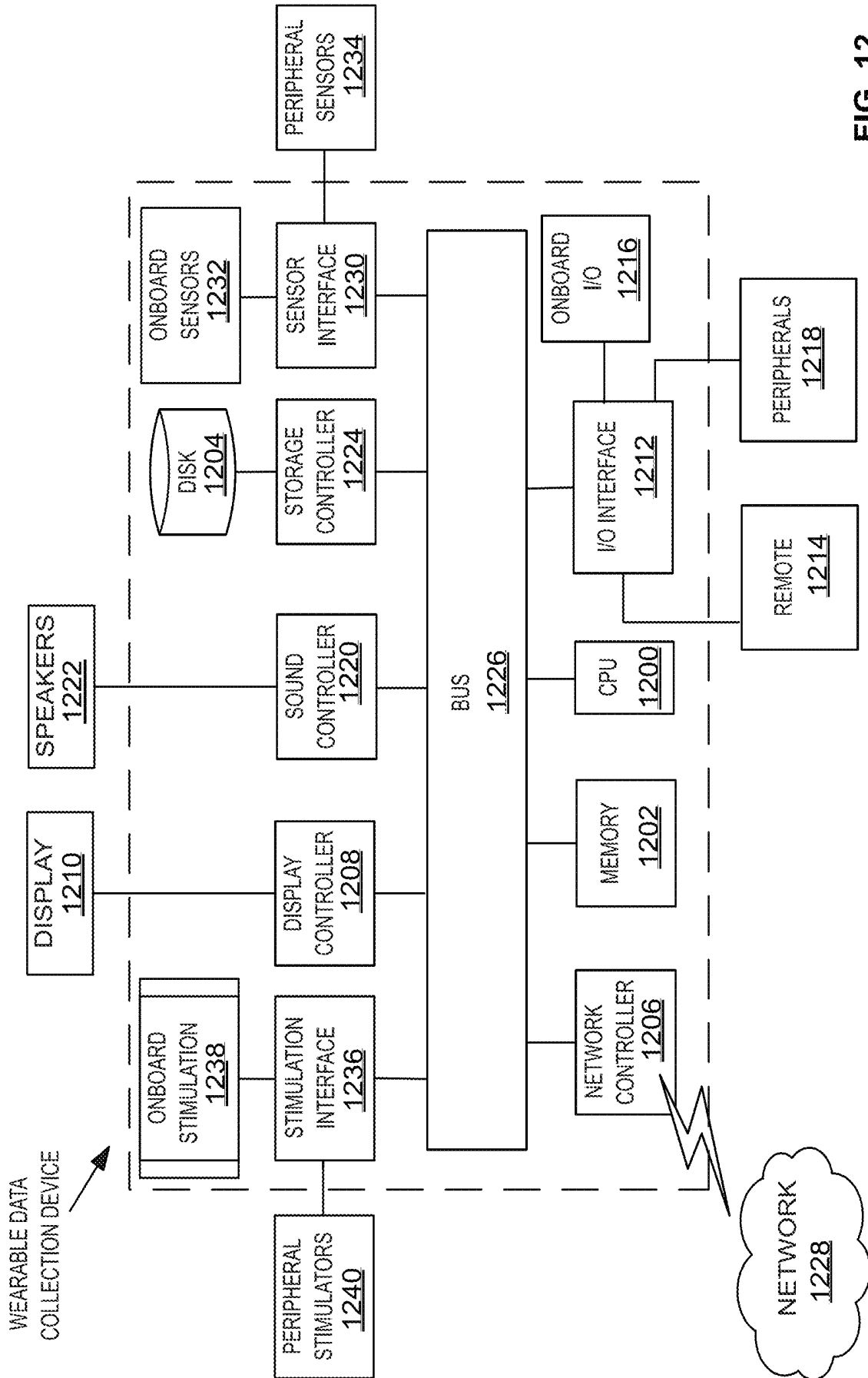


FIG. 12

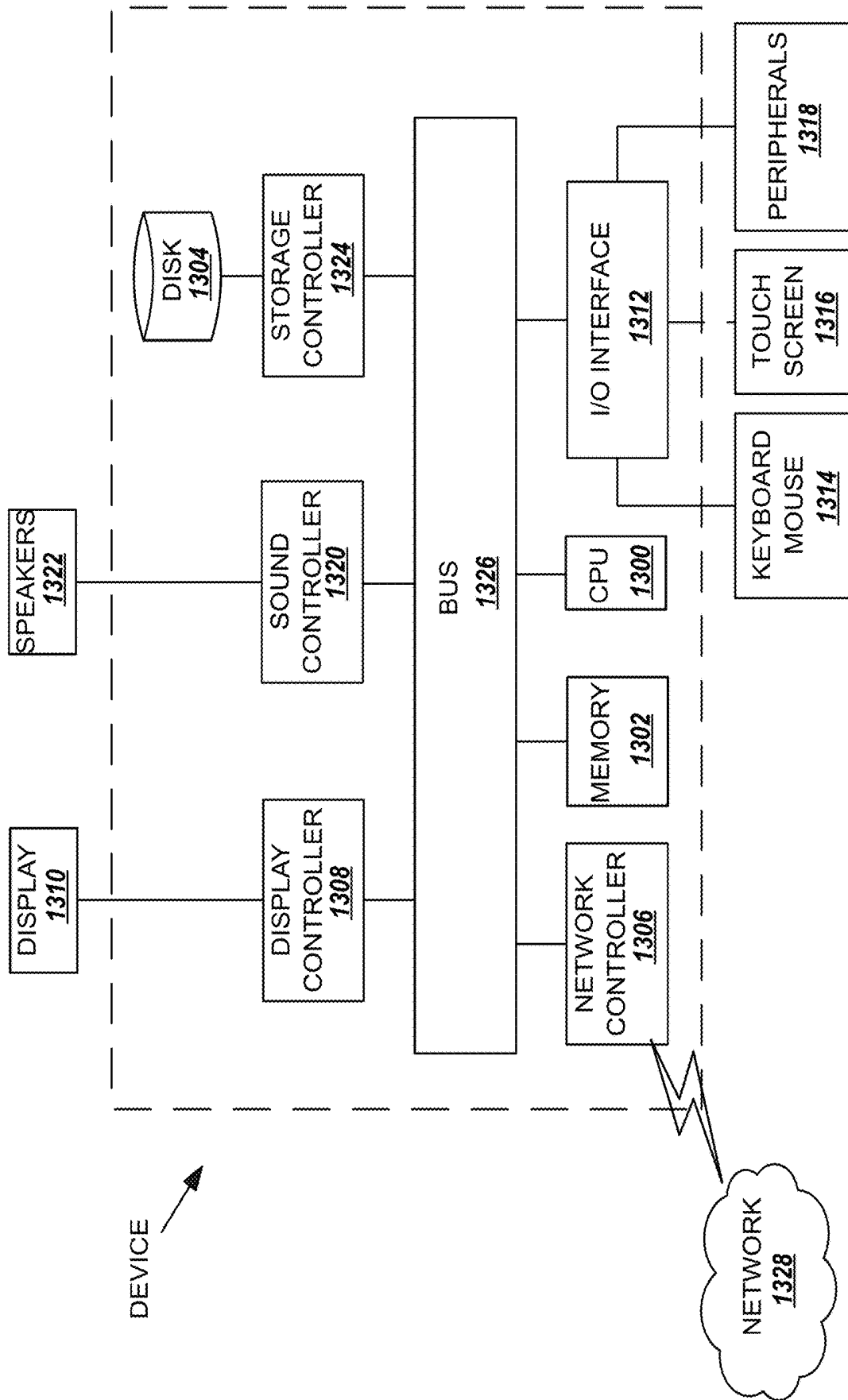


FIG. 13

**SYSTEMS, ENVIRONMENT AND METHODS
FOR EMOTIONAL RECOGNITION AND
SOCIAL INTERACTION COACHING**

RELATED APPLICATIONS

The present application is a continuation application of U.S. application Ser. No. 14/511,039 filed Oct. 9, 2014 which is related to and claims the priority of U.S. Provisional Application No. 61/888,531 entitled "A Method and Device to Provide Information Regarding Autism Spectrum Disorders" and filed Oct. 9, 2013, and U.S. Provisional Application No. 61/943,727 entitled "Method, System, and Wearable Data Collection Device for Evaluation and Management of Autism Spectrum Disorder" and filed Feb. 24, 2014. All above identified applications are hereby incorporated by reference in their entireties for all purposes.

BACKGROUND

Autism probably begins in utero, and can be diagnosed at 4-6 months. However, right now in America, Autism is most often diagnosed at 4-6 years. The median diagnosis age in children with only 7 of the 12 classic Autism Spectrum Disorder symptoms is over 8. In these missed years, the child falls much further behind his or her peers than necessary. This tragedy is widespread, given that 1 in 42 boys is estimated to have Autism (1 in 68 children overall) (based upon U.S. Centers for Disease Control and Prevention, surveillance year 2010). Additionally there are few methods of managing or treating Autism, and almost no disease-modifying medical treatments. Why do these diagnosis and treatment gaps exist?

There is no blood test for autism. Nor is there a genetic, neural or physiological test. Astonishingly, the only way parents can know if their child has autism is to secure an appointment with multiple doctors (pediatrician, speech pathologist, perhaps neurologist) who observe the child playing and interacting with others, especially with the caregiver. This is time-consuming, must be done during doctors' hours, is challenging and contains subjective components, varies by clinician, does not usually generate numerical data or closely quantified symptoms or behaviors; and demands resources, knowledge and access to the health system—all contributing to delayed diagnosis.

There are also social factors. A parent's suspicion that his/her child has autism generally takes time to grow, especially with the first child or in parents with little child experience (no frame of reference). Furthermore, the decision to seek help may be clouded by fear, doubt, denial, guilt, stigma, embarrassment, lack of knowledge, distrust of the medical system, and confusion. Once the decision is made, it can be a protracted, uphill battle to find the right care center and secure the screening appointment and a correct diagnosis. All these factors are amplified for at-risk families with low SES, low education level, language and cultural barriers, familial ASD; and in single-parent or dual-job families. Time that passes before diagnosis reduces the child's social and emotional development, learning of language, and eventual level of function in society.

Even if the family surmounts various hurdles and comes in for an official diagnosis, hospital admission and the test environment can be daunting and unnatural, especially for those with language, cultural or SES barriers.

In this context, a shy child may seem autistic and an ASD child may completely shut down, especially since ASD children are particularly averse to changes in familiar set-

tings and routines. Thus, the child may be diagnosed as further along the Autism spectrum than is the reality, and false diagnoses such as retardation may be attached. This has profound consequences in terms of what schooling options are available to the child, how the parents and community treats the child, and the relationship that gets set up between the parents and the healthcare system. Even in a friendly testing lab, clinicians cannot see the child play and interact exactly as he/she does in the familiar home environment, and can never see the child through the caregiver's eyes, nor see the world through the child's eyes. Importantly, there are no widely adopted systems for objectively quantifying behavioral markers nor neural signals associated with ASD, especially at home.

Even when and if a diagnosis is achieved, there are few options available to the family (or to the school or health care giver) that quantify the degree of severity of the child's symptoms. Autism is a spectrum of course, and people with autism spectrum disorders have a range of characteristic symptoms and features, each to varying degrees of severity if at all. Measuring these and characterizing the overall disorder fingerprint for each person is an important advance for the initial characterization, as per above, but importantly this fingerprint is dynamic over time, especially in the context of attempted treatments and schooling options, so measuring the changing severity and nature of each feature is important. This is the tracking or progress-assessment framework. Additionally, perhaps one of the greatest unmet needs within ASD comes in terms of the treatment or training framework. That is to say, mechanisms for providing intervention of one kind or another that can have a disease-modifying or symptom-modifying impact. There are few options available to the families affected, and again, there are few options for rigorously quantifying the results.

SUMMARY

Ideally, a child would be assessed for ASD in the family's regular home environment, on their schedule, in their language, and perhaps while allowing remote doctors to literally look through the caregiver's eyes at the child (and vice versa). It should be private and confidential, quick and convenient, quantitative and repeatable, and low-cost enough that a worried parent will pay the cost directly (thus bypassing the complexity of insurance reimbursements). In some implementations, the solution tracks and objectively quantifies clinical features such as when the child directs his gaze toward the caregiver's voice, how frequently he interacts with the caregiver verbally, and repetitive verbalizations and motions of his head and body. The solution, in some implementations, records brain activity and other physiology, and applies algorithms to recognize patterns that predict diagnosis and clinical features. The algorithmic analysis, for example, may be conducted in a central (e.g., cloud-based) system. Data uploaded to the cloud can be archived and collected, such that learning algorithms refine analysis based upon the collective data set of all patients. In some implementations, the system combines quantified clinical features and physiology to aid in diagnosing autism objectively, early, and at least semi-automatically based upon collected data.

In some implementations, an evaluator reviews a recorded session uploaded to the central system and makes a diagnosis. Evaluators, in some implementations, may perform a live (supervised) session, or review another clinician's live session, through real-time data feed between the family home session and a remote evaluator computing system.

Although described as an in-home system due to the advantages described above, the system may additionally be used within a clinical environment to aid in evaluation of an individual.

The system has several advantages. Evaluation can be performed in the home, in an organic and comfortable play-space, in the family's language, whenever the caregiver has time, discreetly, privately, extremely rapidly (kits can arrive same-day, and testing complete in a few hours), and inexpensively. The most costly equipment, the wearable data collection device, can be reused, so the main costs are evaluation kit objects (e.g., toys or other interaction objects) and evaluator/technician time.

The system is beneficial to evaluators as well. Evaluators get access to many more subjects. The evaluators can perform diagnosis from home, during commute, or otherwise away from the office. Evaluators are afforded the opportunity to observe patients in their natural environment, and can witness transient behavioral events that otherwise only caregivers might see. If evaluators are working as a team to review an individual, they do not have to match their schedules to be in one place, but can jointly observe a single session with the individual from as many locations as there are team members. Above all, the system could decrease the age of Autism diagnosis drastically, and reach many at-risk families, early.

In some implementations, the system goes beyond the evaluation stage to track an individual's ongoing progress. For example, after diagnose of ASD, there is typically a long series of interventions from schools, doctors, etc. At some point, the child either does or does not develop socially and academically to a level where she can function in society. In between, there is rarely a point for interim evaluation and assessment to gauge progress. Maybe, a few years down the road, the family will have a follow-up "diagnosis" appointment. However, the follow-up visit will likely involve a different set of professionals, leaving the evaluation open to vagueness. Some programs for tracking ASD progress exist, having set goals and milestones, but they too can be vague and infrequently assessed. In employing a system such as the wearable data collection system described above for ongoing tracking of behaviors, abilities, and functionality of an ASD diagnosed child, a family can benefit from an exacting, quantitative-by-nature, cheap, at-home, understandable, standardized, comparable (from one time point to another), numerical assessment of a child's individual characteristics. The system, for example, could provide high-frequency (e.g., up to daily) assessments, each with perhaps hundreds or thousands or more data points or samples such as (in) correct behaviors or relevant brain states, which can be incorporated into the child's everyday home life to measure the child's ongoing progress.

To enable such ongoing assessment, in some implementations, applications for assessment as the child's development progresses may be made available for download to or streaming on a wearable data collection device via a network-accessible content store such as iTunes or Play store, or YouTube or other content repositories, or other content collections. Content providers, in some examples, can include educators, clinicians, physicians, and/or parents supplied with development abilities to build new modules for execution on the wearable data collection device evaluation and progress tracking system. Content can range in nature from simple text, images, or video content or the like, to fully elaborated software applications ("apps") or app suites. Content can be stand-alone, can be playable on a wearable data-collection device based on its existing capa-

bilities to play content (such as in-built ability to display text, images, videos, apps, etc., and to collect data), or can be played or deployed within a content-enabling framework or platform application that is designed to incorporate content from content providers. Content consumers, furthermore, can include individuals diagnosed with ASD or their families as well as clinicians, physicians, and/or educators who wish to incorporate system modules into their professional practices.

In some implementations, in addition to assessment, one or more modules of the system provide training mechanisms for supporting the individual's coping and development with ASD and its characteristics such as, in some examples, training mechanisms to assist in recognition of emotional states of others, social eye contact, language learning, language use and motivation for instance in social contexts, identifying socially relevant events and acting on them appropriately, regulating vocalizations, regulating overt inappropriate behaviors and acting-out, regulating temper and mood, regulating stimming and similar behaviors, coping with sensory input and aversive sensory feelings such as overload, and among several other things, the learning of abstract categories.

In autism as well as other conditions and in healthy individuals, it is advantageous to measure heart rate and other physiological signals, especially when measuring behaviors associated with a condition. For instance if a child looks at an adult who is displaying a facial expression of anger and the child's heart rate quickens, that is an indication that some aspect of the emotional expression was processed. If, however, a child looks at the same adult and experiences no change in heart rate or dynamics, this is consistent with being unaware of or insensitive to the emotional expression, which is more consistent with the response of a child with ASD.

In one aspect, the present disclosure relates to a system and methods for inexpensive, non-invasive measuring and monitoring heart rate and cardiovascular dynamics using a wearable data collection device through analysis of a variety of motion sensor data. It is advantageous to be able to measure heart rate and cardiovascular dynamics as non-invasively as possible. For instance, the ability to avoid electrodes, especially electrodes that must be adhered or otherwise attached to the skin, is in most situations preferable, particularly for children who do not like extraneous sensory stimulus on their skin. It is also advantageous to be able to derive, from a non-invasive signal, additional cardiovascular dynamics beyond simply heart rate, such as dynamics that may indicate unwellness and which may usually require multi-lead ECG setups and complex analysis.

In some implementations, a wearable data collection device including one or more motion sensors capable of discerning small motions of the body is placed comfortably and removably on an individual without need for gels or adhesives. The wearable data collection device may be a device specifically designed to measure and monitor cardiovascular dynamics of the body or a more general purpose personal wearable computing device capable of executing a software application for analyzing small motion data to obtain cardiovascular dynamics data.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1A is a block diagram of an example environment for evaluating an individual for Autism Spectrum Disorder using a wearable data collection device;

FIG. 1B is a block diagram of an example system for evaluation and training of an individual using a wearable data collection device;

FIGS. 2A and 2B are a swim lane diagram of an example method for performing a remote evaluation of an individual using a wearable data collection device;

FIG. 3A is a block diagram of an example computing system for training and feedback software modules incorporating data derived by a wearable data collection device;

FIG. 3B is a block diagram of an example computing system for analyzing and statistically learning from data collected through wearable data collection devices;

FIG. 4 is a flow chart of an example method for conducting an evaluation session using a wearable data collection device donned by a caregiver of an individual being evaluated for Autism Spectrum Disorder;

FIG. 5A is a block diagram of an example environment for augmented reality learning using a wearable data collection device;

FIG. 5B is a block diagram of an example collection of software algorithms or modules for implementing language and communication skill training, assessment, and coaching using a wearable data collection device;

FIG. 5C is a screen shot of an example display for coaching a user in performing a bow;

FIG. 5D is a screen shot of an example display for providing conversation skill feedback to a user;

FIG. 6A through 6D illustrate a flow chart of an example method for augmented reality learning using a wearable data collection device;

FIGS. 7A through 7C illustrate a flow chart of an example method for identifying socially relevant events and collecting information regarding the response of an individual to socially relevant events;

FIG. 7D illustrates a screen shot of an example feedback display for suggesting an intervention to a user;

FIG. 8 is a flow chart of an example method for conditioning social eye contact response through augmented reality using a wearable data collection device;

FIG. 9 is a block diagram of an example collection of software algorithms for implementing identification of and gauging reaction to socially relevant events;

FIG. 10A is a flow chart of an example method for identifying and presenting information regarding emotional states of individuals near an individual;

FIGS. 10B and 10C are screen shots of example user interfaces for identifying and presenting information regarding emotional states of an individual based upon facial expression;

FIG. 11 is a block diagram of an example system for identifying and analyzing circumstances surrounding adverse health events and/or atypical behavioral episodes and for learning potential triggers thereof;

FIG. 12 is a block diagram of an example wearable computing device; and

FIG. 13 is a block diagram of an example computing system.

DETAILED DESCRIPTION

As illustrated in FIG. 1A, an environment **100** for evaluating an individual **102** for autism spectrum disorder includes a wearable data collection device **104** worn by the individual **102** and/or a wearable data collection device **108** worn by a caregiver **106**, such that data **116** related to the interactions between the individual **102** and the caregiver **108** are recorded by at least one wearable data collection

device **104**, **108** and uploaded to a network **110** for analysis, archival, and/or real-time sharing with a remotely located evaluator **114**. In this manner, evaluation activities, to be evaluated in real time or after the fact by the evaluator **114**, may be conducted in the individual's accustomed surroundings without the stress and intimidation of the evaluator **114** being present. For example, evaluation activities may be conducted in a family's home environment at a time convenient for the family members.

Evaluation activities, in some implementations, include a set of play session phases incorporating, for example, various objects for encouraging interaction between the caregiver **106** and the individual **102**. For example, the caregiver **106** may be supplied with an evaluation kit including one or both of the individual's data collection device **104**, the caregiver data collection device **108**, a set of interactive objects, and instructions on how to conduct the session. The set of interactive objects, in one example, may include items similar to those included within the Screening Tool for Autism in Toddlers (STAT™) test kit developed by the Vanderbilt University Center for Technology Transfer & Commercialization of Nashville, Tenn. The instructions, in one example, may be provided textually, either online or in a booklet supplied in the evaluation kit. In another example, the instructions are presented in video form, either online or in a video recording (e.g., DVD) included in the kit.

In some implementations, the instructions are supplied via the caregiver wearable data collection device **108**. For example, the wearable data collection device **108** may include an optical head-mounted display (OHMD) such that the caregiver may review written and/or video instructions after donning the wearable data collection device **108**. The caregiver may perform a play session or test session based on the instructions, or by mirroring or responding to step-by-step directions supplied by a remote evaluator **114**, who can be a trained clinician or autism specialist, such that the remote evaluator **114** can walk the caregiver **106** through the process step by step, and the remote evaluator **114** can observe and evaluate the process and the behaviors of the individual **102** and other data in real time and directly through the eyes of the caregiver **106** (via a camera feed from the data collection device **104**).

The wearable data collection device **104** or **108**, in some implementations, is a head-mounted wearable computer. For example, the wearable data collection device **104** or **108** may be a standard or modified form of Google Glass™ by Google Inc. of Mountain View, Calif. In other examples, the wearable data collection device **104** or **108** is mounted in a hat, headband, tiara, or other accessory worn on the head. The caregiver **108** may use a different style of data collection device **108** than the individual **102**. For example, a caregiver may use a glasses style wearable data collection device **108**, while the subject uses a head-mounted visor style of data collection device **104**.

In some implementations, the data collection device **104** for the individual **102** and/or the data collection device **108** for the caregiver **106** is composed of multiple portions **105** of body-mountable elements configured to mount on different areas of the body. In general, the wearable data collection device **104** or **108** may be configured as a single, physically-contiguous device, or as a collection of two or more units that can be physically independent or semi-independent of each other but function as a whole as a wearable data collection device **104** or **108**. For example, the data collection device **104** or **108** may have a first portion including an optical head-mounted display (OHMD) and which therefore is mounted on or about the head such as in

a modified version of eyeglasses or on a visor, hat, headband, tiara or other accessory worn on the head. Further, the data collection device **104** or **108** may have a second portion separate from the first portion configured for mounting elsewhere on the head or elsewhere on the body. The second portion can contain, in some examples, sensors, power sources, computational components, data and power transmission apparatuses, and other components. For instance, in an illustrative example, the first portion of data collection device **104** or **108** may be used to display information to the user and/or perform various tasks of user interface, whereas the second portion of data collection device **104** or **108** may be configured to perform sensing operations that are best suited to specific parts of the body, and/or may be configured to perform computation and in so doing may consume power all of which may require a size and bulk that is better suited to be elsewhere on the body than a head-mounted device. Further to the example, the second portion of data collection device **104** or **108** may be configured to mount on the wrist or forearm of the wearer. In a particular configuration, the second portion may have a design similar to a watch band, where the second portion can be interchanged with that of a standard-sized wrist watch and thereby convert an off-the-shelf wrist watch into a part of a smart ecosystem and furthermore hide the presence of the second portion of the data collection device **104** or **108**. Although described as having two portions, in other implementations, the wearable data collection device **104** or **108** may include three or more portions physically independent of each other with each portion capable of inter-communicating with at least one of the other portions. Many other configurations are also anticipated.

