US 20080146892A1

(19) United States

(12) Patent Application Publication

LeBoeuf et al.

(10) Pub. No.: US 2008/0146892 A1

(43) Pub. Date: Jun. 19, 2008

(54) PHYSIOLOGICAL AND ENVIRONMENTAL MONITORING SYSTEMS AND METHODS

(75) Inventors: **Steven Francis LeBoeuf**, Raleigh, NC (US); **Jesse Berkley Tucker**, Knightdale, NC (US); **Michael Edward Aumer**, Raleigh, NC (US)

Correspondence Address:
MYERS BIGEL SIBLEY & SAJOVEC
PO BOX 37428
RALEIGH, NC 27627

(73) Assignee: **Valencell, Inc.**

(21) Appl. No.: **11/848,878**

(22) Filed: **Aug. 31, 2007**

Related U.S. Application Data

(60) Provisional application No. 60/905,761, filed on Mar. 8, 2007, provisional application No. 60/876,128, filed on Dec. 21, 2006, provisional application No. 60/875,606, filed on Dec. 19, 2006.

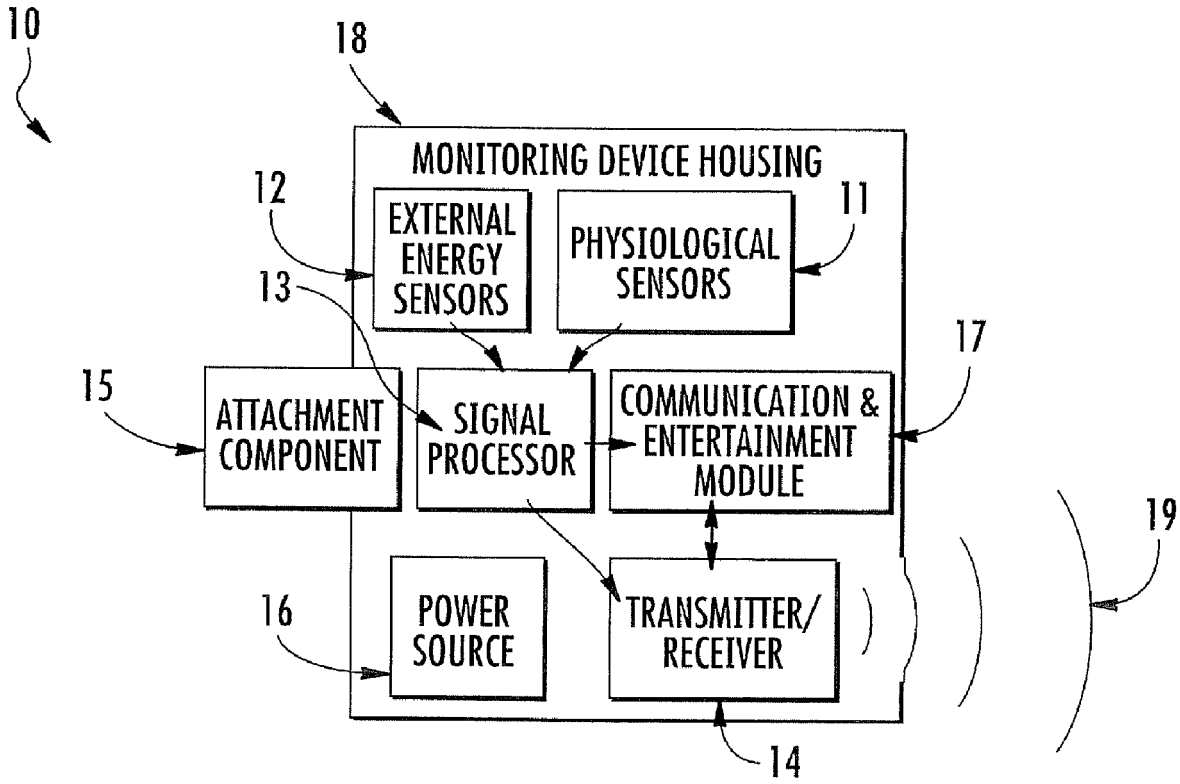
Publication Classification

(51) **Int. Cl.**
A61B 5/00 (2006.01)

(52) **U.S. Cl.** **600/300**

(57) **ABSTRACT**

Systems and methods for monitoring various physiological and environmental factors, as well as systems and methods for using this information for a plurality of useful purposes, are provided. Real-time, noninvasive health and environmental monitors include a plurality of compact sensors integrated within small, low-profile devices. Physiological and environmental data is collected and wirelessly transmitted into a wireless network, where the data is stored and/or processed. This information is then used to support a variety of useful methods, such as clinical trials, marketing studies, biofeedback, entertainment, and others.



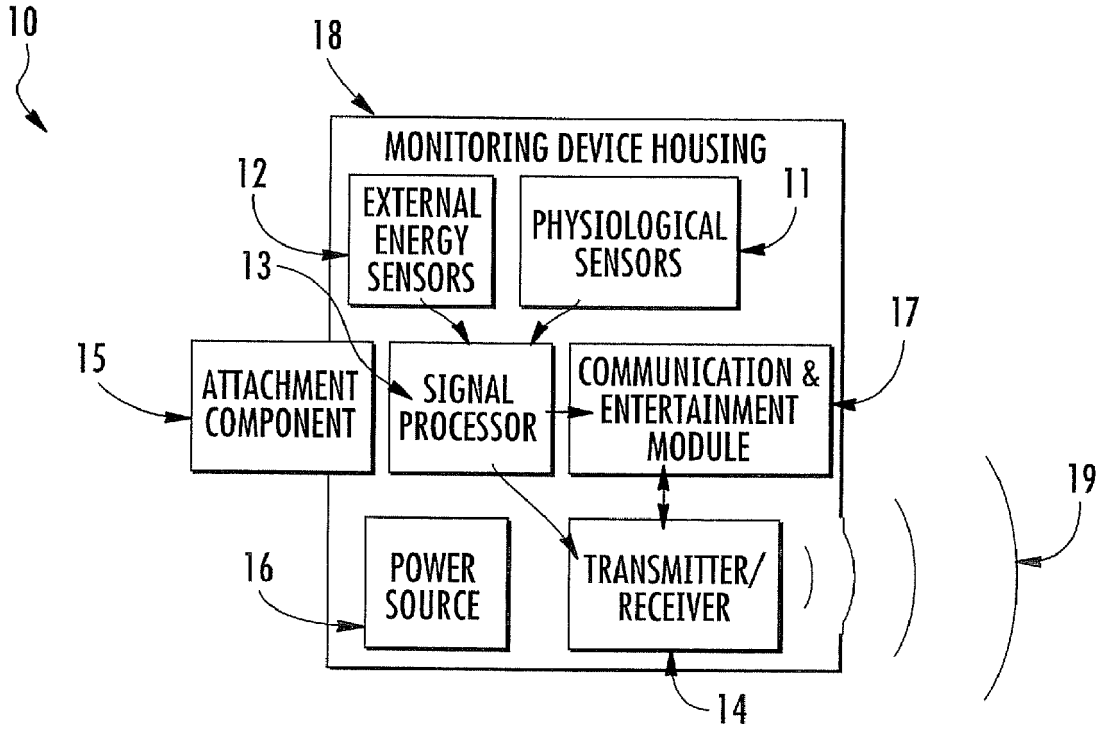

10
18
MONITORING DEVICE HOUSING
12
EXTERNAL ENERGY SENSORS
PHYSIOLOGICAL SENSORS
11
13
17
15
ATTACHMENT COMPONENT
SIGNAL PROCESSOR
COMMUNICATION & ENTERTAINMENT MODULE
19
16
POWER SOURCE
TRANSMITTER/ RECEIVER
14