The wearable data collection device **104** for the subject may be customized for use by an individual, for instance by making it fit the head better of someone of the age and size of a given individual **102**, or by modifying the dynamics of the display such that it is minimally distracting for the individual **102**. Another possible customization of the wearable data collection device **104** includes regulating the amount of time that the wearable data collection device **104** can be used so as to cause minimal change to the individual **102**, such as to the developing visual system of the individual **102**. The wearable data collection device **104**, in a further example, may be customized for the individual **102** to make the wearable data collection device **104** palatable or desirable to be worn by the individual **102** for instance by cosmetic or sensory modifications of the wearable data collection device **104**.

The wearable data collection device **104** or **108**, in some implementations, can be modified for the type of usage discussed herein, for instance by equipping it with an extended-life power source or by equipping it with an extended capacity for data acquisition such as video data acquisition with features such as extended memory storage or data streaming capabilities, or the like.

Rather than performing the described functionality entirely via a wearable data collection device **104** or **108**, in some implementations, the data collection device **104** or **108** includes a bionic contact lens. For example, the OHMD may be replaced with a bionic contact lens capable of providing augmented reality functionality. In another example, an implantable device, such as a visual prosthesis (e.g., bionic eye) may provide augmented reality functionality.

The wearable data collection device **104** or **108** can be arranged on the body, near the body, or embedded within the body, in part or entirely. When one or more components of the wearable data collection device **104** or **108** is embedded

within the body, the one or more components can be embedded beneath the skin; within the brain; in contact with input or output structures of the body such as peripheral nerves, cranial nerves, ganglia, or the spinal cord; within deep tissue such as muscles or organs; within body cavities; between organs; in the blood; in other fluid or circulatory systems; inside cells; between cells (such as in the interstitial space); or in any other manner arranged in a way that is embedded within the body, permanently or temporarily. When one or more components of the wearable data collection device **104** or **108** is embedded within the body, the one or more components may be inserted into the body surgically, by ingestion, by absorption, via a living vector, by injection, or other means. When one or more components of the wearable data collection device **104** or **108** is embedded within the body, the one or more components may include data collection sensors placed in direct contact with tissues or systems that generate discernible signals within the body, or stimulator units that can directly stimulate tissue or organs or systems that can be modulated by stimulation. Data collection sensors and stimulator units are described in greater detail in relation to FIG. **12**.

The wearable data collection device **104** or **108** can be configured to collect a variety of data **116**. For example, a microphone device built into the data collection device **104** or **108** may collect voice recording data **116a**, while a video camera device built into the data collection device **104** or **108** may collect video recording data **116b**. The voice recording data **116a** and video recording data **116b**, for example, may be streamed via the network **110** to an evaluator computing device (illustrated as a display **112**) so that the evaluator **114** reviews interactions between the individual **102** and the caregiver **108** in real-time. For example, as illustrated on the display **112**, the evaluator is reviewing video recording data **116j** recorded by the caregiver wearable data collection device **108**. Additionally, the evaluator may be listening to voice recording data **116a**.

Furthermore, in some implementations, the wearable data collection device **104** is configured to collect a variety of data regarding the movements and behaviors of the individual **102** during the evaluation session. For example, the wearable data collection device **104** may include motion detecting devices, such as one or more gyroscopes, accelerometers, global positioning system, and/or magnetometers used to collect motion tracking data **116h** regarding motions of the individual **102** and/or head position data **116d** regarding motion particular to the individual's head. The motion tracking data **116h**, for example, may track the individual's movements throughout the room during the evaluation session, while the head position data **116d** may track head orientation. In another example, the motion tracking data **116h** may collect data to identify repetitive motions, such as jerking, jumping, flinching, fist clenching, hand flapping, or other repetitive self-stimulating ("stimming") behaviors.

In some implementations, the wearable data collection device **104** is configured to collect eye tracking data **116g**. For example, the wearable data collection device **104** may include an eye tracking module configured to identify when the individual **102** is looking straight ahead (for example, through the glasses style wearable data collection device **104**) and when the individual **102** is peering up, down, or off to one side. In another example, the individual's data collection device **104** is configured to communicate with the caregiver data collection device **108**, such that the wearable data collection devices **104**, **108** can identify when the individual **102** and the caregiver **106** have convergent head orientation. In some examples, a straight line wireless sig-

nal, such as a Bluetooth signal, infrared signal, or RF signal, is passed between the individual's wearable data collection device 104 and the caregiver wearable data collection device 108, such that a wireless receiver acknowledges when the two wearable data collection devices 104, 108 are positioned in a substantially convergent trajectory.

The wearable data collection device 104, in some implementations, is configured to monitor physiological functions of the individual 102. In some examples, the wearable data collection device 104 may collect heart and/or breathing rate data 116e (or, optionally, electrocardiogram (EKG) data), electroencephalogram (EEG) data 116f, and/or Electromyography (EMG) data 116i). The wearable data collection device 104 may interface with one or more peripheral devices, in some embodiments, to collect the physiological data. For example, the wearable data collection device 104 may have a wired or wireless connection with a separate heart rate monitor, EEG unit, or EMG unit. In other embodiments, at least a portion of the physiological data is collected via built-in monitoring systems. Unique methods for non-invasive physiological monitoring are described in greater detail in relation to FIG. 11. Optional onboard and peripheral sensor devices for use in monitoring physiological data are described in relation to FIG. 12.

In some implementations, during an evaluation session, the individual's wearable data collection device 104 gathers counts data 116c related to patterns identified within other data 116. For example, the individual's data collection device 104 may count verbal (word and/or other vocalization) repetitions identified within the voice recording data 116a and movement repetitions identified in the head position data 116d and/or the motion tracking data 116h. The baseline analysis for identifying repetitions (e.g., time span between repeated activity, threshold number of repetitions, etc.), in some embodiments, may be tuned by educators and/or clinicians based upon baseline behavior analysis of "normal" individuals or typical behaviors indicative of individuals with a particular clinical diagnosis such as ASD. For example, verbal repetition counts 116c may be tuned to identify repetitive vocalizations separate from excited stuttering or other repetitive behaviors typical of children of an age or age range of the individual. In another example, movement repetition counts 116c may distinguish from dancing and playful repetitive behaviors of a young child. Autism assessment, progress monitoring, and coaching all are currently done with little or no support via structured, quantitative data which is one reason that rigorous counts 116c are so very important. Counts 116c can include other types of behavior such as rocking, self-hugging, self-injurious behaviors, eye movements and blink dynamics, unusually low-movement periods, unusually high-movement periods, irregular breathing and gasping, behavioral or physiological signs of seizures, irregular eating behaviors, and other repetitive or irregular behaviors.

In other implementations, rather than collecting the counts data 116c, a remote analysis and data management system 118 (e.g., networked server, cloud-based processing system, etc.) analyzes a portion of the session data 116 to identify at least a portion of the counts data 116c (e.g., verbal repetition counts and/or movement repetition counts). For example, a session data analysis engine 120 of the remote analysis and data management system 118 may analyze the voice recording data 116a, motion tracking data 116h, and/or head position data 116d to identify the verbal repetition counts and/or movement repetition counts.

In some implementations, the analysis is done at a later time. For example, the analysis and data management sys-

tem 118 may archive the session data 116 in an archive data store 122 for later analysis. In other implementations, the session data and analysis engine 120 analyzes at least a portion of the session data 116 in real-time (e.g., through buffering the session data 116 in a buffer data store 124). For example, a real-time analysis of a portion of the session data 116 may be supplied to the evaluator 114 during the evaluation session. The real-time data analysis, for example, may be presented on the display 112 as session information and statistics information 126. In some examples, statistics information 126 includes presentation of raw data values, such as a graphical representation of heart rate or a graphical presentation of present EEG data. In other examples, statistics information 126 includes data analysis output, such as a color-coded presentation of relative excitability or stimulation of the subject (e.g., based upon analysis of a number of physiological factors) or graphic indications of identified behaviors (e.g., an icon displayed each time social eye contact is registered).

Session information and statistics information 126 can be used to perform behavioral decoding. Behavioral decoding is like language translation except that it decodes the behaviors of an individual 102 rather than verbal language utterances. For instance, a result of the session data analysis 120 might be that a pattern emerges whereby repetitive vocalizations of a particular type as well as repeated touching of the cheek are correlated, in the individual 102, with ambient temperature readings below a certain temperature level, and the behaviors cease when the temperature rises. Once this pattern has been reliably measured by the system 100, upon future episodes of those behaviors, the system 100 could present to the caregiver 108 or evaluator 114 some information such as that the subject is likely too cold. The system 100 can also interface directly with control systems in the environment, for instance in this case the system 100 may turn up a thermostat to increase the ambient temperature. This example is illustrative of many possibilities for behavioral decoding. The system 100 increases in ability to do behavioral decoding the longer it interacts with the individual 102 to learn the behavioral language of the individual 102. Furthermore, the greater the total number of individuals interacting with the system 100, the greater the capacity of the system 100 to learn from normative data to identify stereotypical communication strategies of individuals within subgroups of various conditions, such as subgroups of the autism spectrum.

During an evaluation session, in an illustrative example, the caregiver 106 is tasked with performing interactive tasks with the individual 102. Video recording data 116j collected by the caregiver wearable data collection device 108 is supplied to a computing system of the evaluator 114 in real-time via the analysis and data management system 118 such that the evaluator 114 is able to see the individual 102 more or less "through the eyes of" the caregiver 108 during the evaluation session. The evaluator 114 may also receive voice recording data 116a from either the caregiver wearable data collection device 108 or the subject wearable data collection device 104.

Should the evaluator 114 wish to intercede during the evaluation session, in some implementations, the evaluator 114 can call the caregiver 106 using a telephone 128. For example, the caregiver 106 may have a cell phone or other personal phone for receiving telephone communications from the evaluator 114. In another example, the caregiver wearable computing device 108 may include a cellular communications system such that a telephone call placed by the evaluator 114 is connected to the caregiver wearable

computing device 108. In this manner, for example, the caregiver 108 may receive communications from the evaluator 114 without disrupting the evaluation session.

In other implementations, a computer-aided (e.g., voice over IP, etc.) communication session is established between the evaluator 114 computing system and the caregiver wearable data collection device 108. For example, the analysis and data management system 118 may establish and coordinate a communication session between the evaluator system and the caregiver wearable data collection device 108 for the duration of the evaluation system. Further, the analysis and data management system 118, in some embodiments, may collect and store voice recording data of commentary supplied by the evaluator 114.

In some examples, the evaluator 114 may communicate with the caregiver 106 to instruct the caregiver 106 to perform certain interactions with the individual 102 or to repeat certain interactions with the individual 102. Prior to or at the end of an evaluation session, furthermore, the evaluator 114 may discuss the evaluation with the caregiver 106. In this manner, the caregiver 106 may receive immediate feedback and support of the evaluator 114 from the comfort of her own home.

FIG. 1B is a block diagram of an example system 150 for evaluation and training of the individual 102 using the wearable data collection device 104. Data 116 collected by the wearable data collection device 104 (and, optionally or alternatively, data collected by the caregiver data collection device 108 described in relation to FIG. 1A) is used by a number of algorithms 154 developed to analyze the data 116 and determine feedback 156 to provide to the individual 102 (e.g., via the wearable data collection device 104 or another computing device). Furthermore, additional algorithms 532, 534, 536, 538, 540, 542, and 544 described in relation to FIG. 5B and/or algorithms 910 and 912 described in relation to FIG. 9 may take advantage of components of the system 150 in execution. The algorithms 154 may further generate analysis information 158 to supply, along with at least a portion of the data 116, to learning engines 162. The analysis information 158 and data 116, along with learning information 164 generated by the learning engines 162, may be archived as archive data 122 for future use, such as for pooled statistical learning. The learning engines 162, furthermore, may provide learned data 166 and, potentially, other system updates for use by the wearable data collection device 104. The learned data 166, for example, may be used by one or more of the algorithms 154 residing upon the wearable data collection device 104. A portion or all of the data analysis and feedback system 152, for example, may execute upon the wearable data collection device 104. Conversely, in some implementations, a portion or all of the data analysis and feedback system 152 is external to the wearable data collection device 104. For example, certain algorithms 154 may reside upon a computing device in communication with the wearable data collection device 104, such as a smart phone, smart watch, tablet computer, or other personal computing device in the vicinity of the individual 102 (e.g., belonging to a caregiver, owned by the individual 102, etc.). Certain algorithms 154, in another example, may reside upon a computing system accessible to the wearable data collection device 104 via a network connection, such as a cloud-based processing system.

The algorithms 154 represent a sampling of potential algorithms available to the wearable data collection device 104 (and/or the caregiver wearable data collection device 108 as described in relation to FIG. 1A). The algorithms 154 include an audio recording analysis algorithm 154a, a video

recording analysis algorithm 154b, an eye motion analysis algorithm 154c, a head motion analysis algorithm 154d, a social eye contact identifying algorithm 154e, a feedback presentation algorithm 154f, a subject response analysis algorithm 154g, a vocalized repetition tracking algorithm 154h (e.g., to generate a portion of the counts data 116c illustrated in FIG. 1A), a movement repetition tracking algorithm 154i (e.g., to generate a portion of the counts data 116c illustrated in FIG. 1A), an object identification algorithm 154j, a physiological state analysis algorithm 154k, an emotional state analysis algorithm 154l, a social response validation algorithm 154m, a desired response identification algorithm 154n, a social event identification algorithm 154o, and a verbal response validation engine 154p. Versions of one or more of the algorithms 154 may vary based upon whether they are executed upon the individual's wearable data collection device 104 or the caregiver wearable data collection device 108. For example, the social eye contact identification algorithm 154e may differ when interpreting video recording data 116b supplied from the viewpoint of the individual 102 as compared to video recording data 116b supplied from the viewpoint of the caregiver 106 (illustrated in FIG. 1A).

The algorithms 154 represent various algorithms used in performing various methods described herein. For example, method 600 regarding identifying objects labeled with standardized index elements (described in relation to FIG. 6A) and/or method 610 regarding extracting information from objects with standardized index elements (described in relation to FIG. 6B), may be performed by the object identification algorithm 154j. Step 662 of method 630 (described in relation to FIG. 6D) regarding validating the subject's response may be performed by the verbal response validation algorithm 154p. Step 664 of method 630 (described in relation to FIG. 6D) regarding providing feedback regarding the subject's response may be performed by the feedback presentation algorithm 154f. Step 704 of method 700 regarding detection of a socially relevant event, described in relation to FIG. 7A, may be performed by the social event identification algorithm 154o. Step 716 of method 700 regarding determination of a desired response to a socially relevant event may be performed by the desired response identification algorithm 154n. Step 718 of method 700 regarding comparison of the subject's actual response may be performed by the social response validation algorithm 154m. Step 740 of method 700 regarding reviewing physiological data, described in relation to FIG. 7B, may be performed by the physiological state analysis algorithm 154k. Step 802 of method 800 regarding identification of faces in video data, described in relation to FIG. 8, may be performed by the video recording analysis algorithm 154b. Step 810 of method 800 regarding identification of social eye contact may be performed by the social eye contact identification algorithm 154e. The social eye contact identification algorithm 154e, in turn, may utilize the eye motion analysis engine 154c and/or the head motion analysis engine 154d in identifying instances of social eye contact between the individual 102 and another individual. Step 816 of method 800 regarding ascertaining an individual's reaction to feedback may be performed by the subject response analysis algorithm 154g. Step 1006 of method 1000 regarding identifying an emotional state of an individual, described in relation to FIG. 10A, may be performed by the emotional state analysis algorithm 154l. Step 1010 of method 1000 regarding analyzing audio data for emotional cues may be performed by the audio recording analysis algorithm 154a.

The algorithms **154**, in some implementations, are utilized by various software modules **302** described in relation to FIG. 3A. For example, a social eye contact training module **302a** may utilize the social eye contact identification algorithm **154e**. A socially relevant event training module **302b**, in another example, may utilize the social response validation algorithm **154m**, the desired response identification algorithm **154n**, and/or the social event identification algorithm **154o**.

The algorithms **154**, in some implementations generate analysis information **158** such as, for example, the derived session data **306** illustrated in FIG. 3A. The analysis information **158** may be provided in real time and/or in batch mode to a learning and statistical analysis system **160** including the learning engines **162**. The learning engines **162**, for example, may include the statistical analysis software modules **352** illustrated in FIG. 3B. A portion of the statistical analysis system **160** may execute upon the wearable data collection device **104**. Conversely, in some implementations, a portion or all of the statistical analysis system **160** is external to the wearable data collection device **104**. For example, certain learning engines **162** may reside upon a computing device in communication with the wearable data collection device **104**, such as a smart phone, smart watch, tablet computer, or other personal computing device in the vicinity of the individual **102** (e.g., belonging to a caregiver, owned by the individual **102**, etc.). The statistical analysis system **160**, in another example, may reside upon a computing system accessible to the wearable data collection device **104** via a network connection, such as a cloud-based processing system.

The learning engines **162**, in some implementations, generate learning information **164**. For example, as illustrated in FIG. 3B, statistically learned data **356** may include social interaction patterns **356e**. The learning engines **162** may execute a subject social interaction progress software module **352a** to track progress of interactions of the individual **102** with the caregiver **106**. Further, statistically learned data **356**, in some implementations, may lead to system updates **166** presented to improve and refine the performance of the wearable data collection device **104**. Statistically learned data **356**, in some implementations, can be used to predict acting out or episodes in people with ASD. In some implementations, statistically learned data **356** can be used to predict, based on current conditions and environmental features as well as physiological or behavioral signals from the subject, unwellness or health episodes such as seizures or migraine onset or heart attacks or other cardiovascular episodes, or other outcomes such as are related to ASD. Statistically learned data **356** can be used to provide behavioral decoding. For instance, statistically learned data **356** may indicate that one type of self-hitting behavior plus a specific vocalization occurs in an individual **102** most frequently before meal times, and these behaviors are most pronounced if a meal is delayed relative to a regular meal time, and that they are extinguished as soon as a meal is provided and prevented if snacks are given before a regular meal. In this context, these behaviors may be statistically associated with hunger. The prior example is simplistic in nature—a benefit of computer-based statistical learning is that the statistical learning data **356** can allow the system to recognize patterns that are less obvious than this illustrative example. In the present example, at future times, statistical learning data **356** that resulted in recognition of a pattern such as mentioned can provide for behavioral decoding such as recognizing the behaviors as an indicator that the individual **102** is likely hungry.

Behavioral decoding can be used for feedback and/or for intervention. For instance, in terms of feedback, the system, in some implementations, provides visual, textual, auditory or other feedback to the individual **102**, caregiver **106**, and/or evaluator **114** (e.g., feedback identifying that the individual **102** is likely hungry). Behavioral decoding can also be used for intervention. For instance, in this case, when the aforementioned behaviors start emerging, a control signal can be sent from the system **100** to trigger in intervention that will reduce hunger, such as in this case ordering of food or instruction to the caregiver to provide food.

Turning to FIGS. 2A and 2B, a swim lane diagram illustrates a method **200** for conducting an evaluation session through a caregiver system **204** and a user system **202** monitored by an evaluator system **208**. Information passed between the evaluator system **208** and either the caregiver system **204** or the user system **202** is managed by an analysis system **206**. The caregiver system **204** and/or the user system **202** include a wearable data collection device, such as the wearable data collection devices **104** and **108** described in relation to FIG. 1A. The evaluation system **208** includes a computing system and display for presentation of information collected by the wearable data collection device(s) to an evaluator, such as the evaluator **114** described in relation to FIG. 1A. The analysis system **206** includes a data archival system such as the data buffer **128** and/or the data archive **122** described in relation to FIG. 1A, as well as an analysis module, such as the session data analysis engine **120** described in relation to FIG. 1A.

In some implementations, the method **200** begins with initiating an evaluation session (**210**) between the caregiver system **204** and the user system **202**. An evaluator may have defined parameters regarding the evaluation session, such as a length of time, activities to include within the evaluation session, and props or objects to engage with during the evaluation session. In initiating the evaluation session, a software application functioning on the caregiver system **204** may communicate with a software application on the user system **202** to coordinate timing and initialize any data sharing parameters for the evaluation session. In a particular example, the caregiver system **204** may issue a remote control “trigger” to the user system **202** (e.g., wearable data collection device) to initiate data collection by the user system **202**. Meanwhile, the caregiver system **204** may initiate data collection locally (e.g., audio and/or video recording).

In some implementations, initiating the evaluation session further includes opening a real-time communication channel with the evaluator system **208**. For example, the real-time evaluation session may be open between the caregiver system **204** and the evaluator system **208** and/or the user system **202** and the evaluator system **208**. In some implementations, the caregiver system **204** initiates the evaluation session based upon an initiation trigger supplied by the evaluator system **208**.

In some implementations, session data is uploaded (**212**) from the user system **202** to the analysis system **206**. For example, data collected by one or more modules functioning upon the user system **202**, such as a video collection module and an audio collection module, may be passed from the subject system **202** to the analysis system **206**. The data, in some embodiments, is streamed in real-time. In other embodiments, the data is supplied at set intervals, such as, in some examples, after a threshold quantity of data has been collected, after a particular phase of the session has been completed, or upon pausing an ongoing evaluation session. The data, in further examples, can include eye tracking data,

motion tracking data, EMG data, EEG data, heart rate data, breathing rate data, and data regarding subject repetitions (e.g., repetitive motions and/or vocalizations).

Furthermore, in some implementations, session data is uploaded (214) from the caregiver system 204 to the analysis system 206. For example, audio data and/or video data collected by a wearable data collection device worn by the caregiver may be uploaded to the analysis system 206. Similar to the upload from the subject system 202 and the analysis system 206, data upload from the caregiver system 204 to the analysis system 206 may be done in real time, periodically, or based upon one or more triggering events.

In some implementations, the analysis system 206 analyzes (216) the session data. Data analysis can include, in some examples, identifying instances of social eye contact between the individual and the caregiver, identifying emotional words, and identifying vocalization of the subject's name. The analysis system 206, in some embodiments, determines counts of movement repetitions and/or verbal repetitions during recording of the individual's behavior. Further, in some embodiments, data analysis includes deriving emotional state of the individual from one or more behavioral and/or physiological cues (e.g., verbal, body language, EEG, EMG, heart rate, breathing rate, etc.). For example, the analysis system 206 may analyze the reaction and/or emotional state of the individual to the vocalization of her name. The analysis system 206, in some embodiments, further analyzes caregiver reactions to identified behaviors of the individual such as, in some examples, social eye contact, repetitive behaviors, and vocalizations. For example, the analysis system 206 may analyze body language, emotional words, and/or vocalization tone derived from audio and/or video data to determine caregiver response.

In some implementations, analyzing the session data (216) includes formatting session data into presentation data for the evaluator system 208. For example, the analysis system 206 may process heart rate data received from the user system 202 to identify and color code instances of elevated heart rate, as well as preparing presentation of the heart rate data in graphic format for presentation to the evaluator. If prepared in real time, the session data supplied by the user system 202 and/or the caregiver system 204 may be time delayed such that raw session information (e.g., video feed) may be presented to the evaluator simultaneously with processed data feed (e.g., heart rate graph).

The analysis system 206, in some implementations, archives at least a portion of the session data. For example, the session data may be archived for review by an evaluator at a later time. In another example, archived system data may be analyzed in relation to session data derived from a number of additional subjects to derive learned statistical data (described in greater detail in relation to FIG. 3B).

In some implementations, the analysis system 206 provides (218) session information, including raw session data and/or processed session data, to the evaluator system 208. At least a portion of the session data collected from the user system 202 and/or the caregiver system 204, in one example, is supplied in real time or near-real time to the evaluator system 208. As described above, the session information may include enhanced processed session data prepared for graphical presentation to the evaluator. In another example, the evaluator system 208 may request the session information from the analysis system 206 at a later time. For example, the evaluator may review the session after the individual and caregiver have completed and authorized upload of the session to the analysis system. In this manner,

the evaluator may review session data at leisure without needing to coordinate scheduling with the caregiver.

In some implementations, if the evaluator is reviewing the session information in near-real-time, the evaluator system 208 issues (222) an instruction to the caregiver system 204. The evaluator, for example, may provide verbal instructions via a telephone call to the caregiver system 204 or an audio communication session between the evaluator system 208 and the caregiver system 204. For example, a voice data session may be established between the evaluator system 208 and the caregiver's wearable data collection device. In another example, the evaluator system 208 may supply written instructions or a graphic cue to the caregiver system 204. In a particular example, a graphic cue may be presented upon a heads-up display of the caregiver's wearable data collection device to prompt the caregiver to interact with the individual using a particular object.

Rather than issuing an instruction, in some implementations the evaluator system 208 takes partial control of either the caregiver system 204 or the user system 202. In some examples, the evaluator system 208 may assert control to speak through the user system 202 to the individual or to adjust present settings of the wearable data collection device of the caregiver. In taking partial control of the caregiver system 204 or the user system 202, the evaluator system 208 may communicate directly with either the caregiver system 204 or the user system 202 rather than via the relay of the analysis system 206.

Similarly, although the instruction, as illustrated, bypasses the analysis system 206, the communication session between the evaluator system 208 and the caregiver system 204, in some implementations, is established by the analysis system 206. The analysis system 206, in some embodiments, may collect and archive a copy of any communications supplied to the caregiver system 204 by the evaluator system 208.

In some implementations, the caregiver system 204 performs (224) the instruction. For example, the instruction may initiate collection of additional data and/or real-time supply of additional data from one of the caregiver system 204 and the subject system 202 to the evaluator system 208 (e.g., via the analysis system 206). The evaluator system 208, in another example, may cue a next phase on the evaluation session by presenting instructional information to the caregiver via the caregiver system 204. For example, upon cue by the evaluator system 208, the caregiver system 204 may access and present instructions for performing the next phase of the evaluation session by presenting graphical and/or audio information to the caregiver via the wearable data collection device.

In some implementations, the user system 202 uploads (226) additional session data and the caregiver system 204 uploads (228) additional session data. The data upload process may continue throughout the evaluation session, as described, for example, in relation to steps 212 and steps 214.

Turning to FIG. 2B, in some implementations, the evaluator enters (230) evaluation data via the evaluator system 208. For example, the evaluator may include comments, characterizations, caregiver feedback, and/or recommendations regarding the session information reviewed by the evaluator via the evaluator system 208.

In some implementations, the evaluator system 208 provides (232) the evaluation data to the analysis system 206. The evaluation data, for example, may be archived along with the session data. At least a portion of the evaluation data, furthermore, may be supplied from the analysis system

206 to the caregiver system 204, for example as immediate feedback to the caregiver. In some embodiments, a portion of the evaluation data includes standardized criteria, such that the session data may be compared to session data of other individuals characterized in a same or similar manner during evaluation.

In some implementations, the analysis system 206 archives (234) the session and evaluation data. For example, the session and evaluation data may be uploaded to long term storage in a server farm or cloud storage area. Archival of the session data and evaluation data, for example, allows data availability for further review and/or analysis. The session data and evaluation data may be anonymized, secured, or otherwise protected from misuse prior to archival.

In some implementations, the analysis system 206 statistically analyzes (236) the archived data from multiple sessions. In one example, archived session data may be compared to subsequent session data to reinforce characterizations or to track progress of the individual. In another example, as described above, the session data may be evaluated in relation to session data obtained from further individuals to derive learning statistics regarding similarly characterized individuals. The evaluation data supplied by the evaluator in step 230, in one example, may include an indication of desired analysis of the session data. For example, the session data may be compared to session data collected during evaluation of a sibling of the subject on a prior occasion.

In some implementations, the analysis system 206 provides (238) analysis information derived from the archived session data to the evaluator system 208. For example, upon analyzing the session data in view of prior session data with the same individual, progress data may be supplied to the evaluator system 208 for review by the evaluator.

FIG. 3A is a block diagram of a computing system 300 for training and feedback software modules 302 for execution in relation to a wearable data collection device. The training and feedback software modules 302 incorporate various raw session data 304 obtained by a wearable data collection device, and generate various derived session data 306. The training and feedback software modules 302, for example, may include software modules capable of executing on any one of the subject wearable data collection device 104, the caregiver wearable data collection device 108, and the analysis and data management system 118 of FIG. 1A. Further, at least a portion of the training and feedback software modules 302 may be employed in a system 500 of FIG. 5A, for example in a wearable data collection device 504 and/or a learning data analysis system 520, or in a system 1100 of the FIG. 11, for example in a wearable data collection device 1104 and/or a learning data analysis system 1118. The raw session data 304, for example, may represent the type of session data shared between the subject system 202 or the caregiver system 204 and the analysis system 206, as described in relation to FIG. 2A.

FIG. 3B is a block diagram of a computing system 350 for analyzing and statistically learning from data collected through wearable data collection devices. The archived session data 354 may include data stored as archive data 122 as described in FIG. 1A and/or data stored as archive data 1122 as described in FIG. 11. For example, the analysis system 206 of FIG. 2B, when statistically analyzing the archived data in step 236, may perform one or more of the statistical analysis software modules 352 upon a portion of the archived session data 354.

FIG. 4 is a flow chart of an example method 400 for conducting an evaluation session using a wearable data collection device donned by a caregiver of an individual being evaluated for Autism Spectrum Disorder. The method 400, for example, may be performed independent of an evaluator in the comfort of the caregiver's home. The caregiver may be supplied with a kit including a wearable data collection device and instructions for performing an evaluation session. The kit may optionally include a wearable data collection device for the individual.

In some implementations, the method 400 begins with the caregiver donning the wearable data collection device (402). Examples of a wearable data collection device are described in relation to FIG. 1A. The wearable data collection device, for example, may include a head-mounted lens for a video recording system, a microphone for audio recording, and a head-mounted display. Further, the wearable data collection device may include a storage medium for storing data collected during the evaluation session.

In some implementations, the evaluation session is initiated (404). Upon powering and donning the wearable data collection device, or launching an evaluation session application, the evaluation session may be initiated. Initiation of the evaluation session may include, in some embodiments, establishment of a communication channel between the wearable data communication device and a remote computing system.

In some implementations, instructions are presented for a first phase of evaluation (406). The instructions may be in textual, video, and/or audio format. Instructions, for example, may be presented upon a heads-up display of the wearable data collection device. If a communication channel was established with the remote computing system, the instructions may be relayed to the wearable data communication device from the remote computing system. In other embodiments, the instructions may be programmed into the wearable data communication device. The evaluation kit, for example, may be preprogrammed to direct the caregiver through an evaluation session tailored for a particular individual (e.g., first evaluation of a 3-year-old male lacking verbal communication skills versus follow-on evaluation of an 8-year-old female performing academically at grade level). In another example, the caregiver may be prompted for information related to the individual, and a session style may be selected based upon demographic and developmental information provided. In other implementations, rather than presenting instructions, the caregiver may be prompted to review a booklet or separate video to familiarize himself with the instructions.

The evaluation session, in some implementations, is performed as a series of stages. Each stage for example, may include one or more activities geared towards encouraging interaction between the caregiver and the individual. After reviewing the instructions, the caregiver may be prompted to initiate the first phase of evaluation. If the phase is initiated, in some implementations, audio and video recording of the evaluation phase is initiated (410). The wearable data collection device, for example, may proceed to collect data related to the identified session.

In some implementations, upon conclusion of the phase, the caregiver is prompted for approval (412). The caregiver may be provided the opportunity to approve the phase of evaluation, for example, based upon whether the phase was successfully completed. A phase may have failed to complete successfully, in some examples, due to unpredicted interruption (e.g., visitor arriving at the home, child running from the room and refusing to participate, etc.).

In some implementations, if the phase has not been approved (414), the phase may be repeated by re-initiating the current phase (408) and repeating collection of audio and video recording (410). In this manner, if the evaluation session phase is interrupted or otherwise failed to run to completion, the caregiver may re-try a particular evaluation phase.

Upon approval by the caregiver of the present phase (414), in some implementations, session data associated with the particular phase is stored and/or uploaded (416). The data, for example, may be maintained in a local storage medium by the wearable data collection device or uploaded to the remote computing system. Metadata, such as a session identifier, phase identifier, subject identifier, and timestamp, may be associated with the collected data. In some implementations, for storage or transfer, the wearable data collection device secures the data using one or more security algorithms to protect the data from unauthorized review.

In some implementations, if additional phases of the session exist (418), instructions for a next phase of the evaluation are presented (406). As described above in relation to step 406, for example, the wearable data collection device may present instructions for caregiver review or prompt the caregiver to review separate instructions related to the next phase.

In some implementations, at the end of each phase, the caregiver may be provided the opportunity to suspend a session, for example to allow the individual to take a break or to tend to some other activity prior to continuing the evaluation session. In other implementations, the caregiver is encouraged to proceed with the evaluation session, for example to allow an evaluator later to review the individual's responses as phase activities are compounded.

If no additional phases exist in the evaluation session (418), in some implementations, remaining session data is uploaded or stored (420) as described in step 416. If the phase data was previously stored locally on the wearable data collection device, at this point, the entire session data may be uploaded to the remote computing system. In other embodiments, the session data remains stored on the wearable data collection device, and the wearable data collection device may be returned for evaluation and reuse purposes. In addition to the session data, the caregiver may be prompted to provide additional data regarding the session, such as a session feedback survey or comments regarding the individual's participation in the evaluation session compared to the individual's typical at-home behaviors. This information may be uploaded or stored along with the data collected for each evaluation phase.

FIG. 5A is a block diagram of an example environment 500 for augmented reality learning, coaching, and assessment using a wearable data collection device 504. As illustrated, the wearable data collection device 504 shares many of the same data collection features 116 as the wearable data collection devices 104 and 108 described in relation to FIG. 1A. Additionally, the wearable data collection device includes data collection and interpretation features 506 configured generally for identifying objects and individuals within a vicinity of an individual 502 and for prompting, coaching, or assessing interactions between the individual 502 and those objects and individuals within the vicinity.

In some implementations, the example environment includes a remote analysis system 514 for analyzing the data 116 and/or 506 using one or more learning data analysis modules 520 executing upon a processing system 518 (e.g., one or more computing devices or other processing cir-

cuitry). The learning data analysis module(s) 520 may store raw and/or analyzed data 116, 506 as session data 516 in a data store 524. Further, the remote analysis system 514 may archive collected data 116 and/or 506 in a data archive 522 for later analysis or for crowd-sourced sharing to support learning engines to enhance performance of the learning data analysis modules 520.

In addition to or in replacement of the learning data analysis module(s) 520, in some implementations, the processing system 518 includes one or more language and communication algorithms 530 (e.g., software, firmware, and/or hardware-based computing algorithms designed to assess, train, and coach the individual 502 in language and communication skills), illustrated in FIG. 5B. Rather than residing in the remote analysis system 514, in some implementations, one or more of the algorithms 530 (or feature portions thereof) are executed upon the wearable data collection device and/or on a peripheral computing device in communication with the wearable data collection device.

Turning to FIG. 5B, the language and communication algorithms 530 include a set of reading tools 532, a set of speech-filtering tools 534, a set of conversational tools 536, a set of communicative gesture tools 538, a set of speech coaching tools 540, a set of interpersonal communication tools 542, and a teleprompter algorithm 544. Although each set of tools 532-542 includes individual topic algorithms, in other implementations, one or more of the algorithms 532-542 may be combined. Additionally, a particular algorithm 532-544 may be divided into two or more algorithm modules. The algorithms 532-544, together, provide a language tool set configured to support reading, linguistics, interpersonal communications, and speech understanding.

Beginning with the reading tools 532, a machine vision language tutor algorithm 532a, in some implementations, supports recognition and learning modules incorporating machine-encoded objects within the vicinity of the individual 502. Turning to FIG. 5A, the machine vision language tutor algorithm 532a may include, for example, the ability to identify encoded objects within the vicinity of the wearable data collection device 504. For example, the machine vision language tutor algorithm 532a may scan the immediate vicinity of the individual 502 wearing the wearable data collection device 504 to identify objects encoded with standardized index elements 512, such as, in some examples, a two-dimensional barcode, three-dimensional barcode, QR code, radio-frequency identification (RFID) tags, and other machine-readable labels or electronically transmitting smart labels. As illustrated, a ball object 508 includes an RFID tag element 512a and a clock object 510 includes a QR code element 512b. Each standardized index element 512, in turn, may be encoded with or otherwise identify a unique object index 506a. In one example, the machine vision language tutor algorithm 532a, executing upon the wearable data collection device 504 or a computing device in communication with the wearable data collection device (e.g., the processing system 518 or a local computing device such as a smart phone, tablet computer, etc.) 504 may use one or more hardware, firmware, or software elements of the wearable data collection device to scan the immediate vicinity to collect object indices 506a associated with each encoded object 508, 510. In a particular example, the machine vision language tutor algorithm 532a may use an RFID scanner feature of the wearable data collection device 504 to scan the vicinity to identify the RFID tag 512a. In another example, the machine vision language tutor algorithm 532a may analyze video recording data 116b captured by the wearable data collection device 504 or a computing

system in communication with the wearable data collection device **504** to identify the standardized index elements **512** (e.g., QR codes or bar codes). In other examples, the machine vision language tutor algorithm **532a** uses machine-vision processes, machine-hearing, or other signal processing abilities of the wearable data collection device **504** to identify objects with standardized index elements in the vicinity. To improve recognition of objects encoded with standardized index elements within the vicinity, in some embodiments, the machine vision language tutor algorithm **532a** may use two or more separate methods of identifying items. The machine vision language tutor algorithm **532a** may cross-reference the objects identified using a first recognition method, for example, with the objects identified using a second recognition method.

In some implementations, each standardized index element **512** is embedded with a particular identifier (e.g., substring) that is otherwise unlikely to occur in that particular type of index element, such that the identifier can be used to identify standardized index elements created for use with the wearable data collection device **504**. For example, while scanning the vicinity for standardized index elements, the machine vision language tutor algorithm **532a** can ignore those labels (e.g., QR codes, RFID tags) lacking the identifier.

In some implementations, the machine vision language tutor algorithm **532a** matches object data **506f** to each object index **506a**. For example, the machine vision language tutor algorithm **532a** may apply the object index **506a** to a look-up table to derive associated object data **506f** regarding the encoded object. In the event that the object data **506f** accessed depends upon a particular functional mode of the machine vision language tutor algorithm **532a** and/or the wearable data collection device **504**, the machine vision language tutor algorithm **532a** may access a mode-specific look-up table to derive associated object data **506f**. In another example, the machine vision language tutor algorithm **532a** may access a database to derive multiple representations of a particular data group, for example object data **506f** including terms for an item in a number of foreign languages. In another example, a smart label such as an RFID tag may include embedded object data **506f** which can be read by the machine vision language tutor algorithm **532a**.

The machine vision language tutor algorithm **532a**, in some implementations, presents a portion of the derived object data **506f** to the individual **502**. For example, video augmentation data **506b** may be used by a video augmentation module of the machine vision language tutor algorithm **532a** to portray the names of each object in a display region of the wearable data collection device **504** as written words floating above or upon each object. In another example, the machine vision language tutor algorithm **532a** may cause the names of each object may be intoned audibly to the individual **502**, for example through a sound system of the wearable data collection device **504** that includes a headphone or bone-conduction speaker. In further examples, the machine vision language tutor algorithm **532a** may present derived object data **506f** associated with the object to the individual **502**, such as a tick-tock and/or chiming sound associated with a clock.

In some implementations, prior to presenting any object data **506f** related to the acquired object indices **506a**, the individual **502** may first select a desired object. Selection, in some examples, may be accomplished via a hand gesture, head gesture, eye movement (e.g., double blink), audible command, thought pattern, or other instruction issued by the

individual **502** via an input system of the wearable data collection device **504**. Upon selection of one of the objects **508**, **510**, for example, the video augmentation module of the machine vision language tutor algorithm **532a** may present the individual **502** with an augmented video representation of the field of vision, including object data **506f** regarding the selected object **508**. In another example, an audio feedback module of the machine vision language tutor algorithm **532a** may play audible object data **506f** regarding the selected object **508**, **510**.

In some implementations, selection of an object triggers a deep information retrieval module of the machine vision language tutor algorithm **532a**. For example, in the context of a chemistry lab, initial object data **506f** may include the name of a chemical compound, while a second (deeper) level of object data **506f** may include a chemistry information sheet regarding the specific compound. Rather than presenting the deeper level object data **506f** via the wearable data collection device **504**, in some embodiments the machine vision language tutor algorithm **532a** may redirect the deeper level object data **506f** to a separate computing device, such as, in some examples, a smart phone, tablet computer, laptop computer, or smart television. The wearable data collection device **504**, in some embodiments, shares the object data **506f** with the separate computing device through a wireless communications link, such as a Wi-Fi or Bluetooth connection.

The type and style of presentation of object data **506f**, in some implementations, depends upon a mode of operation of the wearable data collection device **504** or the machine vision language tutor algorithm **532a**, potentially involving one or more additional software modules or algorithms currently active upon the wearable data collection device **504**. The mode may in part represent a level of complexity of vocabulary, such as a grade level or reading achievement level. Other mode granulations, in some examples, may include picture presentation versus word presentation, parts of speech, category labels for the objects (which can be partially overlapping) such as animal-word or long-word or concrete-word or happy-word or any other semantic or syntactic or pragmatic category, sentence fragments incorporating information regarding the objects, sentences with words for the objects in them, auditory representations of the objects (e.g., tick-tock for the clock object **510**), visual representations of the type of object or category of object, olfactory representations of objects (e.g., flowers, foods, etc.), tactile representations of the objects, haptic representations of the objects, or any mix of types of object representations. In some embodiments, object representations can include items that relate to but might not fully represent the particular object. In one example, upon selection of a particular object **508**, **510**, the machine vision language tutor algorithm **532a** may present the individual **502** with a foreign language lesson incorporating the selected object **508** or **510**, such as the Spanish word for ball or a sentence describing the present time of day in Mandarin Chinese. The foreign language lesson, in some examples, may involve execution of a single word reading algorithm **532b** and/or a graphic enhanced vocabulary algorithm **532d**, described in greater detail in relation to FIG. **5B**.

In some implementations, a caregiver, teacher, or other user associates each label with particular object data. For example, a user may print labels to apply to objects around the home, associating each object with at least a first piece of data (e.g., printed name or vocalized name). In another example, the user or caregiver may purchase labels (e.g., sheets of sticker labels), scan each label with a standardized

index element scanning application (e.g., built into the wearable data collection device or downloadable to a personal computing device including scanning capability such as a smart phone), and associate each scanned label with object data. The user or caregiver may then apply the labels to the associated objects. In this manner, a user or caregiver may customize information gathering within a chosen vicinity (e.g., classroom, child's bedroom, clinical office, etc.).

The mode of operation may further involve receiving responses from the individual **502** regarding presented object data **506f**. For example, as illustrated, the word "clock" **526** is intoned to the individual **502**. The currently active software module may be a verbal skill building module (e.g., English language or foreign language mode) anticipating repetition of the intoned word. Upon identifying a spoken response within voice recording data **116a**, the verbal skill building module may validate the response and store the result (e.g., proximity in pronunciation) as response validation data **506c**. Furthermore, the verbal skill building module may present feedback data **506e** to the individual **502** regarding relative success of pronunciation. The feedback data **506e**, in some examples, can include a visual indication (e.g., green check or red "X" presented in a heads up display) and/or audible indication (e.g., fanfare or buzzer). If the software module is presenting a language lesson game, in some implementations, progress tracking data **506d** is collected to track the success of the individual **502** in learning verbalizations associated with the labeled objects **508**, **510**. A single word reading algorithm **532b**, in another example, may behave similarly to the series of events described above in relation to the verbal skill building module **536c**, but presenting a graphic illustration of the word "clock" **526** in lieu of the intonation.

In some implementations, interactions of the individual **502** with labeled objects **508**, **510** can take place in the form of a game. For example, video augmentation data **506b** may include an augmentation style to convert the vicinity to a virtual reality zone having a particular presentation style. The presentation style, in some examples, can include a line-drawn version of the vicinity, a cartoon-drawn version of the vicinity, or a simplified version of the vicinity, for example where the majority of the scene is reduced to wire frame with only the objects **508** and **510** presented in full color. In another example, the presentation style may include a full color version of the video recording data **116b** with augmentation of the objects **508**, **510** (e.g., cartoon drawing, outlined in colorful lines, sparkling, jiggling, etc.).

In some implementations, the machine vision language tutor algorithm **532a**, executing upon or in conjunction with the wearable data collection device **504**, correlates identified object indices **506a** with the location coordinates **506g** of the index elements **512** at the time of acquisition. The location coordinates **506g**, for example, may include two-dimensional coordinates (e.g., within a video frame reference) or three-dimensional coordinates (e.g., with respect to the individual **102**). Identification of the object indices **506a**, furthermore, may be associated with a time-date stamp identifying the time of acquisition. The location coordinates can be factored into presenting information to the individual **502** related to the objects **508**, **510**. For example, if the ball object **508** had been moving when the wearable data collection device **504** registered the index element **512a**, the machine vision language tutor algorithm **532a** could present a representation of the ball object **508** to the individual **502** showing the ball **508** in a different location based on the passage of time and motion characteristics of the ball **508** (e.g., as identified within the video recording data **116b**).

Likewise, the machine vision language tutor algorithm **532a** may identify movement of the head of the individual **502** based upon sensor elements within and/or coordinating with the wearable data collection device **504** (e.g., via motion tracking data **116h** and/or head position data **116d**) between the time of acquisition of the index element **512a** and time of output of object data **506f** regarding the ball object **508** to the individual **502**. Based upon the identified movements, the machine vision language tutor algorithm **532a** may adjust the object data **506f** accordingly. For instance in the case of a visual image, the machine vision language tutor algorithm **532a** can cause a shift in the visual image to represent the current head gaze direction as opposed to the one at the time of acquisition—a form of motion correction.

Head gaze direction **116d** and subject motion data **116h**, in some implementations, may be used by the machine vision language tutor algorithm **532a** to identify which object data **506f** to present to the individual **502**. For example, based upon a present gaze trajectory of the individual **502** (e.g., based upon head position data **116d** and/or eye tracking data **116g**), object data **506f** regarding the clock object **510**, rather than object data **506f** regarding the ball object **508**, may be presented to the individual **502**.

In some implementations, the machine vision language tutor algorithm **532a** uses the location coordinates **506g** of the index elements **512** to identify three-dimensional locations of the objects **508**, **510** with reference to the individual **502**. For example, location coordinates **506g** may be derived from triangulation of video recording data **116b** obtained at multiple angles. In another example, location coordinates **506g** may be obtained from transmission features of the RFID tag **512a** or other type of electronic label.