FIG. 1

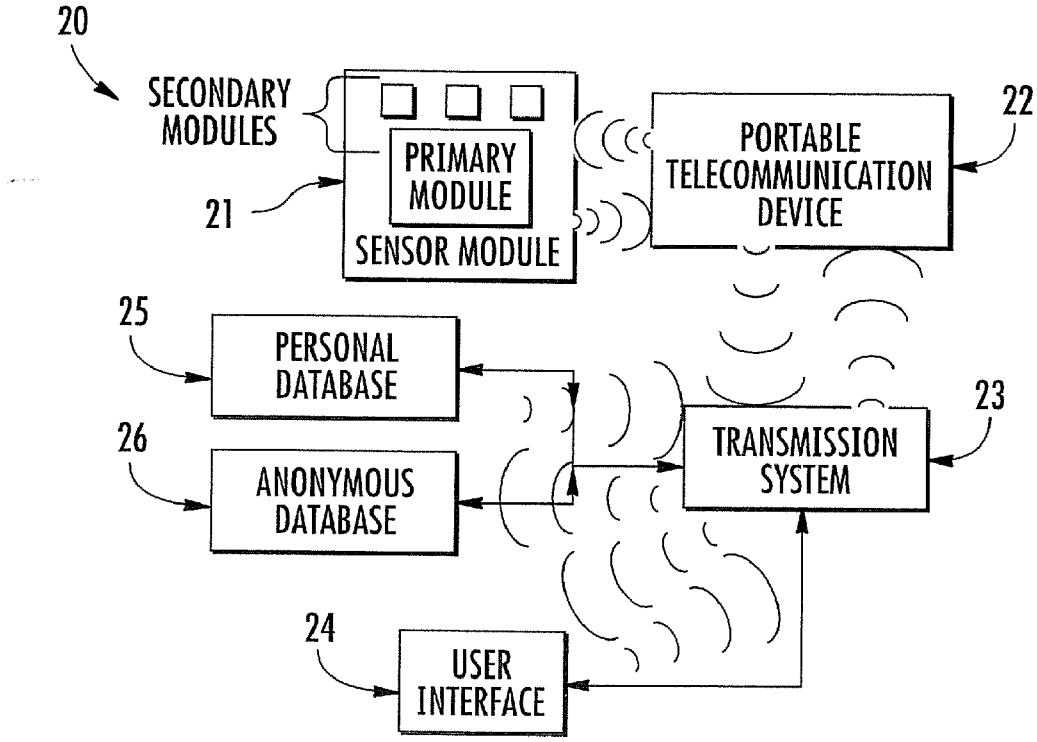

20
SECONDARY MODULES
PRIMARY MODULE
SENSOR MODULE
21
PORTABLE TELECOMMUNICATION DEVICE
22
25
PERSONAL DATABASE
26
ANONYMOUS DATABASE
TRANSMISSION SYSTEM
23
24
USER INTERFACE

FIG. 2

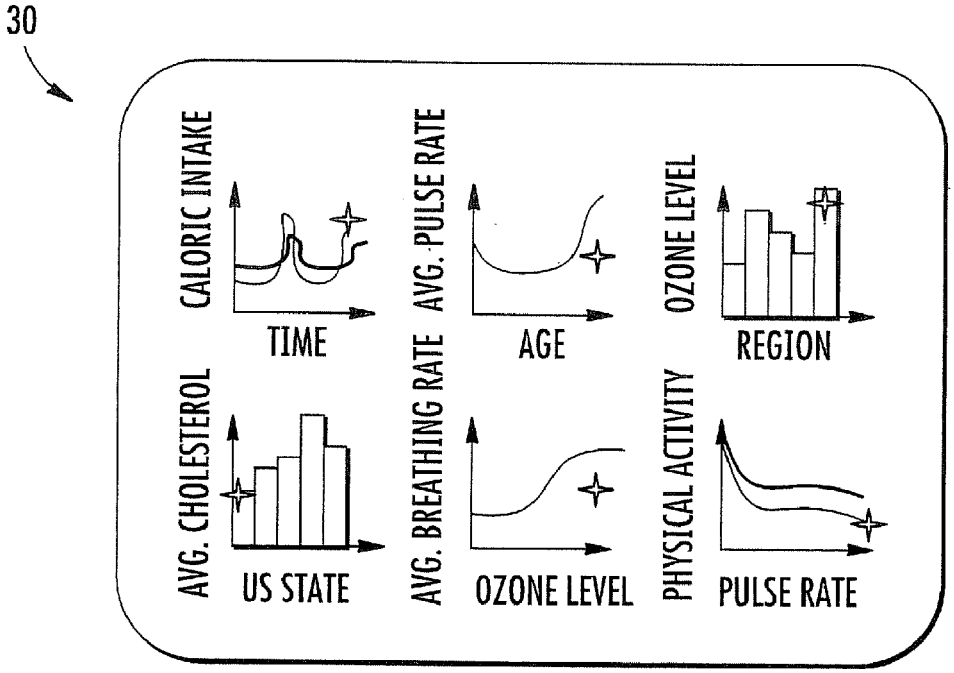

30
CALORIC INTAKE
TIME
AVG. PULSE RATE
AGE
OZONE LEVEL
REGION
AVG. CHOLESTEROL
US STATE
AVG. BREATHING RATE
OZONE LEVEL
PHYSICAL ACTIVITY
PULSE RATE

FIG. 3

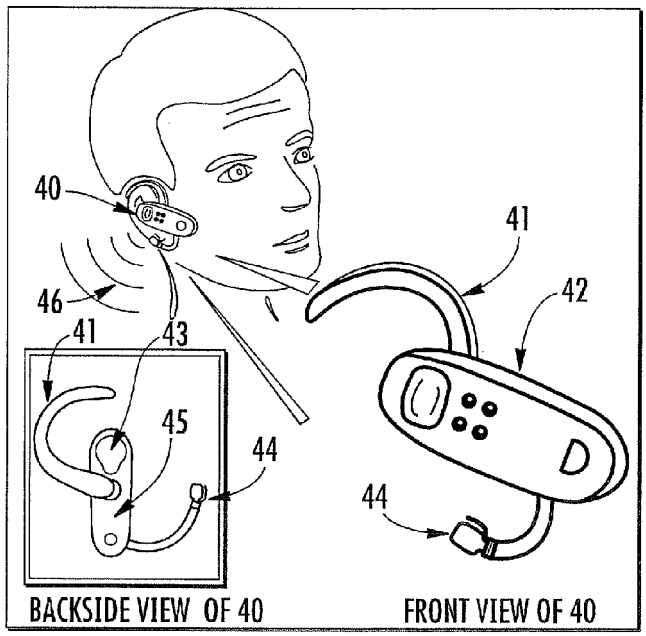


FIG. 4

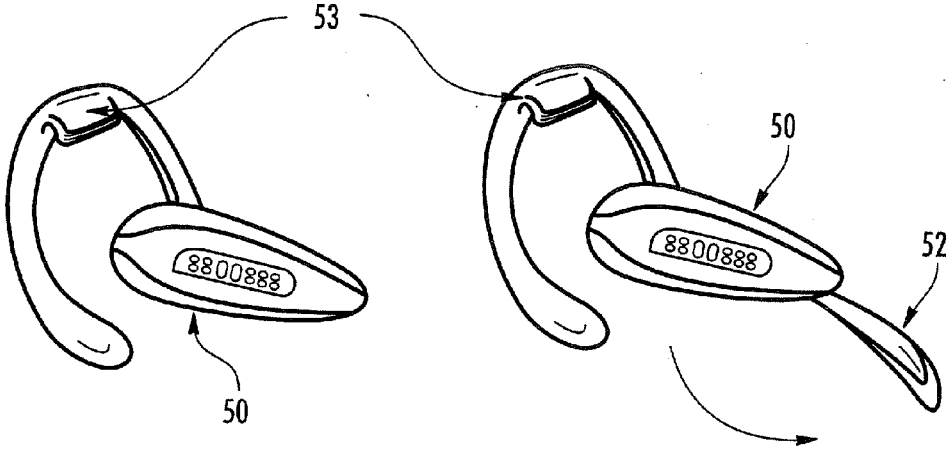


FIG. 5A FIG. 5B

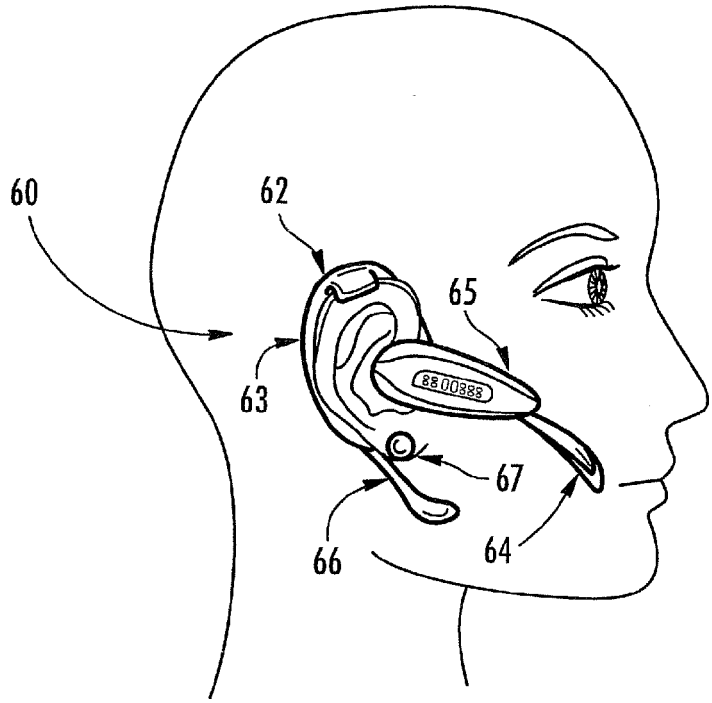


FIG. 6

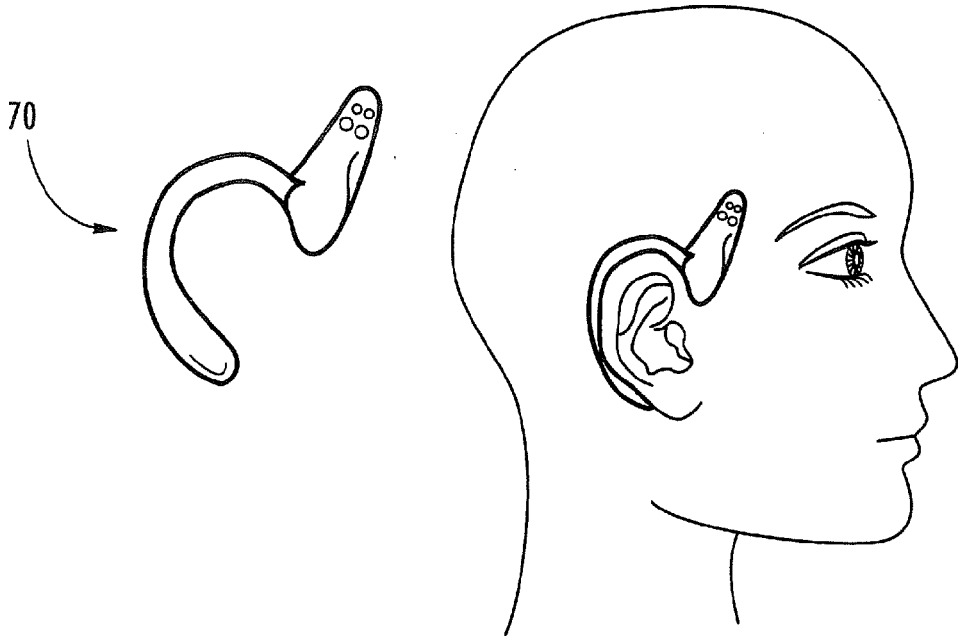


FIG. 7

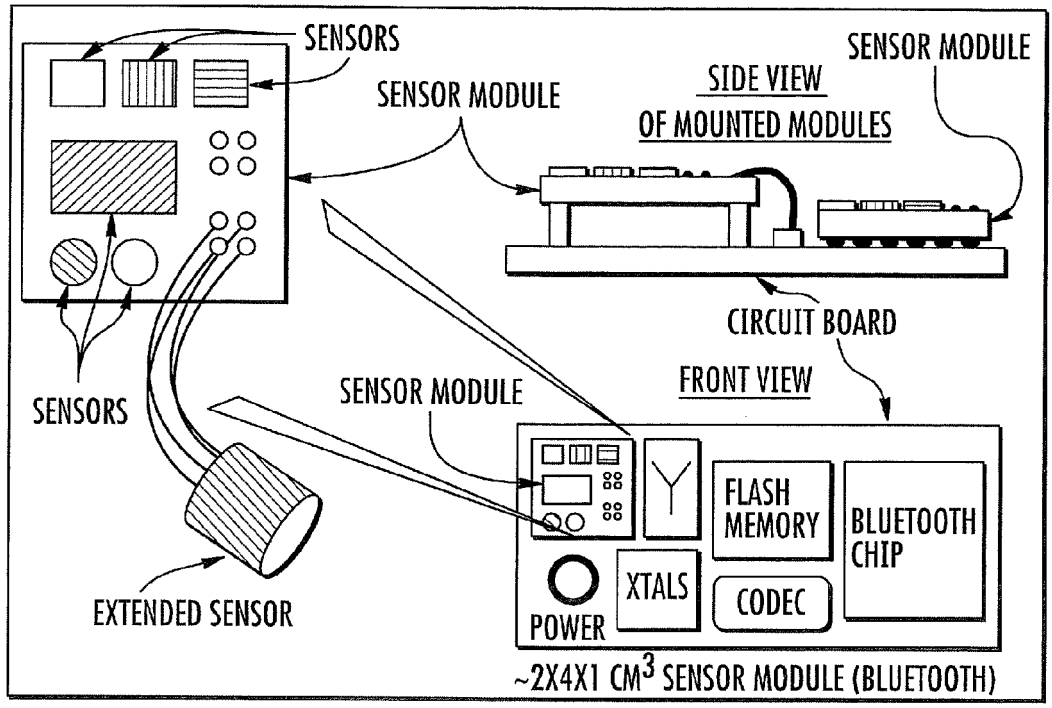

SENSORS
SENSOR MODULE
SIDE VIEW
OF MOUNTED MODULES
SENSOR MODULE
CIRCUIT BOARD
FRONT VIEW
SENSORS
SENSOR MODULE
FLASH MEMORY
BLUETOOTH CHIP
XTALS
CODEC
POWER
EXTENDED SENSOR
~2X4X1 CM3 SENSOR MODULE (BLUETOOTH)

FIG. 8

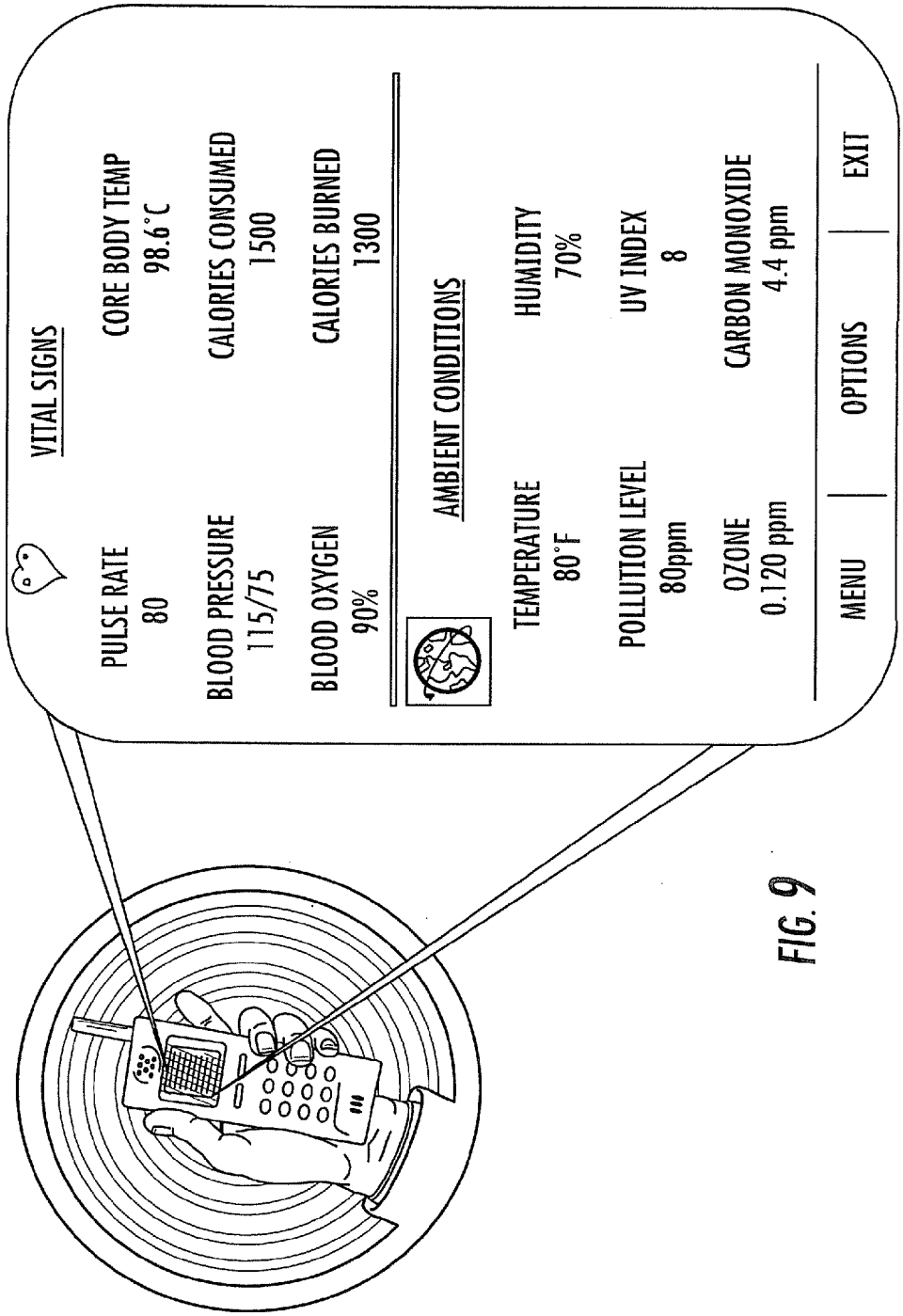

VITAL SIGNS
PULSE RATE
80
CORE BODY TEMP
98.6°C
BLOOD PRESSURE
115/75
CALORIES CONSUMED
1500
BLOOD OXYGEN
90%
CALORIES BURNED
1300
AMBIENT CONDITIONS
TEMPERATURE
80°F
HUMIDITY
70%
POLLUTION LEVEL
80ppm
UV INDEX
8
OZONE
0.120 ppm
CARBON MONOXIDE
4.4 ppm
MENU
OPTIONS
EXIT