Using the location coordinates **506g**, in some implementations, an audible locator module plays audible tones to the individual **502** that indicate relative distance and/or direction of each object **508**, **510** from the individual **502**. The intensity and directionality (e.g., left/right balance or other speaker distribution) of the audible tones, for example, can be stored as presentation feedback data **506e** of the wearable data collection device **504**. Each object **508**, **510**, further, may be associated with a particular sound. For example, the ball object **508** may be indicated by a bouncing noise, while the clock object **510** may be indicated by a tick-tock noise. Using the audible locator algorithm **548**, a blind individual **502** could discover the nature of her environment by receiving audible feedback representing the depth and breadth of a room and the location of objects within it by scanning the scene and receiving audible tone-based feedback from the wearable data collection device **504**. Alternatively or additionally, the presentation feedback data **506e** regarding locations of the objects **508**, **510** can include tactile or haptic feedback. For example, the machine vision language tutor algorithm **532a** may translate distance and relative position of an object into vibrational intensity, patterns, and application point (should multiple tactile feedback application points be available upon the body of the individual **502**).

In some implementations, an object tracking software module of the machine vision language tutor algorithm **532a** tracks the three-dimensional object location during a period of time. For example, tracking of the position of each object within a vicinity may aid in inventory management. During chemistry experiments in a chemistry laboratory, for example, the object tracking software module may determine which laboratory technicians interacted with each of the various chemical compounds, pieces of equipment, and other objects with standardized index elements within the vicinity of the laboratory. Based upon timestamps associated

with object location data **506f**, in one illustration, the object tracking software module may identify, in some examples, when particular laboratory technicians interacted with a particular object, how long a particular object was placed within a freezer, and/or where objects were placed relative to each other in a refrigerated storage area (e.g., on a shelf above or below another object). In other implementations, the object tracking software module functions as a stand-alone algorithm, not including the language learning and/or graphic enhancement features of the machine vision language tutor algorithm **532a**.

In some implementations, by analyzing object location data **506f** cross-referenced with one or more of motion tracking data **116h**, video recording data **116b** and audio recording data **116a**, the machine vision language tutor **532a** (or software tracking module) may identify how the individual **502** has interacted with a particular labeled object **508**, **510**. For example, the machine vision language tutor **532a** may identify that the individual **502** threw the ball **508** to the right of the clock **510**. Furthermore, analysis of the audio recording data **116a** may derive information regarding the level of familiarity of knowledge the individual **502** has with a particular object, for example through recognition of the individual **502** speaking the name of the object.

In some implementations, the level of familiarity, level of comfort, and/or level of discomfort the individual **502** has with a particular object may be derived through physiological data, such as heart and breath data **116e**, EMG data **116i**, or EEG data **116f**, described in relation to FIG. 1A, as well as voice pitch changes (e.g. derived from audio recording data **116a**). Furthermore, in some implementations, the wearable data collection device **504** or peripherals in communication therewith may collect data regarding skin conductance dynamics, skin temperature dynamics, core temperature dynamics, and other physiological data for use in familiarity analysis.

In some implementations, an object learning software module of the machine vision language tutor **532a** acquires information regarding objects with standardized index elements, improving in object identification such that a labeled object may eventually be identified even when the standardized index element is not visible within the video recording data **116b**. In some implementations, a portion of the data **116** and/or **506** acquired by the wearable data collection device **504** is provided to a remote analysis system **514**. The remote analysis system **514** may collect session data **516** provided by the wearable data collection device **504** for analysis by a processing system **518**. The remote analysis system **514**, for example, may perform parts of the machine vision language tutor **532a** functionality described above, such as the object identification software module, the object tracking software module or the audible location identifier module.

As illustrated, the processing system **518** includes a learning data analysis module **520** for learning to identify objects. The learning data analysis module **520**, for example, may collect and archive data from a number of wearable data collection devices in a data archive **522**. The data archive **522**, for example, may include a database or training file providing a machine-learning classifier or cascade of classifiers. Further, the data archive **522** may include a database of object information acquired by multiple wearable data collection devices. The learning and data analysis module **520**, for example, may categorize the object information. The term “Ball” such as the ball object **508**, for example, can represent a category including yoga balls, beach balls, tennis balls, footballs, soccer balls, etc.

In some implementations, the learning and data analysis module **520** recognizes object identifications and categories of object identifications based in part upon demographic data collected from each wearable data collection device. The demographic data, for example, can identify geographic information and spoken language. Through use of demographic data, for example, the learning and data analysis module **520** may learn to differentiate between images of European pears and images of Asian pears while recognizing each as being a “pear”. Further, the learning and data analysis module **520** may identify a yellow curved object as a banana in the Boston but a plantain in Borneo.

In some implementations, the pool of learned data derived by the learning and data analysis module **520** is used to refine standardized index element extraction methods or object recognition accuracy. For example, the learning and data analysis module **520** may collect multiple views and rotations of a given object to enhance recognition of the object. Additionally, the learning and data analysis module **520** may collect many versions of a particular category, such as a ball, mug, or telephone, and extract features of items and relationships between the features within the category to derive information about the category itself (e.g., invariant and variant features and feature-feature relationships). The learning achieved by the learning and data analysis module **520**, for example, may feed back to the machine vision language tutor **532a**, allowing the machine vision language tutor **532a** to recognize items and categories of items without requiring machine code recognition. A portion of this learning may reside in the learning module of the machine vision language tutor **532a** rather than with the learning and data analysis module **520**. Refinements to software modules, such as an object identification module, object data presentation module, and object location tracking module of the machine vision language tutor **532a**, in some embodiments, are provided as software updates to the wearable data collection device **504** from the remote analysis system **514**.

The individual **504**, in some implementations, provides feedback regarding labels applied to objects that do not have standardized index elements (or the standardized index element is not visible from the particular view presented within the video recording data **116b**). For example, the machine vision language tutor **532a** may prompt the individual **504** to respond whether a suggested label for an identified object has been correctly applied. The wearable data collection device **504** may forward the feedback to the learning and data analysis module **520** to aid in refinement of the automated recognition feature. For example, the learning and data analysis module **520** may track frequency of incorrect object identification and evolve better recognition patterns.

The learning and data analysis module **520**, in some implementations, includes a meta-analysis feature for deriving rich information based upon the data collected from a number of wearable data collection devices. In some examples, the learning and data analysis module **520** may analyze the collected data to determine a set of objects most commonly presented to individuals using the machine vision language tutor **532a**. At a further level of refinement, the learning and data analysis module **520** may identify commonly presented objects by age or age range of the individual (e.g., toddlers, grade school children, etc.), geographic location of the individual, or other classifications of the individual based upon demographic and/or medical diagnosis information (e.g., as stored within a user profile associated with each individual). In another example, the

learning and data analysis module 520 may track and analyze the performance of individuals (e.g., including the individual 504) in learning words, phrases, or other information presented by the machine vision language tutor 532a. The performance analysis may be broken down into sub-categories, such as performance by operating mode of the machine vision language tutor 532a (e.g., single word vs. short phrases, etc.), age range, geographic location, or other classifications of individuals based upon demographic and/or medical diagnosis information.

In some implementations, the single word reading algorithm 532b of FIG. 5B recognizes text being reviewed by the individual 502 wearing the wearable data collection device 504 and highlights particular portions of the text for the individual 502. The single word reading algorithm 532b, for example, may use one or more optical character recognition modules to identify that text has been captured within the video recording data 116b. Upon recognition of the text, the single word reading algorithm 532b may magnify, brighten, sharpen, or otherwise draw forth a portion of the text available to the individual 502 within a display region (e.g., heads up display) of the wearable data collection device 504. Further, the single word reading algorithm 532b may adjust a font style or weight, text color, or other aspects of the presented font to enhance readability and/or draw further attention to a particular portion of the text. In adjusting the presentation of the portion of the text identified within the video recording data 116b, in some examples, the single word reading algorithm 532b may enhance readability based upon preferences or capacities of the individual 502. For example, the single word reading algorithm 532b may enhance the text in a manner which allows the individual 502, having impaired vision, to better read the text. The modifications applied by the single word reading algorithm 532b to the rendering of the text, for example, may include adjustment of the presented text to factor in astigmatism of the individual 502, partial blindness, color blindness, or other condition which may frustrate interpretation of the text.

The single word reading algorithm 532b, in some implementations, selects a portion of the text from a greater body of text (e.g., three lines, five words, etc.) to highlight. The single word reading algorithm 532b may additionally de-emphasize the remaining text within the display of the wearable data collection device 504, for example by dimming, blurring, or otherwise obscuring or partially obscuring the remaining text. In this manner, the attention of the individual 502 is directed to a portion of the text that has been highlighted or enhanced by the single word reading algorithm 532b.

The single word reading algorithm 532b, in some implementations, provides a moving enhancement of the text. For example, to aid in the reading of lengthier text, such as a newspaper article or page of a book, the single word reading algorithm 532b may provide the individual 502 with the opportunity to “read along” by adjusting the portion of the enhancement through an input mechanism of the wearable data collection device 504. The individual 502, in some examples, may provide an audible cue (e.g., saying “next”), a visual cue (e.g., “dragging” finger along text within video recording data 116b captured by the wearable data collection device 504), and/or a physical cue (e.g., touching a portion of the wearable data collection device 504 or a peripheral in communication with the wearable data collection device 504) to signal the single word reading algorithm 532b to advance the highlighting to a next portion of the text.

In some implementations, the learning and data analysis modules 520 may learn a reading speed and/or preferred adjustment style of the individual 502, allowing the single word reading algorithm 532b to automatically adjust and present the text accordingly until signaled otherwise by the individual 502 (e.g., via an input cue as described above). For example, the learning and data analysis modules 520 may identify that the individual 502 progresses more quickly through text when presented with a serif font than a sans serif font.

In some implementations, the single word reading algorithm 532b may parse the text to recognize words and/or phrases, for example matching the terms with associated information. In one illustration, through a database look-up (e.g., resident to the wearable data collection device 504, executed upon a separate computing device in communication with the wearable data collection device 504, and/or implemented within the remote analysis system 514 of FIG. 5A), the single word reading algorithm 532b may identify definitions, pronunciations, graphic or video illustrations, audio snippets, and other rich information associated with an identified word or phrase. The single word reading algorithm 532b may then present enhanced information to the individual 502 regarding the presented text, automatically or upon selection. In a particular illustration, the single word reading algorithm 532b provides the individual 502 with the opportunity to select a word or phrase within the text for additional information, such as pronunciation, definition, and/or graphic illustration (e.g., what does a crested gecko look like, what is the pronunciation of “inchoate”, or what does “lethargy” mean).

The single word reading algorithm 532b, in some implementations, may be combined with other algorithms executing on the wearable data collection device 504, such as, in some examples, a bouncing ball reading algorithm 532c or a graphic enhanced vocabulary algorithm 532d. Similar to the single word reading algorithm 532b, in some implementations, the bouncing ball reading algorithm 532c presents, to the individual 502, enhanced text as identified within the video recording data 116b. The enhanced text, for example, may be superimposed with an attention window or otherwise selectively highlighted by the bouncing ball reading algorithm 532c to identify text for the individual 502 to read. For example, a child may interact with the bouncing ball reading algorithm 532c while reading a favorite book. The bouncing ball reading algorithm 532c may present a portion of the text of the book in a highlighted or enhanced fashion, then analyze audio recording data 116a to identify audible terms corresponding to the text on the page. As the child reads, the bouncing ball reading algorithm 532c may advance the enhanced portion of the text along the page of the book as presented in video data upon a display region of the wearable data collection device 504.

The bouncing ball reading algorithm 532c, in some implementations, rewards the individual 502 for correct reading of the text. In some examples, the bouncing ball reading algorithm 532c may allocate points towards a gaming enhanced interaction (e.g., using a gaming module), illustrate an icon or word of congratulations (e.g., a green checkmark for correct reading), or supply audible or tactile feedback identifying to the individual 502 that the individual 502 read the text successfully.

In some implementations, if the individual 502 struggles with pronunciation of the text or misses or misinterprets words within the text, the bouncing ball reading algorithm 532c supplies corrections. For example, the bouncing ball reading algorithm 532c may correct pronunciation, return to

a particular word or phrase to encourage the individual **502** to try again, or supply a visual, audible, or tactile form of feedback to alert the individual **502** that there were problems with the reading performance.

The bouncing ball reading algorithm **532c**, in some implementations, includes a reading style learning module (e.g., as part of the learning and data analysis modules) configured to learn, in some examples, the accent, speech patterns, and other verbal mannerisms of the individual **502**. For example, the reading style learning module may improve the reading recognition of the bouncing ball reading algorithm **532c** in relation to the individual **502**, such that the bouncing ball reading algorithm **532c** may recover for a lisp, stutter, or other impediment which may cause greater difficulties in interpreting the vocalization of the individual **502** during reading. Further, the bouncing ball reading algorithm **532c** may be combined with a speech dysfluency coach algorithm **540a** (described in greater detail below) to aid in correction of speech dysfluencies identified while interacting with the bouncing ball reading algorithm **532c**.

Upon conclusion of a portion of reading (e.g., a page, chapter, book, article, etc.), in some implementations, the bouncing ball reading algorithm **532c** tests comprehension or recall of the individual **502**. For example, the bouncing ball reading algorithm **532c** may include a quizzing module which correlates information within the text (e.g., phrases, characters, actions, etc.) with questions for the individual **502** to gauge the performance of the individual **502** in reading. In some examples, the bouncing ball reading algorithm **532c** may verify understanding of a term (e.g., select an appropriate definition), confirm proper identification of a series of actions within a text (e.g., the baker mixed the bread prior to putting the pan in the oven), or identify a particular character (e.g., is Emily a girl, a boy, or cat). The quizzing module of the bouncing ball reading algorithm **532c** may interoperate with the gaming module, awarding points for correct answers. The quizzing module, in another example, may feed information to the learning and data analysis modules **520** to gauge and track the reading level of the individual **502**, along with strengths and weaknesses of the reading abilities of the individual **502**.

In some implementations, a graphic enhanced vocabulary algorithm **532d** illustrates an image or a visual-sentence action to accompany and transliterate what is being read. For example, while using the single word reading algorithm **532b** or the bouncing ball reading algorithm **532c**, the reading activity may include visual information appended to the display (e.g., proximate to the text being read) by the graphic enhanced vocabulary algorithm **532d**. In another example, the graphic enhanced vocabulary algorithm **532d** may function in tandem with the machine vision language tutor **532a** to provide image data and/or a visual-sentence action corresponding to an identified object in the vicinity of the individual.

In some implementations, a consonant-slowness speech filter algorithm **534a** provides an individual with the opportunity to slow verbal dialogue for better comprehension. Individuals with autism spectrum disorder often struggle to hear consonants well. Because of the difficulty with consonant recognition, boundaries between words may be blurred. The consonant-slowness speech filter algorithm **534a** may filter audio data captured by the wearable data collection device prior to presentation to the individual **502** (e.g., via an audio output feature such as headphones, ear buds, or bone conduction speaker). In the event that the audio output method is not audio-suppressing (e.g., noise-suppressing headphones), the output of the consonant-slowness speech

filter algorithm **534a** may be presented such that it overlays speech the individual is naturally hearing.

In some implementations, the consonant-slowness speech filter algorithm **534a** functions with other modules and algorithms presenting audio data to the individual **502** such that, prior to output, any speech related audio data is filtered to slow consonants for better comprehension by the individual **502**. For example, during review of video training information or presentation of verbal information regarding an object identified through the machine vision language tutor algorithm **532a**, the consonant-slowness speech filter algorithm **534a** may be called to slow the consonants of the speech portion of the audio output prior to presentation to the individual **502**.

A boundary-enhancing speech filter **534b**, in some implementations, alters audio data containing verbal components to accentuate words and segment boundaries. In this manner, the boundary-enhancing speech filter **534b** may act as an edge-detector or edge-enhancement filter for linguistic elements. The boundary-enhancing speech filter **534b** may filter audio data captured by the wearable data collection device **504** prior to presentation to the individual **502** (e.g., via an audio output feature such as headphones, ear buds, or bone conduction speaker). In the event that the audio output method is not audio-suppressing (e.g., as in noise-suppressing headphones), the output of the boundary-enhancing speech filter **534b** may be presented overlaying speech the individual is naturally hearing.

In some implementations, the boundary-enhancing speech filter **534b** functions with other modules and algorithms presenting audio data to the individual **502** such that, prior to output, any speech related audio data is filtered to slow consonants for better comprehension by the individual **502**. For example, during review of video training information or presentation of verbal information regarding an object identified through the machine vision language tutor algorithm **532a**, the consonant-slowness speech filter algorithm **534a** may be called to slow the consonants of the speech portion of the audio output prior to presentation to the individual **502**. Further, the boundary-enhancing speech filter **534b** may coordinate with the consonant-slowness speech filter **534a** to both slow consonants and enhance boundaries of speech prior to presentation to the individual **502**.

A speech dysfluency coach algorithm **540a**, in some implementations, reviews audio data collected by a wearable data collection device **504** in real time to identify speech "tics", filler utterances (e.g., umm, err, etc.), stuttering, and/or other speech dysfluencies. Responsive to identifying a speech dysfluency, the speech dysfluency coach algorithm **540a** may cue the individual **502** using the wearable data collection device **504**, for example using a visual, audible, or haptic cue. Upon providing the cue, the speech dysfluency coach algorithm **540a** may assess effectiveness of the cue. For example, the speech dysfluency coach algorithm **540a** may assess whether the cue threw the individual **502** off-course (e.g., stammering, excessive pause, starting over with a sentence/topic, etc.). Based upon the assessment of effectiveness, the speech dysfluency coach algorithm **540a** may alter the style of the cue when next presenting feedback to the individual **502**.

In some implementations, the speech dysfluency coach algorithm **540a** tracks progress over time. As a training and management exercise, the speech dysfluency coach algorithm **540a** may deduct points for identification of speech dysfluencies, while awarding points for threshold time-frames of speech patterns without evidence of speech dys-

fluency. Progress tracking may include, for example, providing a report to a caregiver, medical practitioner, or educator for assessment including information regarding point accrual, types of speech dysfluencies identified, and/or a comparison of frequency of speech dysfluencies over time.

Similar to the speech dysfluency coach algorithm 540a, in some implementations, a profanity and colloquialism coach algorithm 540c reviews audio data collected by the wearable data collection device 504 in real time to identify usage of profanity and other base or offensive speech. Additionally, the profanity and colloquialism coach algorithm 540c may monitor gestures of the individual 502 to identify profane gestures made by the individual 502. Based upon identification of profane verbal or physical expressions, the profanity and colloquialism coach algorithm 540c may cue the individual 502, deduct points, and/or track frequency and type of uses and generate progress reports. Unlike the speech dysfluency coach algorithm 540a, the profanity and colloquialism coach algorithm 540c may modify response based upon context (e.g., identification of other members of a conversation, location, tone of the conversation, etc.). For example, the profanity and colloquialism coach algorithm 540c may provide strict correction in the school environment when communicating with a teacher, but relaxed correction in the home environment when communicating with a friend.

On a broader range, a social acceptability coach algorithm 540b, in some implementations, reviews audio data collected by the wearable data collection device 504 in real time to identify topics of conversation that may not be socially acceptable in the individual's present environment. The social acceptability coach algorithm 540b, for example, may identify key words and phrases, as well as densities of key words in extended speech, to determine topics of conversation that may be better avoided. The questionable topics of conversation may be cross-referenced with a present environment. For example, a topic of conversation appropriate at the playground may not be as socially appropriate at a funeral. Additionally, the social acceptability coach algorithm 540b may consider a cultural environment of the individual 502 in determining whether a topic of conversation is appropriate. The cultural environment, in some examples, may include information regarding ethnicity, race, gender, age group, context (e.g., school, home, family member's residence, etc.), or religion. Similar to the speech dysfluency coach algorithm 540a and the colloquialism coach algorithm 540c, the social acceptability coach algorithm 540b may issue a warning to the individual 502 to cue the individual 402 to cease engaging in the present topic of conversation. Further, the social acceptability coach algorithm 540b may alert a caregiver or begin recording depending upon the level of inappropriateness of a topic of conversation.

A teleprompter algorithm 544, in some implementations, calls upon a number of the features of other algorithms 532, 538, and 540 to support the individual 502 in giving speeches or otherwise engaging in social interactions with others. For example, the teleprompter algorithm 544 may present a script to the individual 502 in a heads-up display of the wearable data collection device 504. The teleprompter algorithm 544, for example, may present a portion of the script at a time in a similar manner as the bouncing ball reading algorithm 532c. The script, in some examples, may be a transcript of an actual speech or socially appropriate conversations snippets.

In some implementations, a full conversation snippets algorithm 536a, working in tandem with the teleprompter

algorithm 544, accesses archetype conversation snippets appropriate to a given circumstance. The conversation snippets, for example, may be stored in a database within the wearable data collection device 504 or on another computing device in communication with the wearable data collection device 504. In another example, conversation snippets may be fed to the individual 502 through a live coach (e.g., human) feeding conversation snippets to the individual 502 over a network through the full conversation snippets algorithm 536a. The coach, in some examples, may be a personal conversational assistant, a caregiver, or a colleague. For example, if the individual 502 is meeting with a potential business partner, other colleagues of the individual 502 may attend the discussion through a live video feed established with the wearable data collection device 504, similar in manner to the evaluation features described in relation to FIG. 1A. The colleagues may supply information, such as budget numbers, time estimates, and other information, to the individual 502 through the full conversation snippets algorithm 536a.

In automatically selecting an appropriate conversation snippet, in some implementations, the full conversation snippets algorithm 536a uses features of the social acceptability coach 540b and/or the personal distance coach 542a to identify situational circumstances (e.g., type of event, location, ages of other members of the conversation, as well as cultural, racial, religious, or other factors) as well as present attitudes of the other members of the conversation (e.g., emotional and body language cues demonstrating a current emotional state of each member of the conversation).

Additionally, in some implementations, a sentences and exchanges algorithm 536b coordinates with the teleprompter algorithm 544 to parse elements of the conversation, identifying emotional cues within the speech of the individual 502. While the individual 502 is speaking, for example, the sentences and exchanges algorithm 536b may parse audio data collected by the wearable data collection device for speech elements such as, in some examples, the tone of voice and the ongoing lilt and rhythm (prosody) of the individual's voice, using this analysis to derive verbal emotional cues provided by the individual 502 to the other members of the conversation. In the example of prosody, the sentences and exchanges algorithm 536b may analyze individual word choices, words and phrases used as colored by the greater conversations, and/or characteristics applied to words or phrases (e.g., boldness, formality, familiarity, etc.). Further, based upon analysis of the ongoing conversation, the sentences and exchanges algorithm 536b may present one or more cues to the individual 502 through the wearable data collection device 504. For example, the sentences and exchanges algorithm 536b may present an audible cue and/or visual cue to identify a point at which the individual 502 should pause or should emphasize a word while presenting a conversation snippet or speech fed to the individual 502 by the teleprompter algorithm 540.

In some implementations, the teleprompter algorithm 544 coordinates with the timing of cultural and conversational gestures algorithm 538a and/or the performance of cultural and conversational gestures algorithm 538b to prompt the individual 502 to insert appropriate gestures (e.g., nodding, smiling, etc.) at the appropriate time. Further, the timing of cultural and conversational gestures algorithm 538a may prompt the individual 502 to reduce gesturing, for example upon identifying that a level of movement of the individual 502 is likely to have a distracting effect on the other members of the conversation or audience. In some implementations, the timing of cultural and conversational ges-

tures algorithm 538a may monitor a gaze position of the individual 502, prompting the individual 502 to recycle his gaze through the audience during presentation of a speech or to look towards the member of the conversation who is presently speaking.

In some implementations, the teleprompter algorithm 544 coaches the individual 502 on conversational pace during performance of a speech or while in conversation with others. For example, the teleprompter algorithm 544 may prompt the individual 502, visually and/or audibly, to slow down.