FIG. 9

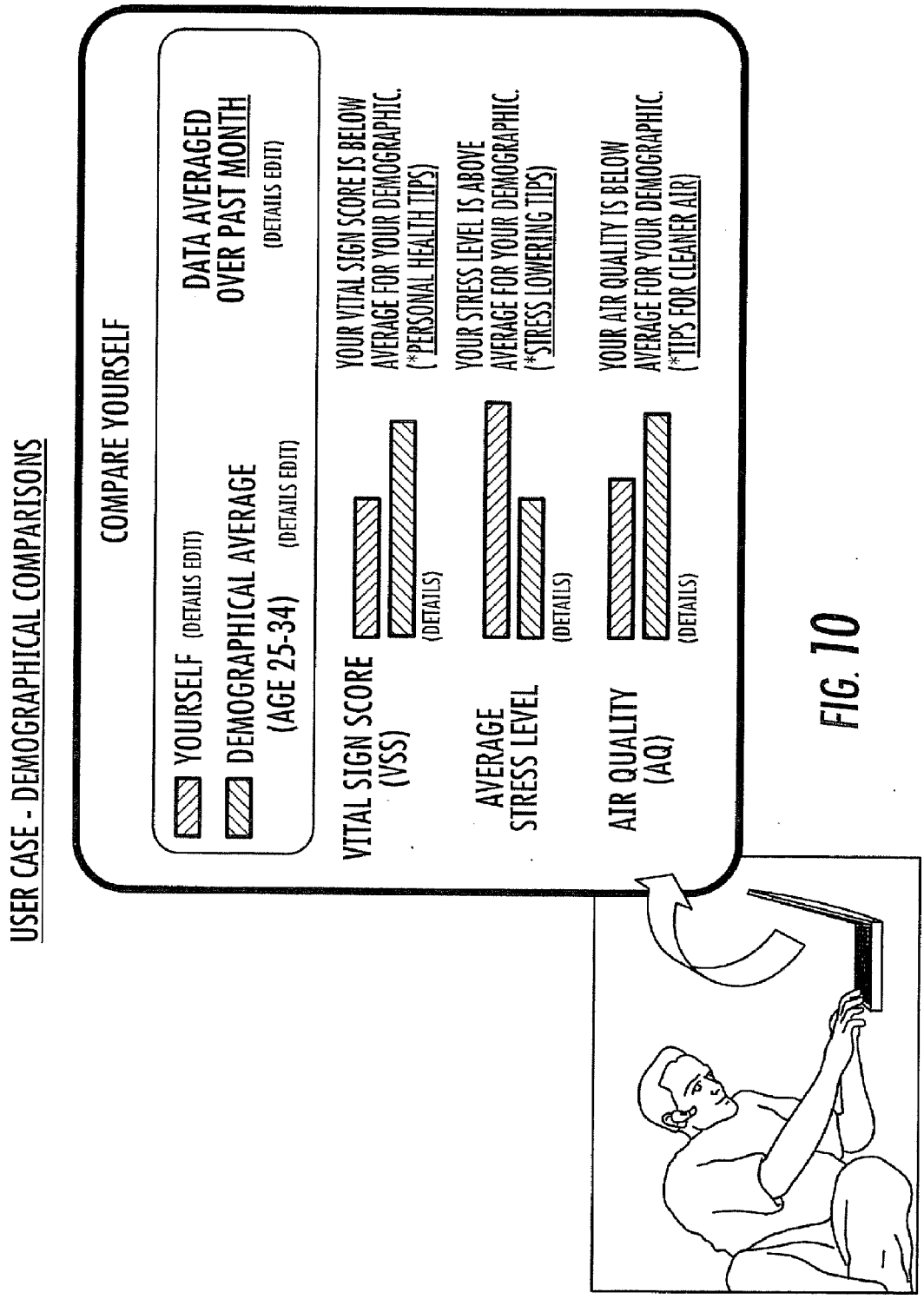

USER CASE - DEMOGRAPHICAL COMPARISONS
COMPARE YOURSELF
YOURSELF (DETAILS EDIT)
DEMOGRAPHICAL AVERAGE (AGE 25-34) (DETAILS EDIT)
DATA AVERAGED OVER PAST MONTH
(DETAILS EDIT)
VITAL SIGN SCORE (VSS)
(DETAILS)
YOUR VITAL SIGN SCORE IS BELOW AVERAGE FOR YOUR DEMOGRAPHIC. (*PERSONAL HEALTH TIPS)
AVERAGE STRESS LEVEL
(DETAILS)
YOUR STRESS LEVEL IS ABOVE AVERAGE FOR YOUR DEMOGRAPHIC. (*STRESS LOWERING TIPS)
AIR QUALITY (AQ)
(DETAILS)
YOUR AIR QUALITY IS BELOW AVERAGE FOR YOUR DEMOGRAPHIC. (*TIPS FOR CLEANER AIR)

FIG. 10

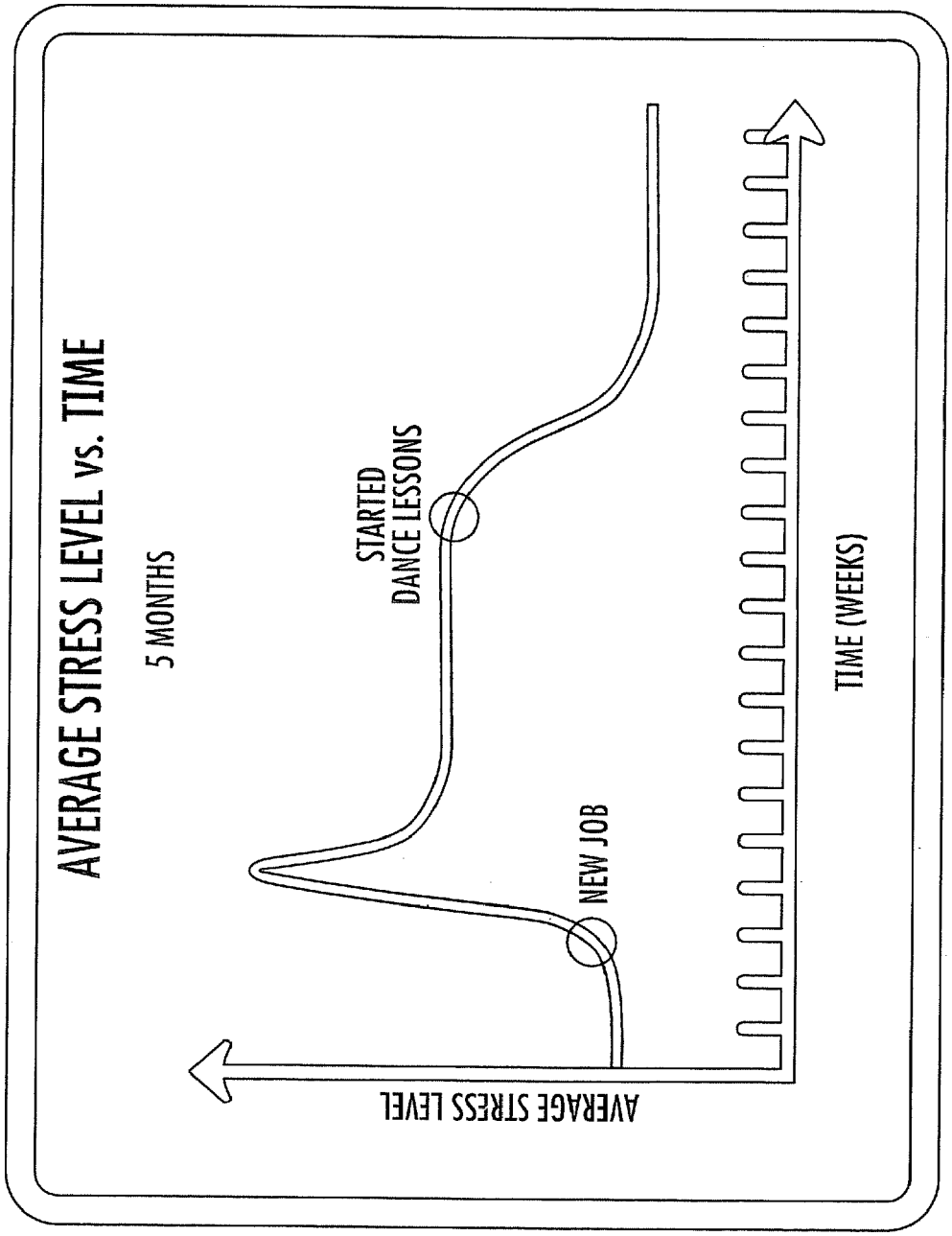

AVERAGE STRESS LEVEL vs. TIME
5 MONTHS
STARTED
DANCE LESSONS
NEW JOB
AVERAGE STRESS LEVEL
TIME (WEEKS)

FIG. 11

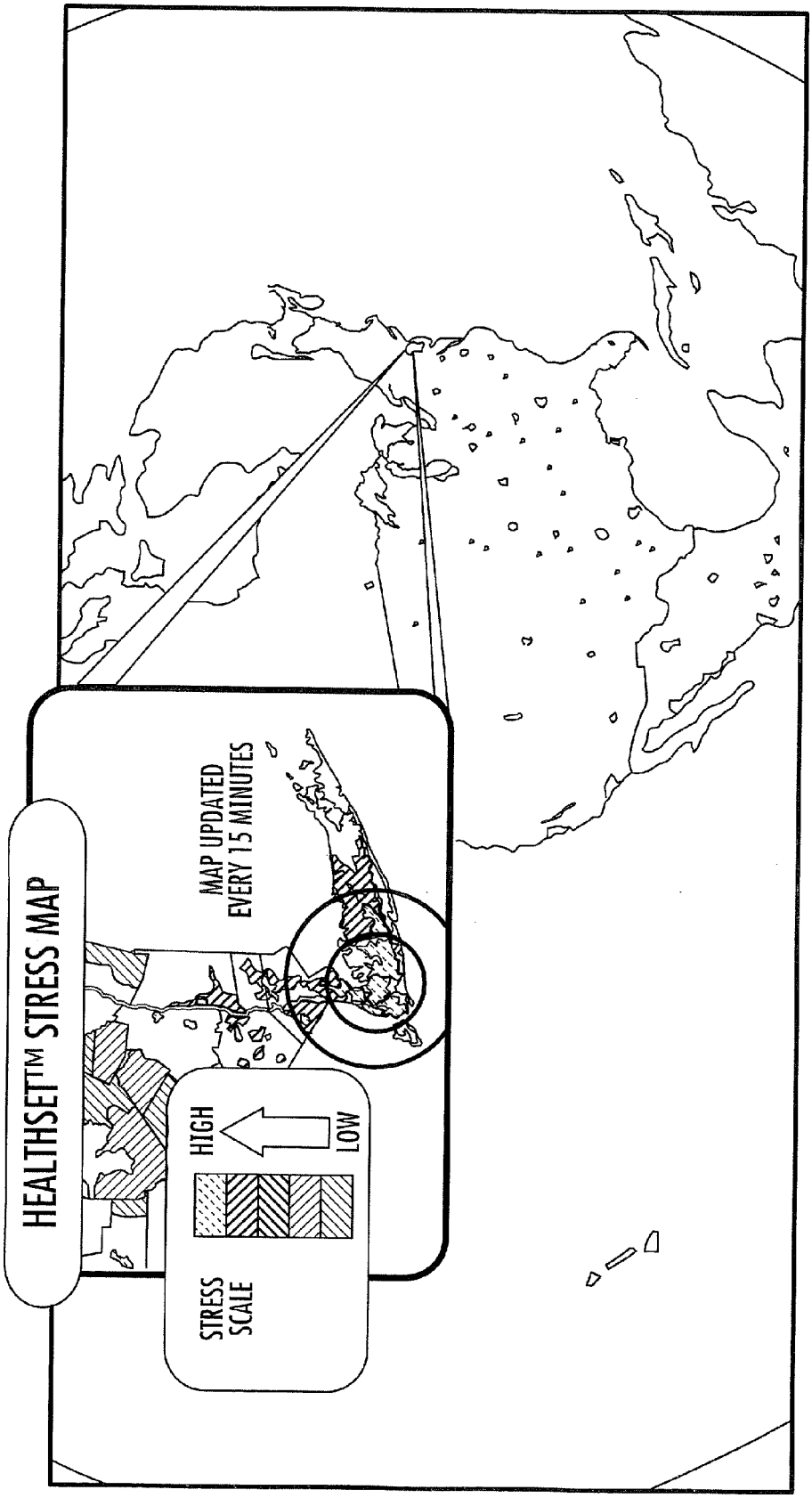

HEALTHSET™ STRESS MAP
MAP UPDATED EVERY 15 MINUTES
HIGH
LOW
STRESS SCALE

FIG. 12

PHYSIOLOGICAL AND ENVIRONMENTAL MONITORING SYSTEMS AND METHODS

RELATED APPLICATION

[0001] This application claims the benefit of and priority to U.S. Provisional Patent Application No. 60/905,761, filed Mar. 8, 2007, U.S. Provisional Patent Application No. 60/876,128, filed Dec. 21, 2006, and U.S. Provisional Patent Application No. 60/875,606, filed Dec. 19, 2006, the disclosures of which are incorporated herein by reference as if set forth in their entireties.

FIELD OF THE INVENTION

[0002] The present invention relates generally to health and, more particularly, to health monitoring.

BACKGROUND

[0003] There is growing market demand for personal health and environmental monitors, for example, for gauging overall health and metabolism during exercise, athletic training, dieting, and physical therapy. However, traditional health monitors and environmental monitors may be bulky, rigid, and uncomfortable—generally not suitable for use during daily physical activity. There is also growing interest in generating and comparing health and environmental exposure statistics of the general public and particular demographic groups. For example, collective statistics enable the healthcare industry and medical community to direct healthcare resources to where they are most highly valued. However, methods of collecting these statistics may be expensive and laborious, often utilizing human-based recording/analysis steps at multiple sites.

SUMMARY

[0004] In view of the above discussion, systems and methods for monitoring various physiological and environmental factors, as well as systems and methods for using this information for a plurality of useful purposes, are provided. According to some embodiments of the present invention, real-time, noninvasive health and environmental monitors include a plurality of compact sensors integrated within small, low-profile devices. Physiological and environmental data is collected and wirelessly transmitted into a wireless network, where the data is stored and/or processed. This information is then used to support a variety of useful methods, such as clinical trials, marketing studies, biofeedback, entertainment, and others.

[0005] Though the methods herein may apply broadly to a variety of form factors for a monitoring apparatus, in some embodiments of the invention an earpiece functions as a physiological monitor, an environmental monitor, and a wireless personal communicator. Because the ear region is located next to a variety of "hot spots" for physiological an environmental sensing—including the tympanic membrane, the carotid artery, the paranasal sinus, etc.—in some cases an earpiece monitor takes preference over other form factors. The earpiece can take advantage of commercially available open-architecture, ad hoc, wireless paradigms, such as Bluetooth®, Wi-Fi, or ZigBee. In some embodiments, a small, compact earpiece contains at least one microphone and one speaker, and is configured to transmit information wirelessly to a recording device such as, for example, a cell phone, a personal digital assistant (PDA), and/or a computer. The earpiece contains a plurality of sensors for monitoring personal health and environmental exposure. Health and environmental information, sensed by the sensors is transmitted wirelessly, in real-time, to a recording device, capable of processing and organizing the data into meaningful displays, such as charts. In some embodiments, an earpiece user can monitor health and environmental exposure data in real-time, and may also access records of collected data throughout the day, week, month, etc., by observing charts and data through an audio-visual display.

[0006] Each physiological sensor is configured to detect and/or measure one or more of the following types of physiological information: heart rate, pulse rate, breathing rate, blood flow, heartbeat signatures, cardio-pulmonary health, organ health, metabolism, electrolyte type and/or concentration, physical activity, caloric intake, caloric metabolism, blood metabolite levels or ratios, blood pH level, physical and/or psychological stress levels and/or stress level indicators, drug dosage and/or dosimetry, physiological drug reactions, drug chemistry, biochemistry, position and/or balance, body strain, neurological functioning, brain activity, brain waves, blood pressure, cranial pressure, hydration level, auscultatory information, auscultatory signals associated with pregnancy, physiological response to infection, skin and/or core body temperature, eye muscle movement, blood volume, inhaled and/or exhaled breath volume, physical exertion, exhaled breath physical and/or chemical composition, the presence and/or identity and/or concentration of viruses and/or bacteria, foreign matter in the body, internal toxins, heavy metals in the body, anxiety, fertility, ovulation, sex hormones, psychological mood, sleep patterns, hunger and/or thirst, hormone type and/or concentration, cholesterol, lipids, blood panel, bone density, organ and/or body weight, reflex response, sexual arousal, mental and/or physical alertness, sleepiness, auscultatory information, response to external stimuli, swallowing volume, swallowing rate, sickness, voice characteristics, voice tone, voice pitch, voice volume, vital signs, head tilt, allergic reactions, inflammation response, auto-immune response, mutagenic response, DNA, proteins, protein levels in the blood, water content of the blood, pheromones, internal body sounds, digestive system functioning, cellular regeneration response, healing response, stem cell regeneration response, and/or other physiological information.