The teleprompter algorithm 544, in some implementations, coaches the individual 502 on loudness of speech. For example, the teleprompter algorithm 544 may analyze data captured by a microphone feature of the wearable data collection device 504 to measure the sound level of the individual's voice. Further, the teleprompter algorithm 544 may adjust its analysis to take into consideration background noise and/or nearness of other members of the conversation (for example by estimating distances using features of the personal distance coach algorithm 542a). Responsive to analysis, the teleprompter algorithm 544 may prompt the individual 502 through the wearable data collection device 504, visually and/or audibly, to adjust speaking volume. In a particular example, the teleprompter algorithm 544 may present, upon a heads up display of the wearable data collection device 504, an icon of a cartoon covering its ears and saying ouch when the individual 502 is speaking too loud or a cartoon tilting its ear and cupping its hand when the individual 502 is speaking too softly.

In some implementations, the individual 502 can invoke the teleprompter algorithm 544 to practice a speech or impromptu conversational skills. For example, the sentences and exchanges algorithm 536b may be used to automatically "respond" to the individual 502 through analysis of sentences verbalized by the individual 502 within audio data captured by the wearable data collection device 504 and selection of appropriate response conversation snippets based upon the analysis. While the individual 502 is practicing performance of a speech or practicing conversation skills, the teleprompter algorithm 544 may analyze the vocalizations of the individual 502 to evaluate strengths and weaknesses of a performance. For example, the teleprompter algorithm 544 may invoke the speech dysfluency coach algorithm 540a to coach the individual 502 on avoiding filler utterances during practice. Additionally, while practicing a predetermined speech, such as a political speech or lines of a play, the teleprompter algorithm 544 may provide the individual 502 with the opportunity to scroll backwards or forwards within the body of the speech (e.g., repeat practice of a particular line or section of a speech prior to continuing to another portion), for example through features of the bouncing ball reading algorithm 532c.

FIGS. 6A-6D are flow charts of example methods for augmented reality learning using a wearable data collection device having capability to obtain one or both of video recording data and electronic label data (e.g., wireless label transmissions such as those described in relation to FIG. 5A regarding standardized index elements). The wearable data collection device may further have the capability to obtain audio recording data and/or present audible feedback. Additional capabilities of the wearable data collection device may include motion sensors, eye tracking sensors, and head position sensors, such as the hardware and sensors described in relation to FIG. 1A. The motion and/or eye tracking data, for example, may be used by a method 630 to track the gaze of a subject wearing the wearable data collection device.

Methods 600, 610, and/or 630 may be performed by one or more software modules executing upon a wearable data collection device such as the wearable data collection device 504 described in relation to FIG. 5A. In another example, one or more of the methods 600, 610, and 630 (or portions thereof) may be executed upon a computing device in communication with a wearable data collection device.

Turning to FIG. 6A, in some implementations, the method 600 begins with obtaining video data (602). The video data, for example, may include images captured by a head-mounted or otherwise body-mounted camera of a vicinity surrounding an individual. The video data may represent the surroundings of the individual as viewed more-or-less through the eyes of the individual.

In some implementations, the video data is analyzed to identify one or more standardized index elements (604). The standardized index elements may be applied as labels to objects, such as the objects described in relation to FIG. 5A. In other implementations, the standardized index elements may include visible markings upon or built into the objects. In further implementations, the standardized index elements may include electronic signals emitted from one or more objects. The standardized index elements, in some examples, may include a two-dimensional barcode, three-dimensional barcode, QR code, radio-frequency identification (RFID) tags, and other machine-readable labels or electronically transmitting smart labels.

In some implementations, if a standardized index element is located (606), location coordinates of the standardized index element are provided for further analysis (608). The location coordinates, for example, may include two-dimensional coordinates (e.g., within a video frame reference) or three-dimensional coordinates (e.g., with respect to the point of capture). Subsequent analysis, for example, may be executed upon a same or different processing system involving a same or different software module or algorithm. The method 600, for example, may call a separate software algorithm for analyzing the video data at the identified location coordinates to extract information from the standardized index element. In addition to location coordinates, a time stamp of the time of video capture may be provided for further analysis.

In other implementations, instead of or in addition to identifying standardized index elements, an object or classification of an object may be identified. For example, the video data may be analyzed to identify features corresponding to various objects. As with the standardized index elements, the location coordinates of the identified objects may be provided for use by a separate software module, algorithm, and/or computing system. Although described as a linear analysis, in other implementations, the video data is analyzed in parallel (e.g., using multiple threads) and/or recursively to identify standardized index elements.

Turning to FIG. 6B, a flow chart illustrates an example method 610 for analyzing an identified standardized index element to derive object information. In some implementations, the method 610 begins with receiving the location coordinates of the standardized index element (612). As described in relation to FIG. 6A, the location coordinates may be supplied from a separate algorithm or module executing upon a same or different processing system. In some implementations, information is extracted from the standardized index element (614). One or more hardware, firmware, or software elements of a wearable data collection device, for example, may be used to scan the video data for the standardized index element. For example, an RFID scanner feature of a wearable data collection device or other

machine-vision processes may be used to scan the standardized index element for information. To improve recognition of objects encoded with standardized index elements within the vicinity, in some implementations, two or more separate methods may be used to identifying items. Objects identified using one recognition method may be cross-referenced with the objects identified using the second recognition method. In other implementations, audio data and/or wireless transmission data may be reviewed using machine-hearing or other signal processing abilities to identify audible or other electronic signals of standardized index elements.

In some implementations, a standardized index element only partially identifiable within the video feed may be read (if readable by one or more scanning systems) to obtain an object index. Further, if the object was previously scanned and recognized, based upon a visible portion of the standardized index element, the method 610 may be able to identify the particular object (e.g., using information in a local database or training file entry associated with the object having the standardized index element). A shape of the object in combination with a partial standardized index element, in a particular example, may be used to uniquely identify the object.

In some implementations, the information extracted is reviewed for a known index or other code (616). Each standardized index element configured for use with the method 610, for example, may be embedded with a particular identifier (e.g., substring) that is otherwise unlikely to occur in that particular type of standardized index element, such that the identifier can be used to identify standardized index elements created for use with the wearable data collection device. Alternatively, the standardized index element may be embedded with a simple indexing term, such as a noun identifying the associated object.

If the standardized index element includes a known index or other code, in some implementations, object information is matched to the registered code or indexing term (618). For example, the object code or index may be applied to a look-up table to derive associated object data regarding the encoded object. In other examples, the standardized index element is a smart label such as an RFID tag including embedded object data. In this circumstance, the embedded object data is extracted from the standardized index element.

In some implementations, the object information is provided to one or more active modules configured to utilize the object information (620). The method 610, for example, may call a separate software algorithm for using the object information to present feedback to an individual.

In some implementations, if the information extracted does not include a known index or other code (616), the standardized index element is reviewed for identifying information (622). If identifying information is extractable by the method 610 from the standardized indexing element, in some implementations, the object information is provided to one or more active modules configured to utilize the object information (620). For example, if a machine-readable code derived from an object can be used to positively identify the object, such as the UPC code upon a product, the name of the product may be provided to the one or more active modules for use. Further, in some implementations, the object, identified by the machine-readable code, may be added to a database or training list of identified objects (e.g., stored within a wearable data collection device or another computing device in communication with the wearable data collection device).

Turning to FIGS. 6C and 6D, a method 630 uses identified objects to present information to an individual donning a

wearable data collection device. In some implementations, the method 630 begins with receiving object information matching a standardized index element extracted from video data as well as location coordinates identifying a location of the object within the video data (632). As described above, the object information and location coordinates may be supplied from a separate algorithm or module executing upon a same or different processing system.

If the object information corresponds to an object which was recently presented to the individual (634), in some implementations, the method 630 returns to awaiting receipt of additional object information. In this manner, if an individual was recently presented with information regarding the object, the individual is not repeatedly presented with identical information. A database or log file lookup, for example, may identify when (if ever) the object information was last presented. A threshold time, for example, may be used to determine whether to present information to the individual regarding the identified object.

If the object was not recently presented to the individual (634), in some implementations, a language mode and/or presentation mode is identified (636). For example, a target language setting (or language settings when presenting both a native language and foreign language) may be accessed to determine a language for presentation of any textual and/or verbal feedback presented to the individual. If a language setting includes a language not stored within the object data, the term in a stored language (e.g., English) may be provided to a translation module (internal to the wearable data collection device or externally accessed via a network connection) for translation. Presentation options, in some examples, may include a visual text display setting, a verbal (audible) presentation display setting, and an associated sound (audible) setting. Other presentation settings can include options of learning level or information scope, such as a level of vocabulary, whether to use meta-category labels (e.g., object “dog” belongs to category “animal”, etc.), and whether to present single terms or sentences.

If one or more visual presentation settings are active (638), in some implementations, a visual presentation is prepared based upon the presentation mode and language mode (640). The visual presentation, for example, may be prepared for overlay upon current video data. For example, as described in relation to FIG. 5A, the video recording data 116b may be overlaid with a textual representation of one of the labeled objects, such as the word “ball” applied upon or over the ball object 508.

Rather than overlaying with object data, in another example, each the object may be identified as selectable within presented video data by augmenting the video data at or proximate to the location coordinates of the object. For example, the presentation may colorfully outline the object, render the object as a cartoon, cause the object to shimmer, or otherwise augment the object to draw the attention of the individual.

In some implementations, if it is determined that the focal point of the video data captured after the time of identification of the standardized index object has moved (642), the location coordinates are adjusted to compensate for the movement (644). For example, based upon motion of the head of the individual donning the wearable data collection device, the current location of the object may be calculated and the placement of the graphic overlay of the video data adjusted. Conversely, if the object was in motion during video capture, motion data associated with the object may be used to estimate a present position of the object within the video.

In some implementations, the visual presentation is presented at or proximate to the location coordinates within the video data (648). The presentation, for example, may be overlaid upon a present video data frame and caused to display to the user. The user, for example, may see the visual presentation upon a heads-up display of the wearable data collection device.

If one or more audio presentation settings are active (650), in some implementations, audible feedback is prepared for presentation to the individual (652). The audible feedback, for example, may include a word, sentence, and/or sound associated with the identified object.

In some implementations, the audible feedback is provided to an auditory output system (654). The auditory output system, in some examples, may include a speaker system, bone conduction speaker system, or a tethered audio output device (e.g., headphones or ear buds, etc.).

The method 630 continues in FIG. 6D. Turning to FIG. 6D, in some implementations, the individual is presented with an opportunity to select an object (656). Selection of an object, in some examples, may be performed by the individual through an input feature of the wearable data collection device such as a tap, voice command, gesture, or thought pattern.

If an object is selected (656), in some implementations, additional object data regarding the selected object is presented (658). The additional data, for example, can include a deeper level of information, such as, in some examples, one or more terms associated with the object used in a grammatically correct sentence, a description associated with the selected object (e.g., brief encyclopedia-style write-up regarding the object), or other terms used to describe the object (e.g., a car can further be called a vehicle, auto, automobile, etc.). In a particular example, the additional object data includes a vocalized pronunciation of the name of the object.

Selection of the additional information, in some implementations, may depend upon an options menu. The menu may include options such as sentences, usage guides and tips, long definition, images of alternative versions of the object or previous exemplars in the world viewed by the wearer.

In some implementations, a response is received from the individual (660). The individual's response, in some examples, can include a vocal response (e.g., name of the object or other vocalization that may represent familiarity with the object), a physical response (e.g., picking up, touching, or otherwise interacting with the object), and/or an emotional response (e.g., an emotional reaction that may be gauged using voice reflection analysis of audio recording data and/or analysis of various physiological data collected by the wearable data collection device, as described, for example, in relation to FIG. 1A).

If a response is received from the individual (660), in some implementations, the response is validated (662). A vocalized response may be analyzed to identify familiarity with the object. A physical response, in some examples, may be analyzed to identify a comfort level the subject has with the object, dexterity demonstrated regarding use of the object, and/or correctness of use of the object (e.g., a ball object is thrown, not bitten). Further to the example above, the individual may repeat the vocalized pronunciation of the name of the object. The individual's utterance may be recorded as audio recording data and analyzed to determine how well the individual pronounced the name of the object. Validation data, in some implementations, may be recorded to aid in assessment of the individual and/or to track

progress of the individual in interacting with objects within the vicinity (e.g., home environment).

In some implementations, feedback regarding the response is provided to the individual (664). The feedback, in some examples, may be presented to encourage a desired reaction to or interaction with the object, discourage an undesired reaction to or interaction with the object, and/or represent relative success in performing a task associated with the object, such as pronouncing the name of the object. Feedback data, in some examples, can include visual feedback, audible feedback, and/or tactile feedback. In the particular example of representing relative success in performing a task associated with the object, a visual indication of a green check or red "X" presented in a heads up display of the wearable data collection device may visually represent success or failure related to the task (e.g., pronouncing the name of the object). Further to the example, in addition to or instead of a visual indication, an audible indication (e.g., fanfare or buzzer) may be used to provide feedback to the individual. Additional discussion regarding the use of feedback and selection of styles of feedback is provided in relation to the method 800 of FIG. 8.

FIGS. 7A through 7C illustrate a flow chart of an example method 700 for identifying socially relevant events and collecting information regarding the response of an individual to socially relevant events using a wearable data collection device. The method 700 may be used in the assessment of an individual's reactions as compared to anticipated typical reactions (e.g., from a typical person sharing characteristics with the subject such as age, sex, developmental stage, etc.). Further, the method 700 may be used in coaching an individual in appropriate responses to social situations.

The wearable data collection device may be capable of collecting video data and/or audio data. The wearable data collection device may further have the capability to present audible and/or visual feedback. Additional capabilities of the wearable data collection device may include motion sensors, eye tracking sensors, and head position sensors, such as the hardware and sensors described in relation to FIG. 1A. The motion and/or eye tracking data, for example, may be used by the method 700 to track the gaze of an individual wearing the wearable data collection device. The method 700 may be performed by a software module executing upon a wearable data collection device such as the wearable data collection device 104 described in relation to FIG. 1A or the wearable data collection device 504 described in relation to FIG. 5A. In another example, the method 700 may be executed upon a computing device in communication with a wearable data collection device.

In some implementations, video data and/or audio data are obtained (702). The video data, for example, may include images captured by a head-mounted or otherwise body-mounted camera of a vicinity surrounding an individual and a second person (e.g., caregiver, family member, evaluator, etc.). The camera may collect video data from the perspective of the individual or the second person. Further, a second camera may be used, such that video data represents both the viewpoint of the individual and the second person. The video data may represent the surroundings of the individual and/or second person, for example, as viewed more-or-less through the eyes of the individual/second person. The audio data, similarly, captures at least vocalizations between the individual and the second person, for example via a microphone mounted on the wearable data collection device or separate computing device.

In some implementations, based upon the video data and/or audio data, a socially relevant event is detected (704). The social relevant event can include an emotional expression typically evocative of an appropriate response by the other party such as, in some examples, smiling, laughing, crying, admonishing in an angry tone, asking a question, using profanity, or invoking the name of the other party. In analyzing the video and/or audio data for a socially relevant event, emotional responses can be characterized by one or more of voice fluctuations, tone, cadence, volume, and prosodic variation of the voice of the speaker, facial expressions, body language, and hand gestures. Furthermore, emotional responses may be derived, in some embodiments, through collection of physiological data, such as the physiological data types described in relation to FIG. 1A (e.g., heart rate, breathing rate, EMG, EEG, etc.). In one example, determining an emotional state associated with the socially relevant event includes providing the various data described above to a classifier which applies a classification of emotion and valence.

In some implementations, it is determined whether to adjust for mitigating factors (708). The method 700, in some embodiments, reviews collected data for extenuating circumstances or other characteristics that may depress typical emotional response. For example, while invocation of the individual's name may typically cause the individual to turn to the attention of the speaker, if the individual is presently distracted (e.g., by a television show, loud noises, nearby activity, or deep concentration in a personal activity) the normal (anticipated) response may be suppressed in the typical individual. Similarly, the individual may respond differently based upon the emotional state of the individual prior to the socially relevant event. In some examples, mitigating factors can include whether the individual was excitable, angry, sad, or otherwise emotionally stimulated in a manner that could accentuate or depress typical response to the socially relevant event. In some examples, an emotional state identifying module may evaluate various physiological data captured by the wearable data collection device and/or peripheral devices in communication with the wearable data collection device such as, in some examples, heart and breath data 116e, EMG data 116i, or EEG data 116f; described in relation to FIG. 1A, as well as voice pitch changes (e.g. derived from audio recording data 116a). Furthermore, in some implementations, the wearable data collection device or peripherals in communication therewith may collect data regarding skin conductance dynamics, skin temperature dynamics, core temperature dynamics, and other physiological data for use in emotional state analysis.

If adjusting for mitigation factors (708), in some implementations, a statistically likely normal response, based upon emotional state, external factors, and/or other internal factors (e.g., level of concentration on a task), is determined (714). The statistically normal response, for example, may be derived from data collected from educators, clinicians, and/or physicians regarding behavioral studies and common emotional response patterns. Otherwise, a normal (desired) response is determined (712), similarly based upon collected data regarding common emotional response patterns. In other implementations, the method 700 determines both the normal (desired) response and a statistically likely normal response based upon present mitigating factors.

In some implementations, based at least in part upon the statistically likely normal response and/or the normal response, a desired response is determined (716). The desired response, for example, may include a response determined to be appropriate to the particular individual

and/or reasonable for the particular individual to achieve. The desired response, for example, may be based upon a spectrum of known responses common to the particular individual and/or a personality assessment of the particular individual.

In some implementations, the actual response of the individual is compared to the desired response and/or the normal response(s) (718). The comparison may represent a closeness in match between the individual's actual response and one or both of the desired response and the normal response. In some examples, the comparison may include a percentage match or numerical (e.g., level) match. The comparison may refer, in a particular example, to a numerical value indicating a positive (e.g., overreaction) difference between the normal response and the actual response or a negative (e.g., suppressed reaction) difference between the normal response and the actual response.

In some implementations, data regarding the socially relevant event, actual response and/or comparison data is recorded (720). The wearable data collection device, for example, may record the data locally (e.g., in storage built in or directly accessible to the wearable data collection device) and/or remotely (e.g., accessing a network-based system for collection and later assessment/statistical learning analysis of the data). Furthermore, data regarding emotional state, circumstances, and/or other mitigating factors may be recorded in relation to the socially relevant event and response thereto.

In some implementations, the method 700 is used for a number of purposes. These purposes are described herein as operational modes. Although represented as separate and discrete modes in the illustrated flow chart, alternatively, the method 700 may perform at least a portion of the steps associated with each of a characterization and learning mode 724 and a training and feedback mode 726.

In some implementations, a characterization and learning (724) operational mode is determined (722). In the characterization and learning (724) operational mode, if no noticeable/noteworthy difference is discerned between the individual's actual response and at least one of the desired and normal responses (728), the method 700 returns to the beginning and continues to obtain video and/or audio data (702). The concept of "noticeable difference" may represent a statistically significant comparison value, for example as determined by behavioral experts, or may be noticeable in some other way or according to some other thresholding than traditional statistical significance.

If, instead, a noticeable difference is identified (728), turning to FIG. 7B, in some implementations, the data record regarding the socially relevant event is flagged as a noticeable detour from a desired or normal social response (730). In this manner, for example, later analysis can incorporate details regarding any failures of the individual in reacting appropriately to social events.

In some implementations, if physiological data is available (732), the physiological data is correlated with the social event, actual response, and comparison data. As described above, the physiological data can include heart and breath data, EMG data, or EEG data, as well as other physiological factors such as, in some examples, metabolic data, neurological signals, chemodynamics signals, and/or central nervous activity.

In some implementations, if historic data is available (736), one or more recent atypical behavioral episodes may be correlated with the social event data (738). Atypical behavioral episodes, in some examples, can include inappropriate behaviors such as acting-out, extreme emotional

fluctuations, and stinging and similar behaviors. Conversely, in some implementations, upon identification of an atypical behavioral episode, historical records regarding recent social response may be reviewed to identify any common behaviors leading up to atypical behavioral episodes. Identification and management of atypical behavioral episodes is discussed in greater detail in relation to FIG. 11.

In some implementations, the physiological data and/or historic data are reviewed to identify susceptibility of the individual to future atypical behavioral episodes (740). As described above, various physiological data captured by the wearable data collection device and/or peripheral devices in communication with the wearable data collection device such as, in some examples, heart and breath data 116e, EMG data 116f, or EEG data 116g, described in relation to FIG. 1A, as well as voice pitch changes (e.g. derived from audio recording data 116a) may be compared to common physiological factors leading up to atypical behavior episodes. The comparison, for example, can be both objective and subjective. Objective comparison of physiological data, for example, can include comparing the individual's physiological data to that of other individuals exhibiting atypical behavioral episodes similar to those of the individual and/or other individuals diagnosed similarly to the individual (e.g., ASD level identification). Subjective comparison of physiological data, for example, can include comparing the individual's present physiological data to historic physiological data of the individual that has been flagged as leading to a past atypical behavioral episode. The comparison may result in a numeric value indicative of present relative susceptibility to an atypical behavioral episode.

Prior to comparison, in some implementations, emotional and physiological states may be derived from the individual's physiological data. The states, for example, can include one or more of a mental state, an arousal level, and an irascibility level. The state information, in turn, may be used to identify a measurement of the individual's present susceptibility to an atypical behavioral episode.

If the review outcome is indicative a likelihood of an impending atypical behavioral episode (742), in some implementations, feedback related to anticipation of a potential atypical behavioral episode is presented (744). In some implementations, a caregiver is alerted to the likelihood of an impending atypical behavioral episode. For example, the wearable data collection device donned by the caregiver may present an audible and/or visual warning regarding the likelihood of an impending atypical behavioral episode and, potentially, an indication of the type of atypical behavior anticipated (e.g., acting out, stinging, etc.). Furthermore, the caregiver may be prompted with recommendations of measures to take to best prevent, redirect, and/or minimize the atypical behavioral episode. In some implementations, the individual is alerted to the likelihood of an impending atypical behavioral episode. The wearable data collection device donned by the individual, for example, may present an audible and/or visual warning regarding the likelihood of an impending atypical behavioral episode similar to the warning supplied to the caregiver. Further, the individual may be prompted with recommendations of measures to take to minimize or protect against the impending behavioral episode. The individual, in some implementations, may be presented with feedback designed to divert a pending atypical behavioral episode. For example, feedback may be presented via the individual's wearable data collection device (e.g., visual, audible, tactile, etc.) designed to alter one or more physiological conditions indicative of a pending atypical behavioral episode. The feedback, in a particular

example, may be designed to calm the emotional state of the individual or focus the individual's attention to divert from a present thought pattern. A variety of particular feedback examples follow. The individual may be presented with a short episode of a game that has proven previously to attract the attention of this individual or others like this individual. The individual may be encouraged to focus on a particular sensation and try to eliminate another sensation from mind. The individual may be instructed to chew or crunch on a food or toy that provides comfort or inward focus for the individual. In a particular example, turning to FIG. 7D, a screen shot 760 includes a prompt pane 762 encouraging the user to relax alongside an image pane 764 configured to provide a pleasurable sensory experience for the user.

Beyond feedback, in some implementations, interventions may be provided on behalf of the individual. For example, a caregiver may be notified and instructed to provide the individual a timeout moment, a pleasant toy, a brief instruction, an enjoyable food or other sensory experience.

In some implementations, the intervention includes a pharmacological or electrical or magnetic form of interaction. For example, the intervention may include triggering of implanted pharmaceutical dispensers or systems for selective release of medicines (including pharmacological agents whose absorption can be influenced externally such as by radio frequency (RF), light, or other method for imparting energy). Furthermore, in some implementations, a stimulator device (described in detail below in relation to FIG. 12) may be used to provide direct intervention via stimulation. For instance, electrical or magnetic pulses may be administered directly to the individual via a stimulator, and the electrical or magnetic pulses may be associated with an instruction or guided behavior that inhibits a potential atypical behavioral episode, or it may directly cause said atypical behavioral episodes to be less likely, for instance by direct neural action or influence. The stimulation, for example, may be used to influence brain circuits by triggering a pleasurable or hedonistic response. Other variations for applying non-invasive effects upon brain functions include, in some examples, transcranial direct-current stimulation (TDCS), transcranial magnetic stimulation (TMS), and radio-frequency energy deposition into tissue, energy deposition into tissue such as brain tissue via radio-frequency oscillations of electromagnetic fields. The magnetic, energy, electrical, and/or pharmaceutical interventions may be automated or semi-automated (e.g., supplied upon approval by a caregiver, medical practitioner, or other authorizing individual). Further, the magnetic, energy, electrical, and/or pharmaceutical interventions, in some implementations, may be used to provide feedback, such as game feedback, to the individual in other tools described herein.

At this point, in some implementations, the method 700 may return to step 702 of FIG. 7A and continue to collect video and/or audio data. In other implementations, the method 700 may further record presentation of feedback such that later analysis can discern whether a particular feedback style appears to stem atypical behavioral episodes in the individual or not.

Turning to FIG. 7C, if the method 700 is performing in the training and feedback mode (726), in some implementations, if a noticeable/noteworthy difference is discerned between the individual's actual response and at least one of the desired and normal responses (744) (e.g., as described in relation to step 728 of FIG. 7A), the individual is directed to perform the desired response (746). In some examples, visual, haptic, and/or audible coaching mechanisms may be used to trigger a desired response from the individual. In a

particular example, a funny sound may be played to invoke a smile or giggle from the individual in response to a socially relevant event that normally invokes pleasure. The video feed of a heads-up display, in another example, may be augmented to highlight a face for the individual to look at or otherwise direct the gaze of the individual towards a speaker, such as by using a graphic arrow indicating to the individual to turn her head in a particular direction. Further to the example, a video icon of an arrow may “grow” and “shrink” based upon whether the individual is turning away or towards the direction of the arrow. Additionally, audio or video feedback may spell out to the individual the particular desired behavior to invoke, such as an audible cue directing the individual to “smile now” or a visual cue including the text “shake hands”. This functionality, in one example, may be supplied in part using features of the performance of cultural and conversational gestures algorithm **538b**, described in relation to FIG. **5B**.

In some implementations, effectiveness of the presented guidance is determined (**748**). For example, based upon recorded video and/or audio data, the socially relevant event identifier can identify a socially relevant response invoked by the individual and compare the response to the prompted response. This step and the following steps **748** and **750**, in one example, may be performed at least in part by features of the social acceptability coach algorithm **540b**, described in relation to FIG. **5B**.

In some implementations, if the guidance is determined as having been effective (**748**) positive feedback is presented to the individual (**750**). The feedback, in some examples, can include visual feedback, audible feedback, and/or tactile feedback. In the particular example, a visual indication of a green check is presented in a heads up display to represent success of the subject in following through on the presented response guidance. Furthermore, in some implementations, the feedback may include triggering magnetic, energy, electrical, and/or pharmaceutical doses for enhancing pleasure signals of the individual.

Conversely, if the guidance is determined as having been ineffective (**748**), in some implementations, negative feedback is presented to the individual (**752**). In the particular example, a visual indication of a red “X” is presented in a heads up display of the wearable data collection device to represent failure of the individual in following through on the presented response guidance. Additional discussion regarding the use of feedback and selection of styles of feedback is provided in relation to the method **800** of FIG. **8**.

Turning to FIG. **8**, a flow chart illustrates an example method **800** for conditioning social eye contact response through augmented reality using a wearable data collection device. The method **800**, for example, may incorporate a type of game or virtual reality activity aimed at conditioning a user assessed for ASD to engage in social eye contact.

In some implementations, the method **800** begins with obtaining video data (**802**). The video data, for example, includes images captured by a head-mounted or otherwise body-mounted camera of a vicinity surrounding the user. The video data may represent the surroundings of the user as viewed more-or-less through the eyes of the user.

In some implementations, one or more faces of individuals are identified within the video data (**804**). The faces, for example, can include family members, social peers, colleagues, or other people in the surroundings. Additionally, in some embodiments, the faces can include animals or inanimate objects, such as a family pet, a therapy dog, or a toy doll.

In some implementations, at least a first face of the one or more faces in captured video data is augmented to draw attention to the face within the video output to the user (**806**). In some examples, the face may be outlined in colors, overlaid with a shimmer, or caricatured in an animated fashion to draw the attention of the user. In other examples, silly hair may be applied to an individual identified within the video data or a distortion field applied to the face region. Alternatively or additionally, in some examples, background video surrounding the face may be dimmed, reduced in complexity, or blurred to reduce focus on any aspects in the video besides the face. In a particular example, a favorite cartoon character may be superimposed upon the face region of an individual (e.g., in an opaque or semi-transparent manner) within the video data to draw the attention of the user to the face of the individual.

Alternatively, in other implementations, faces may be removed from the video output to the user. For example, the face regions of each individual may be edited out of the video feed or supplanted with an overlay (e.g., solid color, animated grayscale noise pattern, etc.).

In some implementations, data is analyzed to identify social eye contact between the user and the first face (**808**). For example, as described in relation to FIG. **1A**, an eye tracking module may analyze eye tracking data **116g** obtained from a face-directed video capture element of the wearable data collection device to determine when the gaze of the user co-registers with the first face of the video data. In another example, video captured by a wearable data collection device worn by the other person is analyzed to determine whether the gaze of the user is directed at the face of the person. Further, in some embodiments, both the user and the other person have donned wearable data collection devices, and a straight line wireless signal, such as a Bluetooth signal, infrared signal, or RF signal, is passed between the user’s wearable data collection device and the other person’s wearable data collection device, such that a wireless receiver acknowledges when the two wearable data collection devices are positioned in a substantially convergent trajectory.

In some implementations, reaction of the user to the augmentation style is assessed and recorded (**808**). If the augmentation style failed to catch the user’s attention towards the first face, for example, the first augmentation style may be recorded as being “ineffective.” Conversely, if the user’s attention turned towards the first face, the first augmentation style may be recorded as being “effective.” In this manner, the method **800** may include a learning aspect to identify most effective methods of gaining and holding the user’s attention.

In some implementations, if co-registration indicative of social eye contact between the user and one of the faces is not identified (**810**), an augmentation style is adjusted (**812**). For example, if the first augmentation style included a line surrounding the first face, the augmentation style may be adjusted to instead apply a jiggling movement to the face. In another example, if the first augmentation style included a black and white caricature version of the face, a second augmentation style may include a colorful caricature version of the face. Furthermore, augmentation style of the background scenery may be applied and/or adjusted.

In some implementations, if co-registration is identified (**810**), positive reinforcement feedback is provided to the user (**814**). Positive reinforcement feedback can include audio, visual, and/or tactile (haptic) feedback designed to reward the user for directing attention to the augmented face. Positive reinforcement feedback may include an enjoyable

or celebratory sound, such as a fanfare, cheering, or happy music. Verbal positive feedback, such as the words “success”, “hooray”, “good job”, or “way to go” may be audibly or visually presented to the user. The positive reinforcement feedback may include a color, image, animation, or other pleasing visual representation presented, for example, in the heads-up display of the wearable data collection device. In some embodiments, positive reinforcement feedback includes adding points, for example in the form of a heads-up display icon representing accumulated points, in a game-style interface. Levels of positive reinforcement may vary based upon desirability of reaction. For example, for a brief period of social eye contact, the user may be presented by pleasing sounds or other encouragement. After a threshold period of time, the positive reinforcement feedback may be enhanced to include an indication of success. For example, any social eye contact may be rewarded in part, but social eye contact for at least a threshold period of time (e.g., one second, three seconds, etc.) may be rewarded with points or a more elaborate/celebratory feedback mechanism.

In some implementations, the user’s reaction to the positive reinforcement feedback is ascertained and the user’s preferences adjusted accordingly (816). For example, upon presentation of positive reinforcement feedback, if the user maintains social eye contact for the threshold period of time, the particular positive reinforcement feedback provided to the user may be flagged as being effective with the user. For example, points associated with the feedback may be incremented or the feedback may be promoted within a list of feedback options. If, instead, the user terminates social eye contact with the face prior to the threshold period of time despite the use of positive reinforcement, the particular positive reinforcement feedback presented may be flagged as being ineffective with the user. For example, points associated with the feedback may be decremented or the feedback may be demoted within a list of feedback options. In this manner, the method 800 may learn the most effective manners of positive feedback for the particular user.

In some implementations, assessment of the user’s reaction to the positive reinforcement feedback is ascertained in part by analyzing various data associated with the user. For example, levels of pleasure or displeasure with the currently presented feedback may be derived from reviewing a subject-pointing video recording to review relative pupil dilation, eye moistness, or eyebrow position. Further, levels of pleasure or displeasure may be derived from reviewing subject physiological data such as heart rate, breathing rate, or neurological data such as EEG/EMG/EKG data.

If, instead of maintaining co-registration for the threshold period of time, the user terminates social eye contact with the face (818), in some implementations, negative feedback is provided to the user (820). Negative feedback, for example, may be selected to discourage an undesirable behavior of the user, such as glancing briefly at the face rather than maintaining social eye contact. The negative feedback may include one or more of audible, visual, and tactile feedback. In particular examples, an irritating vibration may be applied to a point on the skin of the user or an annoying noise may be played to the user.

In some implementations, the user’s reaction to the negative feedback is ascertained and the user’s preferences adjusted accordingly (822). As described above in relation to step 816 regarding positive reinforcement feedback, similar analysis and promotion/demotion of negative reinforcement mechanisms may be made to learn the most effective negative feedback mechanisms to use with the user. Success of

negative reinforcement mechanisms, for example, may be based in part upon how quickly the user returns his or her gaze to the face.

FIG. 9 is a block diagram of an example collection of software algorithms 910 and 912 for implementing identification of and gauging reaction to socially relevant events. Based upon particular implementations, individual software algorithms 910 and 912 may execute upon a wearable data collection device 904 (or 906), a computing device in direct communication with the wearable data collection device 904 (or 906) such as a smart phone, tablet computer, or smart watch, or a computing system accessible to the wearable data collection device 904 (or 906) via a network connection, such as a cloud-based computing system. The subsets of the software algorithms 910 and 912, in a particular example, may be configured for performance of a software application developed for assessment and/or training of a subject with ASD.

The software algorithms 912 may differ in functionality based upon whether they are executing upon or in coordination with a wearable data collection device 904 of an individual 902 or upon or in coordination with a wearable data collection device 908 of a caregiver 906. For example, the eye motion analysis algorithm 912g designed for execution upon the caregiver wearable data collection device 908 may analyze eye motion based upon video recording data capturing the face of the individual 902, while the eye motion analysis algorithm 912g may analyze eye motion based upon a camera mechanism of the individual’s wearable data collection device 904 directed at the face of the individual 902 (e.g., directed at and capturing substantially the eye region of the face of the individual 902). In another example, a head motion analysis algorithm 912a, designed for execution upon the caregiver wearable data collection device 908, may analyze movements of the head of the individual 902 based upon recorded video data of the individual 902, while the head motion analysis algorithm 912a designed for execution upon the individual’s wearable data collection device 904 may analyze movements of the individual’s head based upon one or more motion sensors built into the individual’s wearable data collection device 904. Further, the software algorithms 910 are unique to providing features for the individual 902.

The software algorithms 910 and 912, in some examples, may be used to perform portions of method 700 described in relation to FIGS. 7A through 7C, method 800 described in relation to FIG. 8, and/or method 1000 described in relation to FIG. 10A.

Further, the software algorithms 910 may be used to support functionality of one or more software algorithms designed as learning tools or behavioral management aids for the subject 902. For example, in some implementations, a timing of cultural and conversational gestures algorithm 538a (illustrated in FIG. 5B) may use the body language identifier 910a to analyze performance of cultural and conversational gestures by the individual 902. The cultural and conversational gestures algorithm 538a may provide the individual 902 with coaching and training on the timing and appropriateness of gestures such as, in some examples, handshake styles, bows, nods, smiles, and hand and arm gestures during speech. Through the emotion identifier 910e, for example, the cultural and conversational gestures algorithm 538a may identify that the caregiver 906 is smiling at the individual 902. An appropriate response would be to smile back. The subject physio analysis algorithm 910g may assess the emotional state of the individual 902 and/or determine if the individual 904 is already smiling. The

prompt response algorithm 910c may be invoked by the cultural and conversational gestures algorithm 538a to prompt the individual 902 to smile. Upon recognition of a smile of the individual 904, further to the example, the present feedback algorithm 910f may be invoked to provide positive feedback to the individual 902.

In some implementations, the cultural and conversational gestures algorithm 538a of FIG. 5B may coordinate with a performance of cultural and conversational gestures algorithm 538b of FIG. 5B to train the individual 902 in proper performance of gestures involving large motions. The performance training, in some examples, may be used to coach the individual 902 in proper performance of bowing at proper depth with proper head angle, dancing postures, distress signals, sign language, and other non-verbal communication signals. In a particular example, turning to FIG. 5C, a screen shot 550 illustrates an example user interface for coaching an individual in performing a bow. An image pane 552 contains an illustration of an avatar performing a bow movement with a textual label “perform a bow”, while a coaching pane 554 includes both a message 556 “bend forward keep the ball in the track” as well as an animated illustration 558. In operation, as the individual performs the bow, a ball icon portion of the animated illustration 558 will move within the image pane 552 according to sensed movements of the individual’s head (e.g., based upon data provided by one or more motion sensing devices incorporated into or in communication with the wearable data collection device). If the individual maintains the ball icon portion of the animated illustration 558 substantially following a path portion of the animated illustration 558, the individual’s body will appropriately perform the gesture of the bow. In other implementations, additional sensor data captured from sensors upon the individual’s body may be analyzed to validate positioning and motion corresponding to the motion of the head of the individual such as, in some examples, a motion sensor attached to a wrist-mounted device validating that at least one of the individual’s hands is positioned at his or her side. Although illustrated as a two-dimensional coaching animation, in other implementations, the visual display may present a three-dimensional animated graphic for guiding the individual through proper performance of the gesture. Further, in other embodiments, the avatar icon may be replaced by an animated illustration or video demonstration of the gesture.

Returning to FIG. 9, aspects of the cultural and conversational gestures algorithm 538a, in some implementations, are used to coach the individual 902 in martial arts movements and techniques, yoga postures, role-playing game and re-enactment motions, fighting or defense techniques, and other controlled physical gestures. In further implementations, aspects of the cultural and conversational gestures algorithm 538a are used to provide quantification and feedback for anomalous body motions such as in dystonia or Parkinson’s Disease and Huntington’s Disease or motor ticks. Similar to the cultural and conversational gestures algorithm 538a, the performance of cultural and conversational gestures algorithm 538b may coordinate with the body language identifier algorithm 910a. For example, the cultural and conversational gestures algorithm 538a may invoke the body language identifier algorithm 910a in support of identifying opportunities for performing a large motion gesture, and the cultural and conversational gestures algorithm 538a, responsive to identifying an opportunity, may invoke the performance of cultural and conversational gestures algorithm 538b to coach the individual 902 in performing the gesture.

Although the cultural and conversational gestures algorithm 538a and the performance of cultural and conversational gestures algorithm 538b are described in relation to interactions with another person, in some implementations, the individual 902 may invoke the algorithms 538a and/or 538b for practice mode training in cultural and conversational gestures.

In some implementations, a personal distance coach algorithm 542a of FIG. 5B provides the individual 902 with a tool for coaching appropriate distance to maintain when interacting with another person, such as the caregiver 906. The personal distance coach algorithm 542a, for example, may review video data such as video recording data 116b described in relation to FIG. 1A to estimate distance between the individual 902 and another person. For example, the personal distance coach algorithm 542a may estimate distance based upon depth cues and parallax cues in the video recording data 116b. In another example, a signal transmitted between the individual’s wearable data collection device 904 and the caregiver’s wearable data collection device 906 may be used to measure a present distance. In a further example, distance may be estimated based upon reflection of signals using a laser or sound-based system of the wearable data collection device 904.

In some implementations, the emotion identifier module 910e may contribute to assessment of appropriate distance by gauging a level of comfort of the person communicating with the individual 902, such as the caregiver 906. In one example, the level of comfort of the person communicating with the individual 902 may be based upon an estimated emotional state of the other member of the interaction by invoking the emotion identifier algorithm 910e. In another example, the level of comfort of the person communicating with the individual 902 may be based upon a posture of the other member of the interaction by invoking the body language identifier 910a.

The personal distance coach algorithm 542a, in some implementations, factors in the distance between the individual 902 and the other member of the interaction, the estimated emotional state and/or posture cues of the other member of the interaction, and, potentially, information related to cultural norms (e.g., geographic, racial, religious, etc.) to determine appropriateness of the current personal distance. The personal distance coach algorithm 542a may invoke the prompt response algorithm 910c to prompt the individual 902 to adjust a present distance accordingly.

A turn-taking algorithm 542b of FIG. 5B, in some implementations, monitors conversation and calculates a relative amount of time that the individual is contributing to a conversation in relation to the amount of time each other member of the interaction is speaking. Individuals diagnosed with ASD are frequently quiet and remiss to contribute to conversations, while other individuals diagnosed with ASD will talk on at length without providing opportunity for others to contribute to the discussion. Through reviewing audio data collected by the individual’s wearable data collection device 904, such as audio recording data 116a described in relation to FIG. 1A, the turn-taking algorithm 542b may prompt the individual 902a to speak up or, conversely, to politely pause to allow another member of the conversation to jump in. Further, the turn-taking algorithm 542b may monitor appropriate turn-taking during a period of time, tracking progress of the individual 902.

Turning to FIG. 5D, in some implementations, the turn-taking algorithm 542b presents visual feedback, such as the feedback user interface presented within a screen shot 560. As illustrated in the screen shot 560, a topic pane 562

contains an illustration of a speech bubble icon with the textual label “Share!”, while a feedback pane 564 includes both a message 566 “Remember to take turns in conversation” as well as statistical feedback 568 representing a percentage time that the individual has dominated the conversation (e.g., illustrated as 85% and labeled “your speaking time”). The screen shot 560, for example, may be presented within a heads up display of a wearable data collection device to prompt a user to take turns in conversations with other members of the conversation.

Returning to FIG. 9, in some implementations, the turn-taking algorithm 542b generates a report regarding the individual’s progress in conversational turn-taking. The report, for example, may be generated on a periodic basis and supplied to a caregiver, medical practitioner, educator, or other person tasked with assessing the progress of the individual 902.

FIG. 10A is a flow chart of an example method 1000 for identifying and presenting information regarding emotional states of individuals near a user. Individuals living with ASD frequently struggle with identifying and reaction appropriately to emotional states of others. The method 1000 can support understanding by an ASD individual of the emotional states of those around them and appropriate response thereto through automated identification of emotional states of nearby individuals.

In some implementations, the method 1000 begins with obtaining video data (1002). The video data, for example, may include images captured by a head-mounted or otherwise body-mounted camera of a vicinity surrounding a user. The video data may represent the surroundings of a user as viewed more-or-less through the eyes of the user. In one example, the video data is video recording data 116a captured by the wearable data collection device 104, as described in relation to FIG. 1A.

In some implementations, one or more individuals are identified within the video data (1004). The individuals, for example, can include family members, social peers, colleagues, or other people in the surroundings. Additionally, in some embodiments, the individuals can include animals, such as a family pet or a therapy dog. For example, as illustrated in FIG. 10B, an individual 1022 is identified within video data, as illustrated in a screen shot 1020.

In some implementations, for each individual identified, body language is analyzed to identify the emotional state of the individual (1006). For example, an emotional identification and training module may review an individual’s posture, including head position, arm position, and hand gestures or other gestures (e.g., hugging, self-hugging, cheek stroking, head scratching, head holding, high-fiving, fist-bumping, patting another on the shoulder) for evidence of body language associated with a particular emotion. In another example, the emotional identification and training module may review an individual’s facial expression, including mouth shape, eyebrow position, pupil dilation, eye moistness, and other facial cues regarding emotional state. Turning to FIG. 10B, for example, the emotional identification and training module has identified both a face (designated by a focus frame 1024a) of the individual 1022 and a mouth position 1026 (designated by a focus frame 1024b) of the individual 1022, as illustrated in an analysis pane 1026. Returning to FIG. 10A, the emotional identification and training module may also review body dynamics such as, in some examples, trembling, bouncing, shaking, rocking, or other motions associated with emotional state.

If audio data is available (1008), in some implementations, the audio data is analyzed for emotional cues (1010).

For example, the emotional identification and training module may extract audio associated with verbalizations of a particular individual identified within the video recording data. The audio may be reviewed for tone, volume, pitch, patterns in pitch (e.g., sing-song, questioning, etc.), vocal tremors, sobbing, hiccuping, laughing, giggling, snorting, sniffing, and other verbalizations and/or intonations that may be associated with emotional state. In some implementations, the emotional identification and training module may further identify one or more emotional words or phrases within the audio data.

In some implementations, the audio-derived emotional cues are applied to the identified emotional state(s) to refine the emotional state of at least one individual (1012). For example, if the emotional state of the individual, based upon video analysis alone, suggested two or more potential emotional states, the audio-derived emotional cues may be used to promote or demote the various options to identify a most likely emotional state candidate. In other implementations, for example if the audio-derived emotional cues are more reliable because the video is obscured or the individual is not facing the camera, the audio-derived emotional cues may be used as primary reference or sole reference to determine the emotional state of at least one individual.

In some implementations, information regarding the emotional state of at least one individual is presented to a user (1014). For example, a feedback algorithm may augment the video feed of a heads-up display of a data collection device to overlay a description of the emotional state of the individual, such as the word “irritated” floating above the individual’s head or a simplified cartoon icon representing an emotional state such as bored, happy, tired, or angry may supplant the individual’s face in the heads-up display or hover near the individual’s face within the heads-up display. As illustrated in the screen shot 10B, for example, an icon 1028 representing the emotional state of the individual 1022, as well as a label 1029 (“happy”), are presented within the analysis pane 1026. Alternatively or individually, a term or sentence for the emotional state may be presented audibly to the user, such as “mom is happy.” Further, audio or video feedback may spell out to the user the particular response behavior to invoke, such as an audible cue directing the subject to “smile now” or a visual cue including the text “nod your head and look concerned.” If the individual is an animal, the user may be presented with verbal and/or audible warnings, such as “may bite” or “back away”.

In some implementations, rather than presenting an emotional state of the individual, the application may take a form of a game, where the user is presented with a multiple choice selection of three potential emotional states. In this manner, the user may be quizzed to pay close attention to learning physical and audible cues identifying emotional states. Further, based upon the user’s responses, an emotional state awareness tracking module may learn which emotional states are difficult for the user to identify or whose emotional states are difficult for the user to identify. For example, the user may have difficulty recognizing emotional states of bearded men. To aid in recognition, feedback to the user may include hints for identifying particular emotional states, such as “raised eyebrows indicate surprise”. Turning to FIG. 10C, for example, a screen shot 1030 including the individual 1022 includes a set of selectable emoticons 1032, where emoticon 1032a represents a happy emotional state and emoticon 1032b represents a surprised emotional state. The user may select one of the emoticons 1032 (e.g., through an input device of a wearable data collection device such as a tap, head movement, verbal command, or thought pattern).

The game may then present feedback to the user to correct or congratulate the user, based upon a selected emoticon **1032**.

Although described in a particular series of steps, in other implementations, the method **1000** may be performed in a different order, or one or more steps of the method **1000** may be removed or added, while remaining in the spirit and scope of the method **1000**. For example, rather than analyzing live video data and presenting information related to emotion, in some implementations, the method **1000** may be adjusted to present a review exercise incorporating images of people that the individual interacted with recently (e.g., in the past hour, day, week, etc.). In a familiar faces review exercise module, for example, aspects of the method **1000** may be used to quiz the individual on emotional states represented by images or short video segments of one or more faces identified in video data captured by the wearable data collection device. By using short video segments rather than still images, for example, the familiar faces review exercise module may allow the individual to derive emotional cues from body language, vocalizations, and other additional information.