[0007] Each environmental sensor is configured to detect and/or measure one or more of the following types of environmental information: climate, humidity, temperature, pressure, barometric pressure, soot density, airborne particle density, airborne particle size, airborne particle shape, airborne particle identity, volatile organic chemicals (VOCs), hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), carcinogens, toxins, electromagnetic energy, optical radiation, X-rays, gamma rays, microwave radiation, terahertz radiation, ultraviolet radiation, infrared radiation, radio waves, atomic energy alpha particles, atomic energy beta-particles, gravity, light intensity, light frequency, light flicker, light phase, ozone, carbon monoxide, carbon dioxide, nitrous oxide, sulfides, airborne pollution, foreign material in the air, viruses, bacteria, signatures from chemical weapons, wind, air turbulence, sound and/or acoustical energy, ultrasonic energy, noise pollution, human voices, animal sounds, diseases expelled from others, exhaled breath and/or breath constituents of others, toxins from others, pheromones from others, industrial and/or transportation sounds, allergens, animal

hair, pollen, exhaust from engines, vapors and/or fumes, fuel, signatures for mineral deposits and/or oil deposits, snow, rain, thermal energy, hot surfaces, hot gases, solar energy, hail, ice, vibrations, traffic, the number of people in a vicinity of the person, coughing and/or sneezing sounds from people in the vicinity of the person, loudness and/or pitch from those speaking in the vicinity of the person, and/or other environmental information.

[0008] In some embodiments, the signal processor is configured to process signals produced by the physiological and environmental sensors into signals that can be heard and/or viewed by the person wearing the apparatus. In some embodiments, the signal processor is configured to selectively extract environmental effects from signals produced by a physiological sensor and/or selectively extract physiological effects from signals produced by an environmental sensor.

[0009] A monitoring system, according to some embodiments of the present invention, may be configured to detect damage to a portion of the body of the person wearing the apparatus, and may be configured to alert the person when such damage is detected. For example, when a person is exposed to sound above a certain level that may be potentially damaging, the person is notified by the apparatus to move away from the noise source. As another example, the person may be alerted upon damage to the tympanic membrane due to loud external noises.

[0010] Information from the health and environmental monitoring system may be used to support a clinical trial and/or study, marketing study, dieting plan, health study, wellness plan and/or study, sickness and/or disease study, environmental exposure study, weather study, traffic study, behavioral and/or psychosocial study, genetic study, a health and/or wellness advisory, and an environmental advisory. The monitoring system may be used to support interpersonal relationships between individuals or groups of individuals. The monitoring system may be used to support targeted advertisements, links, searches or the like through traditional media, the internet, or other communication networks. The monitoring system may be integrated into a form of entertainments, such as health and wellness competitions, sports, or games based on health and/or environmental information associated with a user.

[0011] According to some embodiments of the present invention, a method of monitoring the health of one or more subjects includes receiving physiological and/or environmental information from each subject via respective portable monitoring devices associated with each subject, and analyzing the received information to identify and/or predict one or more health and/or environmental issues associated with the subjects. Each monitoring device has at least one physiological sensor and/or environmental sensor. Each physiological sensor is configured to detect and/or measure physiological information from the subject, and each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the subject. The physiological information and/or environmental information may be analyzed locally via the monitoring device or may be transmitted to a location geographically remote from the subject for analysis. The collected information may undergo virtually any type of analysis. In some embodiments, the received information may be analyzed to identify and/or predict the aging rate of the subjects, to identify and/or predict environmental changes in the vicinity of the subjects, and to identify and/or predict psychological and/or physiological stress for the subjects.

[0012] According to some embodiments of the present invention, corrective action information may be communicated to the subjects in response to identifying one or more health and/or environmental problems associated with the subject. In addition or alternatively, corrective action information for the subjects may be communicated to third parties.

[0013] In some embodiments, a geographical map illustrating health-related and/or environmental conditions associated with the subjects may be created.

[0014] According to some embodiments of the present invention, a health and environmental monitoring system includes a plurality of portable monitoring devices, each comprising at least one physiological sensor and/or environmental sensor, a plurality of portable communication devices, wherein each communication device is in communication with a respective monitoring device and is configured to transmit data from the monitoring device to remote data storage, and a processor configured to analyze data within the remote data storage and to identify and/or predict health and/or environmental issues associated with each subject. Each physiological sensor is configured to detect and/or measure physiological information from a respective subject, and each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the respective subject. Each monitoring device is configured to be worn by a respective subject (e.g., attached to a body of a respective subject, etc.). For example, a monitoring device may be configured to be attached to an ear of a respective subject.

[0015] In some embodiments, the processor is configured to communicate corrective action information to each respective subject. Corrective action information may be communicated to each subject via the monitoring device associated with each respective subject, or via other methods.

[0016] In other embodiments, the processor communicates corrective action information for a subject to a third party. The processor may be configured to perform various analyses including, but not limited to, identifying and/or predicting the aging rate of one or more subjects, identifying and/or predicting environmental changes in the vicinity of one or more subjects, and identifying and/or predicting psychological and/or physiological stress for one or more subjects. In some embodiments of the present invention, the processor is configured to create a geographical map illustrating health and/or environmental conditions associated with one or more subjects.

[0017] Information collected from each monitoring device may include information that is personal and private and information that can be made available to the public. As such, data storage, according to some embodiments of the present invention, may include a private portion and a public portion. In the private portion, health and environmental data that is personalized for each subject is stored. In the public portion, anonymous health and environmental data is stored and is accessible by third parties.

[0018] In other embodiments of the present invention, a method of delivering targeted advertising to a person includes collecting physiological and/or environmental information from the person, selecting an advertisement for delivery to the person based upon the collected physiological and/or environmental information, and delivering the selected advertisement to the person. The physiological and/or environmental information is collected via a monitoring device associated with the person and that includes at least one physiological sensor and/or environmental sensor, as described above. The

received physiological and/or environmental information is analyzed to identify a physiological condition of the person and/or environmental condition in a vicinity of the person, and an advertisement is selected for a product or service related to an identified physiological and/or environmental condition. The selected advertisement can be delivered via any of various channels including, but not limited to, email, postal mail, television, radio, newspaper, magazine, the internet, and outdoor advertising.

[0019] According to some embodiments of the present invention, a system for delivering targeted advertising to people includes a plurality of portable monitoring devices, each comprising at least one physiological sensor and/or environmental sensor, as described above, and a remotely located advertisement selection device that receives physiological and/or environmental information from the monitoring devices, selects advertisements based upon the collected physiological and/or environmental information, and delivers selected advertisements to the monitored persons. The advertisement selection device receives physiological and/or environmental information from each monitoring device via a communication device (e.g., PDA, cell phone, laptop computer, etc.) associated with each respective monitoring device. In some embodiments, the advertisement selection device is configured to select an advertisement for a product and/or service related to a physiological condition of a person and/or for a product and/or service related to an environmental condition in a vicinity of a person.

[0020] In some embodiments, the advertisement selection device includes an ad server configured to deliver online advertisements. In other embodiments, the advertisement selection device includes an email server configured to deliver advertisements via email. In some embodiments, the advertisement selection device is configured to communicate with a third party service that can deliver selected advertisements via one or more of the following delivery channels: postal mail, television, radio, newspaper, magazine, the internet, and outdoor advertising.

[0021] According to some embodiments of the present invention, a method of supporting interpersonal relationships includes collecting physiological and/or environmental information from a monitoring device associated with a first person when the first person is in the presence of a second person, determining a stress level of the first person using the collected physiological and/or environmental information, and displaying the stress level to the first person. The monitoring device includes at least one physiological sensor and/or environmental sensor, as described above, and is configured to collect physiological and/or environmental information that includes indicators associated with stress experienced by the first person. The stress level of the first person may also be communicated to one or more third parties.

[0022] In some embodiments, the physiological and/or environmental information collected from the first person is analyzed to identify a source of stress. A solution for reducing stress also may be recommended to the first person. In some embodiments, the monitoring device can identify the second person.

[0023] According to some embodiments of the present invention, a system for supporting interpersonal relationships includes a portable monitoring device that collects physiological and/or environmental information from a first person when the first person is in the presence of a second person, and a processor that receives physiological and/or environmental information from the monitoring device. The processor determines a stress level of the first person using the collected physiological and/or environmental information, and transmits and/or displays the stress level to the first person. In some embodiments, the processor receives physiological and/or environmental information from the monitoring device via a communication device (e.g., PDA, cell phone, laptop computer, etc.) associated with the monitoring device. The processor may be configured to analyze the information and identify a source of stress. The processor may be configured to recommend solutions for reducing stress.

[0024] In another embodiment of the present invention, a method of supporting interpersonal relationships includes collecting physiological and/or environmental information from a monitoring device associated with a first person, and determining a mood of the first person using the collected physiological and/or environmental information. The collected information includes indicators associated with one or more moods of the first person. The mood of the first person may be communicated to a second person, for example, via a communication network (e.g., text message, email, voice message, etc.).

[0025] A system for supporting interpersonal relationships, according to other embodiments of the present invention, includes a portable monitoring device that collects physiological and/or environmental information from a first person, and a processor that receives physiological and/or environmental information from the monitoring device, and determines a mood of the first person using the collected physiological and/or environmental information. The processor receives physiological and/or environmental information from the monitoring device via a communication device (e.g., PDA, cell phone, laptop computer, etc.) associated with the monitoring device. The processor is configured to communicate the mood of the first person to a second person, for example, via a communication network (e.g., text message, email, voice message, etc.).

[0026] According to further embodiments of the present invention, a method of monitoring one or more subjects includes collecting physiological and/or environmental information from a monitoring device associated with each respective subject, storing the collected physiological and/or environmental information at a remote storage device, and comparing the stored physiological and/or environmental information with benchmark physiological and/or environmental information to identify at least one behavioral response of the one or more subjects. Behavioral responses may include, but are not limited to, behavioral responses to a product and/or service, behavioral responses to product and/or service marketing, behavioral responses to medical treatment, behavioral responses to a drug, etc.

[0027] According to some embodiments of the present invention, a system for monitoring one or more subjects includes a plurality of portable monitoring devices configured to collect physiological information from a subject and environmental condition information in a vicinity of a subject, as described above, and a processor that compares collected physiological and/or environmental information with benchmark physiological and/or environmental information to identify at least one behavioral response of the one or more subjects. As described above, behavioral responses may include, but are not limited to, behavioral responses to a product and/or service, behavioral responses to product and/or service marketing, behavioral responses to medical treat-

ment, behavioral responses to a drug, etc. In some embodiments, a monitoring device may include a dosimeter configured to measure a dose of a drug taken by a respective subject.

[0028] According to further embodiments of the present invention, a method of monitoring patients, includes collecting physiological and/or environmental information from each patient via a monitoring device associated with each respective patient, and analyzing the collected information to determine caloric intake, health, and physical activity of each patient.

[0029] According to further embodiments of the present invention, an entertainment system includes a gaming device, and a plurality of portable, monitoring devices in communication with the gaming device, wherein each monitoring apparatus is associated with a game participant and is configured to transmit participant physiological information and/or environmental information wirelessly to the gaming device. The gaming device is configured to integrate into the gaming strategy physiological information and/or environmental information received from each monitoring apparatus. Each monitoring apparatus includes at least one physiological sensor and/or environmental sensor, as described above.

[0030] According to further embodiments of the present invention, a method of interacting with an electronic game includes collecting physiological and/or environmental information from a monitoring device associated with a person, analyzing the collected information to identify one or more health and/or environmental issues associated with the person, sending the identified one or more health and/or environmental issues to a gaming device, and incorporating the identified one or more health and/or environmental issues into a strategy of a game executing on the gaming device. The monitoring device includes at least one physiological sensor and/or environmental sensor, as described above.

[0031] In some embodiments, a gaming character may be created based on the person using the identified one or more health and/or environmental issues. In other embodiments, biofeedback may be provided to the person for improving at least one skill associated with the electronic game.

[0032] According to further embodiments of the present invention, a method of monitoring a participant in an activity includes collecting physiological and/or environmental information from a monitoring device associated with the participant, analyzing the collected physiological and/or environmental information to identify one or more health-related and/or environmental issues associated with the participant, and providing feedback to the participant, wherein the feedback is relevant to a skill utilized by the participant in the activity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] FIG. **1** is a block diagram of a telemetric monitoring device for physiological and/or environmental monitoring and personal communication, according to some embodiments of the present invention.

[0034] FIG. **2** is a block diagram of a telemetric network for health and environmental monitoring through portable telemetric monitoring devices, such as the device of FIG. **1**, according to some embodiments of the present invention.

[0035] FIG. **3** illustrates a graphical user interface for displaying data, according to some embodiments of the present invention.

[0036] FIG. **4** illustrates an earpiece module according to some embodiments of the present invention.

[0037] FIGS. **5**A-**5**B illustrates an earpiece module with an adjustable mouthpiece for monitoring physiological and environmental information near the mouth, according to some embodiments of the present invention, wherein FIG. **5**A illustrates the mouthpiece in a stored position and wherein FIG. **5**B illustrates the mouthpiece in an extended operative position.

[0038] FIG. **6** illustrates an earpiece module incorporating various physiological and environmental sensors, according to some embodiments of the present invention, and being worn by a user.

[0039] FIG. **7** illustrates an earpiece module according to other embodiments of the present invention that includes a temple module for physiological and environmental monitoring.

[0040] FIG. **8** illustrates a monitoring device having a plurality of health and environmental sensors and mounted onto a Bluetooth® headset module, according to some embodiments of the present invention.

[0041] FIG. **9** illustrates the display of physiological and environmental information collected by a monitoring device, according to some embodiments of the present invention.

[0042] FIG. **10** illustrates the display of demographic comparisons of physiological and environmental information, according to some embodiments of the present invention.

[0043] FIG. **11** illustrates the display of stress level over time as measured by a monitoring device, according to some embodiments of the present invention.

[0044] FIG. **12** illustrates the display of a healthy/stress map, according to some embodiments of the present invention.

DETAILED DESCRIPTION

[0045] The present invention now is described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention, however, may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[0046] Like numbers refer to like elements throughout. In the figures, the sizes of certain lines, layers, components, elements or features may be exaggerated for clarity.

[0047] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0048] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood

that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the specification and relevant art and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein. Well-known functions or constructions may not be described in detail for brevity and/or clarity.

[0049] It will be understood that when an element is referred to as being "on", "attached" to, "connected" to, "coupled" with, "contacting", etc., another element, it can be directly on, attached to, connected to, coupled with or contacting the other element or intervening elements may also be present. In contrast, when an element is referred to as being, for example, "directly on", "directly attached" to, "directly connected" to, "directly coupled" with or "directly contacting" another element, there are no intervening elements present. It will also be appreciated by those of skill in the art that references to a structure or feature that is disposed "adjacent" another feature may have portions that overlap or underlie the adjacent feature.

[0050] Spatially relative terms, such as "under", "below", "lower", "over", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of a device in use or operation in addition to the orientation depicted in the figures. For example, if a device in the figures is inverted, elements described as "under" or "beneath" other elements or features would then be oriented "over" the other elements or features. Thus, the exemplary term "under" can encompass both an orientation of "over" and "under". The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly. Similarly, the terms "upwardly", "downwardly", "vertical", "horizontal" and the like are used herein for the purpose of explanation only unless specifically indicated otherwise.

[0051] The term "earpiece module" includes any type of device that may be attached to or near the ear of a user and may have various configurations, without limitation.

[0052] The term "real-time" is used to describe a process of sensing, processing, or transmitting information in a time frame which is equal to or shorter than the minimum timescale at which the information is needed. For example, the real-time monitoring of pulse rate may result in a single average pulse-rate measurement every minute, averaged over 30 seconds, because an instantaneous pulse rate is often useless to the end user. Typically, averaged physiological and environmental information is more relevant than instantaneous changes. Thus, in the context of the present invention, signals may sometimes be processed over several seconds, or even minutes, in order to generate a "real-time" response.

[0053] The term "monitoring" refers to the act of measuring, quantifying, qualifying, estimating, sensing, calculating, interpolating, extrapolating, inferring, deducing, or any combination of these actions. More generally, "monitoring" refers to a way of getting information via one or more sensing elements. For example, "blood health monitoring" includes monitoring blood gas levels, blood hydration, and metabolite/electrolyte levels.

[0054] The term "physiological" refers to matter or energy of or from the body of a creature (e.g., humans, animals, etc.). In embodiments of the present invention, the term "physiological" is intended to be used broadly, covering both physical and psychological matter and energy of or from the body of an organism. However, in some cases, the term "psychological" is called-out separately to emphasize aspects of physiology that are more closely tied to conscious or subconscious brain activity rather than the activity of other organs, tissues, or cells.

[0055] The term "psychosocial stress" refers to events of psychological or social origin which challenge the homeostatic state of biological systems.

[0056] The term "body" refers to the body of a person (or animal) that may utilize an earpiece module according to embodiments of the present invention. Monitoring apparatus, according to embodiments of the present invention may be worn by humans and animals.

[0057] The term "health" refers generally to the quality or quantity of one or more physiological parameters with reference to an organism's functional abilities.