FIG. **11** is a block diagram of an example system **1100** for identifying and analyzing circumstances surrounding adverse health events and/or atypical behavioral episodes and for learning potential triggers thereof. The system **1100** may analyze factors surrounding the onset of adverse health events and/or atypical behavioral episodes to anticipate future events. The factors may include, in some examples, dietary factors, fatigue, light sensitivity, noise sensitivity, olfactory sensitivity, and prescription and/or over-the-counter drug consumption patterns. Adverse health events, for example, may include migraine headaches, epileptic seizures, heart attack, stroke, and/or narcoleptic “sleep attacks”. Particular individuals may be monitored for adverse events related to known health conditions, such as individuals in congestive heart failure or in presence of aneurysm, individuals recovering from stroke, or individuals suffering from cardiac disease, diabetes, or hypo/hypertension. Further, individuals may be monitored due to psychiatric conditions such as panic disorders. Atypical behavioral episodes may include, in some examples, swings in manic-depressive behavior or bipolar behavior, emotional outbursts triggered by post-traumatic stress disorder (PTSD), and acting out or stimming episodes related to ASD.

An individual **1102** wears or otherwise carries a data collection device **1104**, such as the wearable data collection device **104** or **108** described in relation to FIGS. **1A** and **1B**. In further examples, the data collection device **1104** may be incorporated in a general purpose personal electronics device such as a smart phone, tablet computer, or smart watch or in a specialized health and fitness computing device such as a Fitbit® wireless activity monitor by Fitbit, Inc. of San Francisco, Calif. The data collection device **1104** is configured for collection of various data **116**, including, in some illustrated examples, audio recording data **116a**, video recording data **116b**, EEG data **116f**, EMG data **116i**, heart and breathing data **116e**, motion tracking data **116h**, and eye tracking data **116g**, as discussed in relation to FIGS. **1A** and **1B**. Furthermore, in some implementations, the data collection device **1104** may be configured to collect temperature monitoring data **1106a**, including a skin or body temperature of the individual **1102** and/or ambient temperatures of the area surrounding the individual **1102**. In some implementations, the data collection device **1104** may be configured to collect light monitoring data **1106b**, for example as derived from a camera device or simpler light sensor. Scent moni-

toring data **1106c** may identify various fragrances in the vicinity of the individual **1102**. Enhanced physiological data monitoring of the data collection device **1104**, in some examples, may include blood dynamics and chemistry data **1106d** (pulse oximetry, blood flow or volume changes, etc.), skin dynamics data **1106e** (galvanic skin response and skin conductance response measurements, etc.), and vestibular dynamics data **1106f** used to monitor the movements of the individual **1102** to gauge whether they are standing upright versus falling or wobbling and gyrating, such as a horizon monitor in combination with a motion monitor.

Data **1108** collected by the wearable or portable data collection device **1104** (and, potentially, data collected by peripheral devices in communication with the data collection device **1104**), in some implementations, are used by a number of algorithms **1110** developed to analyze the data **1108** and determine feedback **1112** to provide to the individual **1102** (e.g., via the data collection device **1104** or another computing device). The algorithms **1110** may further generate analysis information **1114** to supply, along with at least a portion of the data **1108**, to learning engines **1118**. The analysis information **1114** and data **1108**, along with learning information **1120** generated by the learning engines **1118**, may be archived as archive data **1122** for future use, such as for pooled statistical learning. The learning engines **1118**, furthermore, may provide learned data **1124** and, potentially, other system updates for use by the data collection device **1104**. The learned data, for example, may be used by one or more of the algorithms **1110** executed upon the data collection device **1104**. A portion or all of the algorithms **1110**, for example, may execute upon the data collection device **1104**. Conversely, in some implementations, a portion or all of the algorithms **1110** are external to the data collection device **1104**. For example, certain algorithms **1104** may reside upon a computing device in communication with the data collection device **1104**, such as a smart phone, smart watch, tablet computer, or other personal computing device in the vicinity of the individual **1102** (e.g., belonging to a caregiver, owned by the individual **1102**, etc.). Certain algorithms **1110**, in another example, may reside upon a computing system accessible to the data collection device **1104** via a network connection, such as a cloud-based processing system.

The algorithms **1110** represent a sampling of potential algorithms available to the data collection device **1104**. The algorithms **1104** may vary based upon the goal of a particular implementation. For example, a first set of algorithms may be used to anticipate migraine headaches, while a second set of algorithms are used to anticipate ASD-related acting out events. Basic to anticipation of events or atypical behavior episodes is an event identifier algorithm **1110a**, configured to recognize occurrence of an adverse event or episode. Data collected by the data collection device **1104** immediately leading to and during the event identified by the event identifier algorithm **1110a**, for example, may be presented to the learning engines **1118** for review and analysis.

Based upon data collected regarding the individual **1102** and, optionally, additional individuals having the same disorder and potentially sharing similarities of symptoms, the learning engines **1118** may derive correspondence between events and one or more corresponding factors. Many of the algorithms **1110** are designed to identify factors which may contribute to one or more health events. For example, an activity identification algorithm **1110d** identifies activities the individual **1102** is engaged in such as, in some examples, driving, watching television, eating, sleeping, bicycling, working out at a gym, working at a computer, reading a

book, and tooth brushing. The activity identification algorithm **1110d**, in some implementations, provides information to a fatigue analysis algorithm **1110e** which monitors sleep patterns and/or other symptoms of fatigue (e.g., skin temperature data **1106a**, EEG data **116f** and/or EMG data **116i**, heart and breathing data **116e**, etc.).

Certain algorithms **1110**, in some implementations, are designed to monitor consumption factors. For example, a stimulant consumption identification algorithm **1110b** may identify consumption of caffeinated beverages, such as coffee and soda, while a dietary intake identification algorithm **1110f** may identify consumption of various types of foods. The stimulant consumption identification algorithm **1110b** and/or the dietary intake identification algorithm **1110f**, in some implementations, identifies food “objects” through data learned by the learning and data analysis modules **520** described in relation to FIG. 5A towards object identification. For example, label scanning capabilities as described in relation to object identification in FIG. 5A may be used to identify packaged food items (e.g., bottles of soda, etc.) and identify ingredients within packaged food items which may prove to be triggers (e.g., aspartame, monosodium glutamate, etc.). Further, the prescription intake identification algorithm **1110n** may use one or more label scanning capabilities, described in relation to FIG. 5A, to identify prescription or over-the-counter drug consumption.

In monitoring consumption factors, in some implementations, the learning engines **1118** may include a dietary intake analysis module for tracking (or estimating) consumption factors such as, in some examples, calories, vitamins, minerals, food category balance, fats, sugars, salt, and/or fluid volume. Based upon video recording data **116b**, for example, the dietary intake identification algorithm **1110f** may estimate (from relative sizes of items within an image) a portion of various foods consumed by the individual **1102**. For example, the dietary intake identification algorithm **1110f** may recognize, through label scanning, dietary intake analysis of a prepackaged food item. Additionally, the dietary intake identifier may recognize the consumption of an apple. A learning engine **1118** may correlate a medium-sized apple with a particular intake analysis, as well as logging the apple as belonging to the fruits food group.

Food intake data collected by the dietary intake identifier **1110f** and analyzed by one of the learning engines **1118**, in some implementations, may be provided to the individual **1102** via feedback **1112**, for example, to aid in healthy eating choices and weight loss monitoring. In another example, food intake data may be provided to a caregiver, personal coach, or health professional for review in relation to treatment of a health condition, such as hypertension.

In some implementations, a portion of the algorithms **1110** are designed to monitor triggering factors such as, in some examples: loud, irritating, or potentially frightening noises via a noise intensity analysis algorithm **1110i**; strobing, intense, or unusually colored ambient light via a light intensity analysis algorithm **1110j**; subtle but potentially aggravating noises via a background noise analysis algorithm **1110k**, and strong or potentially evocative scents via a scent analysis algorithm **1110g** (e.g., fed by scent data **1106c** collected by a scent monitor). In the example of ASD, a potential trigger includes vowel-consonant boundary analysis to identify when nearby speakers may be mumbling or slurring words. The vowel-consonant boundary analysis, furthermore, can indicate the state of the individual **1102**, such as contributing to fatigue analysis **1110e** or identifying a drugged state (e.g., building into the prescription intake identifier **1110n**).

In some implementations, a portion of the algorithms **1110** are designed to monitor for physiological factors leading to an event. For example, a vocalization analysis algorithm **1110o** may identify voice fluctuation patterns that may later be identified (e.g., by the learning engines **1118**) to commonly precede adverse health events. EMG data **116i** and/or EEG data **116f** may further be analyzed by the learning engines **1118** to identify neurological data patterns commonly preceding events. Algorithms **1110** may then be designed to identify the advent of such neurological data patterns.

In some implementations, rather than collecting EMG data **116i** and/or EEG data **116f**, the data collection device **1104** is designed to indirectly monitor cardiovascular dynamics to reveal underlying physiological functions. The core principle is the following: when the heart beats, an impulse-wave of blood courses through the body via the vasculature. As the impulse travels through the body, the body actually moves, physically. Certain parts, such as extremities, move in more pronounced ways. The head, for instance, moves in a bobble fashion, perhaps in part because the exquisite joints of the neck allow many degrees of freedom of motion and because the head is weighty and receives a large amount of the force of traveling blood and because muscles in the neck serve to stabilize the head and may cause reverberations with each beat. This may result in particularly pronounced head motions in the case of anomalous heart beats, such as in disease or sudden exertion, if the musculature evolved and learned to accommodate for healthy and statistically more frequent heart beat and pulse-wave dynamics. Specific heart defects or types of cardiac disease typically result in anomalous head motions. For instance, a forward-backward head bob can indicate one type of heart problem while a side-to-side head bob can indicate another.

A portion of the algorithms **1110**, thus, may be designed to indirectly measure physiological dynamics of the body, such as heart rate and cardiovascular dynamics by means of motion sensors, such as one or more accelerometers, gyroscopes, magnetometers, gravity sensors, and/or linear accelerometers. The motion sensors may be positioned at strategic points on the body of the individual **1102** such as on the head or at other extremities. Various configurations and deployments of motion sensors may include standalone motion sensors, one or more motion sensors incorporated into a separate device, and one or more sensors incorporated into the wearable data collection device **1104**. The wearable data collection device **1104**, for example, may be head-mounted, incorporating a number of sensors feeding data to a small motion analysis algorithm **1110m** to derive cardiovascular dynamics information. The small motion analysis algorithm **1110m**, for example, may be designed to measure motions of the body, especially body parts distant from the heart, that are secondary to actual heart (muscular) motions. For example, the small motions may relate to flow dynamics of blood, impulse waves in the vascular system related to heart contractions (healthy or atypical), motions related to muscular contractions in the body functioning as part of bodily systems to control and counteract pulse-related motions (e.g., such as pulses in the neck region, temples, etc.), and/or other related motions.

In some implementations, a body motion analysis system includes number of algorithms **1110** as well as one or more learning engines **1118** to extract physiological-motion data and to interpret the physiological-motion data. For example, the small motion analysis algorithm **1110m** separates motions related to relevant physiological events (such as

heart beats or breaths, among other possible physiological target motions) from other motions (such as those from walking or gestures). An additional algorithm **1110** or learning engine **1118** component of the body motion analysis system, further to the example, receives physiological event motion data from the extraction component and operates on the information, in order to reveal physiological information such as heart dynamics or breathing dynamics.

In a simple illustrative example, the wearable data collection device **1102** includes an inertial measurement unit (IMU) sensor system such as an accelerometer and gyro complex, integrated directly with hardware and software drivers. While worn by the individual **1102**, the sensor system physically moves with the head with the pulsatile motion of the blood coursing through, e.g., the carotid and cerebral arteries (the “ballistocardiogram”). The sensor system, further to the example, may be directly attached to a sensor driver complex including a printed circuit board with components that drive the IMU and acquire data from it, an analysis unit, and a power source.

In some implementations, to allow the data collection device **1104** to collect physiological data based upon small motions, the individual **1102** first calibrates the data collection device **1104** to identify the pulse or breathing patterns through motion data. For example, if the data collection device **1104** includes a portable personal electronics device such as a smart phone, the individual **1102** may hold the data collection device **1104** at arm’s length while aiming a camera lens at his face to determine pulse, and calibrate motion-based one. For the wearable data collection device **1104** with a face-presenting camera device, in another example, a calibration mode may include standing quietly and still while the data collection device **1104** calibrates based on motions identified via the face-presenting camera.

In addition to motion sensors, other sensors incorporated into the data collection device, in some implementations, are used to derive small motion data. For example, the small motion analysis algorithm **1110m** may analyze video recording data **116b** to interpret deflections of a head-mounted camera as motions indicative of heartbeat, or sinusoidal are motions as breathing. In another example, a laser sensor, for example incorporating interferometry readings, may be used to sense small motions. A light sensor collecting light monitoring data **1106b**, for example, may provide interferometry data for the analysis.

In some implementations, additional data sources may be used to infer cardiovascular dynamics data. For example, a heat fluctuation analysis algorithm **1110l** may measure heat fluctuations related to small motions of the body. These heat fluctuations, for example, may be related to cardiovascular or other dynamics. Heat fluctuations may be measured by any number of available heat measurement devices for surface and radiant heat, including commercially available thermometers, thermistors, digital heat sensors, and other temperature sensors as well as devices or elements thereof having thermoelectric and pyroelectric materials and/or generators. When incorporating thermoelectric and pyroelectric materials, the wearable data collection device **1104** may further be configured to collect heat energy as a supplemental source of power for charging a battery system of the wearable data collection device **1104** and/or one or more peripheral devices. In an example configuration, the wearable data collection device **1104** may include a heat measurement device such as a far-infrared camera or sensor mounted proximate to the face of the individual **1102** and separated by a small distance (e.g., mounted on a short stalk extending from the wearable data collection device **1104**),

with a line of sight to the facial skin or other bodily skin. In another example, a small noise analysis algorithm **1110p** may “listen” for breathing or other small sounds associated with heart beat or pulse, as well as sounds associated with small body motions that result from the pulse and/or breathing. An eye motion analysis algorithm **1110c**, in a further example, may analyze blinking, eyelid dynamics, and/or eye movement dynamics.

Using the data collected by the small motion analysis algorithm **1110m**, eye motion analysis algorithm **1110c**, heat fluctuation analysis algorithm **1110l**, and/or small noise analysis algorithm **1110p**, in some implementations, one or more learning engines **1118** may infer a variety of physiological data. The physiological data can include heart dynamics such as, in some examples, heart rate, heart rate variability, QRS complex dynamics, heart beat amplitude, or murmur, and fibrillation. Further, the physiological data can include breathing dynamics such as breathing depth, breathing rate, and identification of yawning (e.g., potentially feeding back to the fatigue analysis algorithm **1110e**). Other possible extensions include gut dynamics, body motions associated with seizures or autistic tantrums, and cerebral blood flow dynamics (e.g., providing insight into brain dynamics).

Using the data collected by the small motion analysis algorithm **1110m**, eye motion analysis algorithm **1110c**, heat fluctuation analysis algorithm **1110l**, and/or small noise analysis algorithm **1110p**, in some implementations, one or more learning engines **1118** may infer information related to various unwellness conditions or health states. The unwellness conditions can include, in some examples, neurodegenerative conditions such as Huntington’s Disease, Alzheimer’s Disease, Parkinson’s Disease, prion diseases, other spongiform encephalopathies, or other neurodegenerative conditions, as well as other neural conditions such as dystonia.

For instance, in the case of Parkinson’s Disease, the wearable data collection device **1104** may be configured to collect data, using the small motion analysis algorithm **1110m** and/or other algorithms **1110**, related to rhythmic, side-to side and rotational head motions that are characteristic of the condition. Further, the learning engines **1118** corresponding to the Parkinson’s Disease condition may apply pattern analysis and/or other analysis to identify variance(s) in those motions corresponding to data capture-related metadata such as, in some examples, time of day of data capture, location at time of capture, etc. Further, the learning engines **1118** may correlate collected data to subject clinical data, such as contemporaneous medical interventions and/or medication schedule (e.g., accessed from a separate system and/or identified by the prescription intake identifying algorithm **1110n**). In an additional example, the learning engines **1118** may correlate small motion data with data obtained through other algorithms **1110** such as, in some examples, diet data collected by the dietary intake identifier **1110f**, activity data collected by the activity identifier **1110d**, mental tasks and engagement cues collected, for example, by the fatigue analysis algorithm **1110e**, eye motion analysis algorithm **1110c**, and/or vocalization analysis algorithm **1110o**, and/or environmental conditions and events collected by the noise intensity analysis algorithm **1110j**, event identifier **1110a**, and/or scent analysis algorithm **1110g**. Further, additional algorithms **1110** and/or external data may provide cyclical fluctuation data such as circadian rhythms and/or seasonal rhythms for correlation with the small motion data by the learning engines **1118**. Although described in relation to the various algorithms **1110**, in other

implementations, data may be accessed from a separate system (e.g., such as a patient information portal connecting the learning engines 1118 to user medical records), input directly by the wearer, and/or input to an independent software application accessed by a caregiver, physician, or other individual.

In some implementations, small motion data collected by the wearable data collection device 1104 (e.g., via algorithms such as the small motion analysis algorithm 1110m, eye motion analysis algorithm 1110c, heat fluctuation analysis algorithm 1110l, and/or small noise analysis algorithm 1110p) may be used to assist in diagnosis of an unwellness condition such as Parkinson's. For example, a practitioner may employ the wearable data collection device 1104 as a tool for gathering information regarding an individual outside of a clinician's office. The individual, for example, may be instructed to don the wearable data collection device 1104 for a certain period of time to provide data to the practitioner in identifying an unwellness condition or stage/progression of the unwellness condition. The learning engines 1118 may include a diagnosis support module configured to identify similarities between data patterns collected by the wearable data collection device 1104 and patterns associated with one or more unwellness conditions and provide this information to the practitioner for analysis. Additionally, data collected may be "crowd sourced" and analyzed to refine small motion recognition patterns for behaviors related to an unwellness condition such as Parkinson's as well as small motion recognition patterns matching particular stages or progressions of a particular unwellness condition. In a particular example, pattern analysis may be used to identify small motions indicating an imminent seizure episode in individuals with epilepsy.

In some implementations, as an ongoing support tool for practitioner monitoring of an individual diagnosed with an unwellness condition, the practitioner may review data collected by the wearable data collection device 1104 for periodic evaluations or check-ups, for example to track symptoms, symptom severity, and/or frequency of symptomatic behaviors. Additionally, with the support of data collected by other algorithms 1110, the practitioner may be presented with patterns identified by the learning engines 1118 related to controlled and non-controlled factors tending to correlate with the expression of symptoms or with symptom severity.

In some implementations, the individual 1102 uses the wearable data collection device 1104 in an ongoing manner to aid in managing symptoms and/or evaluating interventions or treatments related to behaviors identified through the algorithms 1110. The individual 1102, in a particular example, may wear the wearable data collection device 1104 as part of a clinical trial related to a particular treatment or intervention for an unwellness condition. In another example, the wearable data collection device 1104 may be configured to provide feedback directly to the individual 1102 to support management of symptoms. In either of the above cases, the learning engines may identify patterns of behaviors correlating to elements within direct control of the individual 1102 which appear to contribute to the frequency or severity of symptoms and recommend non-clinical interventions that the individual 1102 can personally attempt to manage the unwellness condition. The behaviors, in some examples, may include diet, meditation, exercise, sleep patterns, or ingestion of stimulants.

In some implementations, the wearable data collection device 1104 may provide cues for immediate management of symptoms or behaviors corresponding to an unwellness

condition. For example, the learning engines 1118 may use the data 1114 related to small (e.g., head) motions and their dynamics to make ongoing assessments or quantifications of the symptoms and behaviors of the individual 1102 and feed back learned data 1124, such as volitional control or bio-feedback data, for use in empowering the individual 1102 to conduct "smart management" of symptoms or behaviors, thus gaining better control and autonomy. The feedback, for example, may be presented to the individual 1102 via the wearable data collection device 1104 or another peripheral computing device to provide cues to the individual 1102 for suppressing or extinguishing symptoms or behaviors. In a particular example for an unwellness condition involving vestibular system damage, leading to loss of balance, based upon how level the individual 1102 is maintaining head position, the wearable data collection device 1104 may prompt the individual 1102 (e.g., with a visual target on a heads-up display) to adjust head positioning. Further to this example, the wearable data collection device 1104 may include a balance coaching module for training the individual 1102 to accurately compensate for the effects of the vestibular system damage through correction and feedback. Similar management techniques may be applied an individual 1102 with Huntington's Disease to support the individual 1102 in management of stereotypical Huntington's Chorea movements. In another illustration, the system 1100 may analyze small motion data 1114 to anticipate onset of a seizure in an epileptic individual 1102. In anticipation of seizure activity, the system 1100 may issue a warning to the individual 1102 via the wearable data collection device 1104 or other peripheral computing device.

In some implementations, feedback may incorporate suggestions of coping mechanisms for coping with behavioral episodes stemming from a particular unwellness condition, such as, in some examples, panic disorders and attention deficit hyperactivity disorder (ADHD). The wearable data collection device 1104, in a particular example, may visually present and/or "whisper" an attention focusing mechanism for an individual 1102 coping with ADHD to perform to regain focus. The system 1100, further, may monitor and assess effectiveness of a given coping mechanism for the particular individual 1102, such as a deep breathing exercise for controlling panic.

Rather than or in addition to feeding information back to the individual 1102, in some implementations, the learning engines 1118 may generate learned data 1124 for use by one or more systems within or in communication with the wearable data collection device 1104 and/or the individual 1102 to support automated or semi-automated interventions. Such interventions may include, but are not limited to, triggering an implanted device that can disseminate drugs into the body of the individual 1102 appropriately to treat the symptoms or mechanisms of the unwellness condition (e.g., injecting L-Dopa or related pharmaceuticals into the body, etc.) or triggering a neural stimulation device such as a deep brain electrical stimulator or a stimulator using transcranial magnetic or direct-current stimulation.

In a semi-automated intervention, rather than triggering a therapeutic response to identified symptoms, the wearable data collection device 1104 may prompt the individual 1102 for approval of the intervention. For example, a message may appear on a heads-up display of the wearable data collection device 104, requesting approval to proceed with an identified intervention. In another example, rather than prompting for approval of the individual 1102, the system 1100 may prompt a caregiver or practitioner for authorization to exercise the intervention. Combinations of these

features are possible. For example, based upon the perceived immediacy and criticality of the intervention, the system **1100** may exercise an automatic intervention rather than a semi-automatic intervention (e.g., in the circumstance where the system **1100** anticipates that the individual **1102** is not in a condition to provide approval).

In the event of a serious condition needing intervention, in some implementations, the system **1100** may present a medical alert to medical professionals, such as calling for an ambulance or directing a medic at a treatment facility to the current location of the individual **1102**. The wearable data collection device **1104**, for example, may derive coordinates (e.g., GPS coordinates, an address, etc.) for directing aid to the individual **1102**. If the medical professionals addressed are connected to the system **1100** (e.g., via a coordinating software application, etc.), the system **1100** may provide a feed of data and other information for immediate assessment of the condition, such as a portion of the data and analysis information **1114** most recently and/or currently captured. In another example, if the system **1100** has a direct communication link with the medical professionals (e.g., telephone number for text message or short recorded message), the system **1100** may issue a message to the medical professionals with brief assessment data.

In some implementations, the algorithms **1110**, individually, in concert, or through data review provided by one or more learning engines **1118**, may provide information to a video and/or gaming system to assess the individual's response to a video or game presented to the individual **1102**. The video or gaming system may be part of the wearable data collection device **1104** or another computing system in communication with the system **1100**. In a particular example, a marketing algorithm may assess the individual's response to the video or game to identify or anticipate the individual's interest in material such as advertisements, political campaign materials, products, product marketing, or other materials involving personal preferences and/or having commercial interests. In another example, a simulation or training system may include one or more algorithms for assessing responses to participants of a simulation (e.g., military training, police officer training, flight training, etc.), such as emotional response.

In some implementations, the video or gaming system may use the assessment of the response of the individual **1102** to the video or game to influence the structure of a game or video that the individual **1102** is presently engaged in. For example, data derived from the algorithms **1110** may be used to alter a difficulty level, direction, or mode of the video game to enhance a desired response from the individual **1102**. In a particular example, if the individual **1102** appears bored or disinterested, the difficulty, direction, and/or mode of the game may be altered to encourage great interest from the individual **1102**. In another example, the video or gaming system may identify responses of excitement, fear, or other arousal and, in response, provide additional video or game sequences which are similar in nature (e.g., anticipated to elicit the same or similar response from the individual **1102**).

In some implementations, the algorithms **1110**, individually, in concert, or through data review provided by one or more learning engines **1118**, provide feedback **1112** regarding inclination towards an impending adverse health event or atypical behavioral episode. For example, depending upon the severity and/or certainty of the impending adverse health event, the individual **1102**, a caregiver, and/or a physician may be alerted to the impending health concern. For example, the wearable data collection device donned by

the individual **1102** may present an audible and/or visual warning regarding the likelihood of an impending health event or atypical behavioral episode and, potentially, an indication of the type of event anticipated. Furthermore, the individual **1102** may be prompted with recommendations of measures to take to best prevent, redirect, and/or minimize the atypical behavioral episode (e.g., take an aspirin). The subject, in some implementations, may be presented with feedback **1112** designed to divert a pending health event. For example, feedback **1112** may be presented via the subject's wearable data collection device **1104** (e.g., visual, audible, tactile, etc. feedback) designed to alter one or more physiological conditions indicative of a pending health event, such as subduing a panic attack.

In some implementations, the learning engines **1118** evaluates events identified by the event identifier **1110a** associated with many individuals as well as corresponding metadata (e.g., demographics, geographic location, time, weather patterns, and other aspects associated with the onset of the event) to identify event patterns similar to a subject group. In some examples, the learning engines **1118** may identify a particular location at a particular time of day associated with multiple events, such as Tuesdays at 12:00 at a particular intersection of a downtown area. Further, the learning engines **1118** may recognize, from archive data **1122**, that the events are all associated with a loud noise. For example, a train may pass nearby the intersection on one or more days of the week at particular times, and the whistle of the train may trigger events in one or more individuals susceptible to loud noises. In identifying geographic (and, optionally temporal) "hot spots", the system **1100** may further evolve the capability of issuing warnings to other individuals (or caregivers thereof) within the suspect geographic area at a suspect time.

Further, in some implementations the learning engines **1118** analyze event data corresponding to a collection of individuals to generate a hot spot map. The hot spot map, for example, may be supplied to researchers and clinicians for further review and analysis. In another example, the hot spot map may be supplied to individuals and/or caregivers for informational purposes. As the learning engines **1118** evolve in analysis of event data, the hot spot map may be refined to maps corresponding to individuals having similar demographic, diagnostic, and/or clinical backgrounds. For example, a PTSD hot spot map may differ from a ASD hot spot map.

Although described above as learning algorithms **1118**, in other implementations, a portion or all of the learning algorithms **1118** may be replaced with assessment algorithms **1118** lacking an adaptive learning capability. For example, static algorithms for analyzing the data and analysis information **1114** may perform similar roles to learning algorithms **1118** but are not learning algorithms in that they do not change or evolve relative to new data. Instead, static algorithms may be designed to filter or extract information from the data and analysis information **1114**, transform, analyze, and/or combine data **1114** with externally obtained data to perform various functions described above while remaining stable over time until they are altered, updated, or replaced. As with the learning engines **1118**, one or more static algorithms may be programmed initially into the software, firmware, and/or hardware of a component of the wearable data collection device **1104** or other peripheral computing system. As with the learning engines **1118**, static algorithms may also be updated from time to time, for instance in the process of updating software or firmware or

hardware as may be accomplished, in some examples, via remote-pushed updates, by user intervention, or by servicing by service technicians.

In some implementations, one or more of the learning algorithms **1118** are replaced or enhanced by concierge intervention via a concierge intervention system (not illustrated) including a data connection to one or more computer systems, such as a network portal connection, to supply data and analysis information **1114** and/or data, analysis, and learning information **1120** to a human operator. In this manner, the concierge intervention system may be used in a manner whereby data related to the individual **1102** may be processed in part by human operators, including, for example, trained health practitioners, data analysts, and/or technicians, rather than being processed solely by automated processes (e.g., algorithms **1110** and/or learning engines **1118**). The human operator, for example, may review the data and analysis information **1114** and/or data, analysis, and learning information **1120**, performing actions and mental tasks that replace or augment one or more functions or roles performed by learning algorithms **1118**. During review of the data and analysis information **1114** and/or data, analysis, and learning information **1120**, the actions and mental tasks performed by a human operator may involve or be supplemented by actions or data transformations executing upon a computing device. In one illustrative example, a human operator may review data obtained by the small motion analysis algorithm **1110m** to manually count heart beats or breaths, potentially with the assistance of some analysis or computation software. The human operator may further enter results of the manual count into the computing device to feed the information back into the system **1100**. In another illustrative example, the concierge intervention system can receive the voice recording data **116a** collected by the wearable data collection device **1104**. In such as example, a human operator may listen to the voice recording data **116a**, count the breaths based on the sound of the person breathing in and out, and then forward the results of this analysis (e.g., manual breath count) to the system **1100** (e.g., the learning engines **1118**, wearable data collection device **1104**, archive data **1122**, etc.). In some implementations, the concierge intervention system may perform the same or similar functions performed by the learning algorithms **1118** and/or algorithms **1110**, for instance in cases of quality assurance or oversight or during testing.

In another example, feedback **1112** may be designed to correct for an issue exhibited by the individual **1102**. For example, based upon analysis of vestibular dynamics data **1106f**, feedback **1112** regarding present balance may be presented to the individual **1102**. Further, a game or task such as virtual balance beam may be presented to the individual **1102** to encourage corrective behavior.

In some implementations, a subject identification algorithm **1110h** may review the data **1108** or analysis information derived by one or more of the other algorithms **1110** to uniquely identify the individual **1102** based upon biometric identification. The biometric identification, in turn, may be used to recognize a current user of the data collection device **1104** in view of a group of potential users (e.g., family members, health club members, etc.). Furthermore, the biometric identification may be used in an authentication process when communicating with third party systems via the data collection device **1104** such as, in some examples, web sites, banks, ATMs, or building security access systems.

The learning engines **1118**, in some implementations, review the data **1108** and analysis information **1114** for biometric signatures regarding groups of individuals. For

example, biometric similarities may be derived in families, age groups, racial classifications, and/or disease categories.

Next, a hardware description of an example wearable data collection device according to exemplary embodiments is described with reference to FIG. **12**. In FIG. **12**, the wearable data collection device includes a CPU **1200** which performs a portion of the processes described above. The process data and instructions may be stored in memory **1202**. These processes and instructions may also be stored on a storage medium disk **1204** such as a portable storage medium or may be stored remotely. Further, the claimed advancements are not limited by the form of the computer-readable media on which the instructions of the inventive process are stored. For example, the instructions may be stored in FLASH memory, RAM, ROM, or any other information processing device with which the wearable computing system communicates, such as a server or computer.

Further, components of the claimed advancements may be provided as a utility application, background daemon, or component of an operating system, or combination thereof, executing in conjunction with CPU **1200** and an operating system such as and other systems known to those skilled in the art.

CPU **1200** may be an ARM processor, system-on-a-chip (SOC), microprocessor, microcontroller, digital signal processor (DSP), or may be other processor types that would be recognized by one of ordinary skill in the art. Further, CPU **1200** may be implemented as multiple processors cooperatively working in parallel to perform the instructions of the inventive processes described above.

The wearable computing system in FIG. **12** also includes a network controller **1206** for interfacing with network **1228**. As can be appreciated, the network **1228** can be a public network, such as the Internet, or a private network such as an LAN or WAN network, or any combination thereof and can also include PSTN or ISDN sub-networks. The network **1228** can be wireless such as a cellular network including EDGE, 3G and 4G wireless cellular systems. The wireless network can also be Wi-Fi, Bluetooth, or any other wireless form of communication that is known.

The wearable data collection device further includes a display controller **1208** interfacing with display **1210**, such as a remotely located display or a heads up display. A general purpose I/O interface **1212** interfaces with an input device (e.g., microphone for voice commands, etc.). General purpose I/O interface can also communicate with a variety of on board I/O devices **1216** and/or peripheral I/O devices **1218** including, in some examples, a video recording system, audio recording system, microphone, gyroscopes, accelerometers, gravity sensors, linear accelerometers, global positioning system, magnetometers, EEG, EMG, EKG, bar code scanner, QR code scanner, RFID scanner, temperature monitor, skin dynamics sensors, scent monitor, light monitor, blood dynamics and chemistry monitor, vestibular dynamics monitor, external storage devices, and external speaker systems.

A sound controller **1220** is also provided in the wearable data collection device, to interface with speakers/microphone **1222** thereby both recording and presenting sounds to the wearer.

The general purpose storage controller **1224** connects the storage medium disk **1204** with communication bus **1226**, such as a parallel bus or a serial bus such as a Universal Serial Bus (USB), or similar, for interconnecting all of the components of the wearable computing system. A description of the general features and functionality of the display **1210**, as well as the display controller **1208**, storage con-

troller **1224**, network controller **1206**, sound controller **1220**, and general purpose I/O interface **1212** is omitted herein for brevity as these features are known.

The wearable data collection device in FIG. **12**, in some embodiments, includes a sensor interface **1230** configured to communicate with one or more onboard sensors **1232** and/or one or more peripheral sensors **1234**. The onboard sensors **1232**, for example, can be incorporated directly into the internal electronics and/or a housing of the wearable device. The peripheral sensors **1234** can be in direct physical contact with the sensor interface **1230** e.g. via a wire; or in wireless contact e.g. via a Bluetooth, Wi-Fi or NFC connection. Alternatively, one or more of the peripheral sensors **1234** may communicate with the sensor interface **1230** via conduction through the body tissue or via other mechanisms. Furthermore, one or more peripheral sensors **1234** may be in indirect contact e.g. via intermediary servers or storage devices that are based in the network **1228**; or in (wired, wireless or indirect) contact with a signal accumulator somewhere on or off the body, which in turn is in (wired or wireless or indirect) contact with the sensor interface **1230**. The peripheral sensors **1234** can be arranged in various types of configurations relative to the body. For instance, they can be mounted on the body, near the body, looking at the body, and/or implanted within the body of a human or animal subject. The onboard sensors **1232** and/or peripheral sensors **1234** can include, in some examples, one or more microphones, bone-conduction microphones, physiological events microphones, cameras, video cameras, high-speed cameras, temperature monitors, accelerometers, gyroscopes, magnetic field sensors, magnetic compasses, tap sensors and/or vibration sensors—internal or external to a gyroscope/accelerometer complex, infrared sensors or cameras, and/or eye-tracking cameras or eye-tracking sensor complex. In further examples, onboard sensors **1232** and/or peripheral sensors **1234** may include one or more skin-mounted electrodes, body-proximal electrodes (contact or non-contact), pulse oximetry devices, laser and laser-light sensors, photodiodes, galvanic skin response sensor modules, RF or other electromagnetic signal detectors, electrical signal pre-amplifiers, electrical signal amplifiers, electrical signal hardware filter devices, chemical sensors, and/or artificial noses.

A group of sensors communicating with the sensor interface **1230** may be used in combination to gather a given signal type from multiple places such as in the case of EEG or skin temperature in order to generate a more complete map of signals. One or more sensors communicating with the sensor interface **1230** can be used as a comparator or verification element, for example to filter, cancel, or reject other signals. For instance, a light sensor can pick up ambient light or color changes and use them to subtract or otherwise correct light-based signals from a camera pointed at the eye or skin to pick up small color or reflectance changes related to physiological events. Likewise, a microphone mounted against the body can pick up internal sounds and the voice of the subject donning the wearable data communication device and subtract the internal sounds from ambient sounds such as the voice of a separate individual or noise from environmental events, in order to more concentrate on the audible features of external events. Conversely, sensor data may be used to subtract environmental noise from body-internal sound signatures that can give evidence of physiology. Similarly, the input of multiple temperature monitors can aid in adjusting for major changes in ambient temperature or for narrowing a temperature signature to more narrowly identify the temperature of a particular

element (e.g., device/electronics temperature or body temperature) without contamination from heat provided by other elements.

The wearable data collection device in FIG. **12**, in some embodiments, includes a stimulation interface **1236** for supplying stimulation feedback to an individual donning the wearable data collection device. The stimulation interface **1236** is in communication with one or more onboard stimulators **1238** and/or peripheral stimulators **1240** configured to deliver electrical pulses to the individual, thereby altering physiological conditions of the individual. For example, one or more onboard stimulators **1238** and/or peripheral stimulators **1240** may be situated and/or configured to electrically stimulate heart rate or breathing or brain waves at particular frequencies. The onboard stimulators **1238** and/or peripheral stimulators **1240** can be mounted on or near the body, and/or implanted within the body, and can include components that are external and others that are internal to the body which may be configured for intercommunication with each other. In some examples, onboard stimulators **1238** and/or peripheral stimulators **1240** can include one or more of electrical signal generators and stimulation (output) electrodes, vibrator devices, heat-imparting devices, heat-extraction devices, sound generators/speakers, electromagnets, lasers, LEDs and other light sources, drug administering devices, brain stimulation or neural stimulation devices, gene transcription or expression modulation system, and/or pain or sensory stimulation generators.

Next, a hardware description of the computing device, mobile computing device, or server according to exemplary embodiments is described with reference to FIG. **13**. In FIG. **13**, the computing device, mobile computing device, or server includes a CPU **1300** which performs the processes described above. The process data and instructions may be stored in memory **1302**. These processes and instructions may also be stored on a storage medium disk **1304** such as a hard drive (HDD) or portable storage medium or may be stored remotely. Further, the claimed advancements are not limited by the form of the computer-readable media on which the instructions of the inventive process are stored. For example, the instructions may be stored on CDs, DVDs, in FLASH memory, RAM, ROM, PROM, EPROM, EEPROM, hard disk or any other information processing device with which the computing device, mobile computing device, or server communicates, such as a server or computer.

Further, a portion of the claimed advancements may be provided as a utility application, background daemon, or component of an operating system, or combination thereof, executing in conjunction with CPU **1300** and an operating system such as Microsoft Windows 7, UNIX, Solaris, LINUX, Apple MAC-OS and other systems known to those skilled in the art.

CPU **1300** may be a Xenon or Core processor from Intel of America or an Opteron processor from AMD of America, or may be other processor types that would be recognized by one of ordinary skill in the art. Alternatively, the CPU **1300** may be implemented on an FPGA, ASIC, PLD or using discrete logic circuits, as one of ordinary skill in the art would recognize. Further, CPU **1300** may be implemented as multiple processors cooperatively working in parallel to perform the instructions of the inventive processes described above.

The computing device, mobile computing device, or server in FIG. **13** also includes a network controller **1306**, such as an Intel Ethernet PRO network interface card from Intel Corporation of America, for interfacing with network

13X. As can be appreciated, the network 1328 can be a public network, such as the Internet, or a private network such as an LAN or WAN network, or any combination thereof and can also include PSTN or ISDN sub-networks. The network 1328 can also be wired, such as an Ethernet network, or can be wireless such as a cellular network including EDGE, 3G and 4G wireless cellular systems. The wireless network can also be Wi-Fi, Bluetooth, or any other wireless form of communication that is known.

The computing device, mobile computing device, or server further includes a display controller 1308, such as a NVIDIA GeForce GTX or Quadro graphics adaptor from NVIDIA Corporation of America for interfacing with display 1310, such as a Hewlett Packard HPL2445w LCD monitor. A general purpose I/O interface 1312 interfaces with a keyboard and/or mouse 1314 as well as a touch screen panel 1316 on or separate from display 1310. General purpose I/O interface also connects to a variety of peripherals 1318 including printers and scanners, such as an OfficeJet or DeskJet from Hewlett Packard.

A sound controller 1320 is also provided in the computing device, mobile computing device, or server, such as Sound Blaster X-Fi Titanium from Creative, to interface with speakers/microphone 1322 thereby providing sounds and/or music.

The general purpose storage controller 1324 connects the storage medium disk 1304 with communication bus 1326, which may be an ISA, EISA, VESA, PCI, or similar, for interconnecting all of the components of the computing device, mobile computing device, or server. A description of the general features and functionality of the display 1310, keyboard and/or mouse 1314, as well as the display controller 1308, storage controller 1324, network controller 1306, sound controller 1320, and general purpose I/O interface 1312 is omitted herein for brevity as these features are known.

One or more processors can be utilized to implement various functions and/or algorithms described herein, unless explicitly stated otherwise. Additionally, any functions and/or algorithms described herein, unless explicitly stated otherwise, can be performed upon one or more virtual processors, for example on one or more physical computing systems such as a computer farm or a cloud drive.

Reference has been made to flowchart illustrations and block diagrams of methods, systems and computer program products according to implementations of this disclosure. Aspects thereof are implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer-readable medium that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable medium produce an article of manufacture including instruction means which implement the function/act specified in the flowchart and/or block diagram block or blocks.

The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to

produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of this disclosure. For example, preferable results may be achieved if the steps of the disclosed techniques were performed in a different sequence, if components in the disclosed systems were combined in a different manner, or if the components were replaced or supplemented by other components. The functions, processes and algorithms described herein may be performed in hardware or software executed by hardware, including computer processors and/or programmable circuits configured to execute program code and/or computer instructions to execute the functions, processes and algorithms described herein. Additionally, some implementations may be performed on modules or hardware not identical to those described. Accordingly, other implementations are within the scope that may be claimed.

The invention claimed is:

1. An image processing system, comprising:

at least one camera for capturing images of a surrounding environment of a user;
at least one processor; and

a non-transitory computer readable memory containing software, wherein the software directs the at least one processor to

obtain data comprising a sequence of images captured by the at least one camera,

detect a face for a target person of at least one person within a plurality of images in the sequence of images,

detect at least one emotional cue in the face based upon the plurality of images,

identify at least one emotion expressed by the face based on the at least one emotional cue,

display, to the user, a graphical user interface comprising

at least one of an image of the target person and a live image sequence of the target person, and

two or more visual emotion indicator labels wherein

a first label of the two or more emotion indicator labels identifies a respective emotion of the at least one emotion, and

a second label of the two or more emotion indicator labels identifies a different emotion than any emotion of the at least one emotion,

receive, from the user, selection of one label of the two or more emotion indicator labels for the target person,

determine whether the selection corresponds to the first label identifying the respective emotion, and

provide feedback to the user based on the determining.

2. The image processing system of claim 1, wherein the at least one camera comprises at least one outward facing camera of a wearable video capture system.

3. The image processing system of claim 2, wherein: the wearable video capture system is one of a) a virtual reality headset, b) an augmented reality headset, and c) glasses comprising a heads-up display; and displaying the two or more emotion indicator labels comprises displaying the two or more emotion indicator labels on the heads-up display.

4. The image processing system of claim 2, wherein the wearable video capture system communicates with at least one mobile device, wherein a first processor of the at least one processor is executing on the at least one mobile device.

5. The image processing system of claim 1, wherein the software directs the at least one processor to obtain supplementary data comprising data captured from at least one sensor selected from the group consisting of a microphone, an accelerometer, a gyroscope, an eye tracking sensor, a body temperature sensor, a heart rate sensor, a blood pressure sensor, and a skin conductivity sensor.

6. The image processing system of claim 1, wherein displaying the two or more emotion indicator labels comprises performing at least one of displaying the two or more emotion indicator labels within a heads-up display, generating an audible signal, or generating a vibration.

7. The image processing system of claim 1, wherein the emotional cue comprises information selected from the group consisting of facial expressions, body language, gestures, body pose, head pose, and fidgeting.

8. The image processing system of claim 1, wherein the software directs the at least one processor to store the selection of the one label for the target person in a non-transitory computer readable medium.

9. The image processing system of claim 1, wherein the software directs the at least one processor to: store social interaction data regarding one or more interactions between the user and the target person to a non-transitory computer readable medium; and provide, at a user interface, at least a portion of the social interaction data for review by an individual.

10. The image processing system of claim 1, wherein the software directs the at least one processor to detect gaze events between the user and the face using at least one inward-facing eye tracking data in conjunction with outward-facing video data.

11. The image processing system of claim 1, wherein the software directs the at least one processor to: provide, in a graphical user display, a review of activities recorded by the at least one camera to an individual; and provide, in the graphical user display, user behavioral data generated based on one or more reactions by the user to the recorded activities.

12. The image processing system of claim 1, wherein providing feedback comprises providing, via at least one of audio and visual feedback, a hint for identifying the respective emotion.

13. The image processing system of claim 1, wherein receiving the selection of the one label comprises receiving one of a tap, a head movement, or a verbal command captured by an input sensor of a wearable video capture system.

14. The image processing system of claim 1, wherein displaying the two or more visual emotion indicator labels comprises displaying the two or more visual emotion indicator labels as a multiple choice selection of a game.

15. The image processing system of claim 1, wherein each label of the two or more visual emotion indicator labels is presented as an emoticon representing a respective emotional state.

16. The image processing system of claim 1, wherein the emotional cue comprises information selected from the group consisting of a social eye contact event and a conversational gesture.

17. A method comprising:

obtaining, by an image processing system, data comprising a sequence of images captured by at least one camera of the image processing system, wherein at least one camera captures the sequence of images of a surrounding environment of a user;

detecting, by at least one processor of the image processing system, a face for a target person of at least one person within a plurality of images in the sequence of images,

detecting, by the at least one processor, at least one emotional cue in the face based upon the plurality of images,

identifying, by the at least one processor, at least one emotion expressed by the face based on the at least one emotional cue,

displaying, to the user, a graphical user interface comprising

at least one of an image of the target person and a live image sequence of the target person, and

two or more visual emotion indicator labels, wherein a first label of the two or more emotion indicator labels identifies a respective emotion of the at least one emotion, and

a second label of the two or more emotion indicator labels identifies a different emotion than any emotion of the at least one emotion,

receiving, from the user, selection of one label of the two or more emotion indicator labels for the target person, determining, by the at least one processor, whether the selection corresponds to the first label identifying the respective emotion, and

causing, by the at least one processor, feedback to be provided to the user based on the determining.

18. The method of claim 17, wherein the at least one camera comprises at least one outward facing camera of a wearable video capture system.

19. The method of claim 18, wherein:

the wearable video capture system is one of a) a virtual reality headset, b) an augmented reality headset, and c) glasses comprising a heads-up display; and

displaying the two or more emotion indicator labels comprises displaying the two or more emotion indicator labels on the heads-up display.

20. The method of claim 17, wherein the wearable video capture system communicates with at least one remote computing device via a network, wherein a first processor of the at least one processor is executing on the at least one remote computing device.

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摘要(译)

本文描述的系统，环境和方法支持在家庭环境中对个人进行ASD评估。通过个人穿戴的可穿戴数据收集设备收集的数据，可以在评估过程中跟踪并客观地量化与护理人员的眼神交流，言语互动以及重复的言语和头部和身体的运动。此外，可穿戴数据收集设备可以支持对大脑活动和其他生理的监视，继而可以在评估期间通过本文所述的系统和环境对其进行分析，以识别预测评估结果和其他临床特征的模式。可穿戴数据收集设备支持的各种软件模块和工具可为ASD患者提供培训，持续进度跟踪和管理解决方案。