[0058] The term "ad hoc" refers generally to a wireless connection established for the duration of one session without the need for a base station. Instead, devices discover others within range to form a network. Bluetooth®, Zigbee, and Wi-Fi protocols are a few examples.

[0059] The term "processor" refers to a device that takes one form of information and converts this information into another form, typically having more usefulness than the original form. For example, in this invention, a Bluecore processor may collect raw physiological or environmental data from various sensors and process this data into a meaningful assessment, such as pulse rate, blood pressure, or air quality. A variety of microprocessors or other processors may be used herein.

[0060] The term "clinical study" refers broadly to the application of science to health, where "health" may refer to both physical health as well as mental or psychological health. The term "clinical study" and "clinical trial" are used interchangeably herein. As an example, the interaction between a therapy and health or physiology—such as a drug therapy, exercise/diet plan, physical regime, etc.—can constitute a clinical study. As another example, the interaction between the health and the environmental exposure of individuals or groups can constitute a clinical study. In some cases a clinical study is performed by professionals in medicine or science. In other cases, a clinical study is performed by amateurs, computer programs, or individuals themselves, sometimes in the form of self help.

[0061] The term "marketing" refers to the act of bringing together buyers and sellers, and the term "marketing study" refers to the study of the needs and wants of buyers and sellers and how the buyers and sellers can come together.

[0062] The term "health study" refers to monitoring the health of an organism and studying the data regardless of the method of study.

[0063] The term "wellness" generally refers to a healthy balance of the mind-body and spirit that results in an overall feeling of well-being, and/or the state of being healthy. The term "wellness study" refers to the study of the quality of health and wellbeing. In some cases a wellness study is performed by professionals in medicine or science. In other cases, a clinical study is performed by amateurs, computer programs, or individuals themselves, sometimes in the form of self help.

[0064] The term "dieting plan" refers to a method of planning and/or regulating the intake of food or nutrients into the

body. The term "exercise plan" refers to a method of planning or regulating physical activity. In many cases, a diet/exercise plan are used together to improve or reduce health. These plans can be operated by professionals, such as professional dieticians or physical trainers, or by amateurs. In some cases, these plans are regulated by computer programs or individuals themselves, sometimes in the form of self help.

[0065] The term "health study" refers to studying health as in its raw form, without necessarily being concerned about interactions between health and other factors.

[0066] The term "sickness and/or disease" refers generally to aspects of a sickness, disease, or injury in an individual or group of individuals.

[0067] The term "environmental exposure" refers to any environmental occurrence (or energy) to which an individual or group of individuals is exposed. For example, exposure to solar energy, air pollution, temperature, nuclear radiation, humidity, water, etc. may all constitute environmental exposure. A variety of relevant environmental energies are listed elsewhere herein.

[0068] In many cases, the above cases may overlap. As an example, a clinical study or wellness study may explore or record the interaction between physiological elements and environmental elements.

[0069] The term "aggregated" refers to information that is stored and/or grouped. In some cases, these groupings can be based on personal or demographical information, such as grouping based on ethnicity, sex, income, personal preferences or the like.

[0070] The terms "health and environmental network" and "health and environmental monitoring system" are used interchangeably herein. The terms "monitoring system" and "network" may be used interchangeably, as well.

[0071] The term "biofeedback" relates to measuring a subject's bodily processes such as blood pressure, heart rate, skin temperature, galvanic skin response (sweating), muscle tension, etc., and conveying such information to the subject in real-time in order to raise the subject's awareness and conscious control of the related physiological activities. Herein, biofeedback is synonymous with personal physiological monitoring, where biochemical processes and environmental occurrences may be integrated into information for one or more individuals. For example, monitoring hormone levels and air quality through the innovative sensor network described herein for the purpose of tracking, predicting, and/or controlling ovulation is also considered biofeedback.

[0072] The term "profile" relates to a summary of noteworthy characteristics and/or habits of an individual or group of individuals. These characteristics may be physiological (health-related), environmental, statistical, demographical, behavioral, and the like. Age, location, gender, sex, weight, ethnicity, and/or height may be included in a profile. Additionally, a profile may reference the buying and/or spending habits of an individual or group. Profiles may be utilized in making predictions about an individual or group.

[0073] The term "support," when used as a verb, means to assist and/or provide at least one method or outcome for something. For example, a method of supporting a therapy for something may refer to a method of assisting a therapeutic technique. In some cases, supporting a therapy may involve providing an entirely new method having a therapeutic outcome. As a more specific example, a noninvasive health and environmental monitor system/network may support a therapeutic drug study by noninvasively monitoring the real-time drug dosage in the body through multiwavelength pulse oximetry, monitoring core body temperature through thermal sensing of the tympanic membrane, and monitoring environments which may positively or negatively affect the quality of the drug therapy.

[0074] In the following figures, earpiece modules will be illustrated and described for attachment to the ear of the human body. However, it is to be understood that embodiments of the present invention are not limited to those worn by humans. Moreover, monitoring apparatus according to embodiments of the present invention are not limited to earpiece modules and/or devices configured to be attached to or near the ear. Monitoring apparatus according to embodiments of the present invention may be worn on various parts of the body or even worn inside the body.

[0075] Some embodiments of the present invention arise from a discovery that the ear is an ideal location on the human body for a wearable health and environmental monitor. The ear is a relatively immobile platform that does not obstruct a person's movement or vision. Devices located along the ear can have access to the inner-ear canal and tympanic membrane (for measuring core body temperature), muscle tissue (for monitoring muscle tension), the pinna and earlobe (for monitoring blood gas levels), the region behind the ear (for measuring skin temperature and galvanic skin response), and the internal carotid artery (for measuring cardiopulmonary functioning). The ear is also at or near the point of exposure to: environmental breathable toxicants of interest (volatile organic compounds, pollution, etc.); noise pollution experienced by the ear; and lighting conditions for the eye. Located adjacent to the brain, the ear serves as an excellent location for mounting neurological and electrical sensors for monitoring brain activity. Furthermore, as the ear canal is naturally designed for transmitting acoustical energy, the ear provides an optimal location for monitoring internal sounds, such as heartbeat, breathing rate, and mouth motion.

[0076] Bluetooth®-enabled and/or other personal communication earpiece modules may be configured to incorporate physiological and/or environmental sensors, according to some embodiments of the present invention. Bluetooth® earpiece modules are typically lightweight, unobtrusive devices that have become widely accepted socially. Moreover, Bluetooth® earpiece modules are cost effective, easy to use, and are often worn by users for most of their waking hours while attending or waiting for cell phone calls. Bluetooth® earpiece modules configured according to embodiments of the present invention are advantageous because they provide a function for the user beyond health monitoring, such as personal communication and multimedia applications, thereby encouraging user compliance. Exemplary physiological and environmental sensors that may be incorporated into a Bluetooth® or other type of earpiece module include, but are not limited to accelerometers, auscultatory sensors, pressure sensors, humidity sensors, color sensors, light intensity sensors, pulse oximetry sensors, pressure sensors, etc.

[0077] Wireless earpiece devices incorporating low-profile sensors and other electronics, according to embodiments of the present invention, offer a platform for performing near-real-time personal health and environmental monitoring in wearable, socially acceptable devices. The capability to unobtrusively monitor an individual's physiology and/or environment, combined with improved user compliance, is expected to have significant impact on future planned health and environmental exposure studies. This is especially true

for those that seek to link environmental stressors with personal stress level indicators. The large scale commercial availability of such low-cost devices can enable cost-effective large scale studies. The combination of monitored data with user location via GPS (Global Positioning System) and/or other location data can make on-going geographic studies possible, including the tracking of infection over large geographic areas. The commercial application of the proposed platform encourages individual-driven health maintenance and promotes a healthier lifestyle through proper caloric intake and exercise.

[0078] Embodiments of the present invention are not limited to devices that communicate wirelessly. In some embodiments of the present invention, devices configured to monitor an individual's physiology and/or environment may be wired to a device that stores, processes, and/or transmits data. In some embodiments, this information may be stored on the earpiece module itself.

[0079] FIG. **1** is a block diagram illustrating a wearable monitoring device **10**, according to some embodiments of the present invention. The illustrated wearable monitoring device **10** includes one or more of the following: at least one physiological sensor **11**, at least one environmental sensor **12** (also referred to as an external energy sensor), at least one signal processor **13**, at least one transmitter/receiver **14**, at least one power source **16**, at least one communication & entertainment module **17**, at least one body attachment component **15**, and at least one housing **18**. Though the health and environmental sensor functionality can be obtained without the communication and entertainment module **17**, having this additional module may promote use of the wearable monitoring device **10** by users. The illustrated wearable monitoring device **10** is intended primarily for human use; however, the wearable monitoring device **10** may also be configured for use with other animals. In one preferred embodiment, the wearable monitoring device **10** is an earpiece module attached to the ear.

[0080] A physiological sensor **11** can be any compact sensor for monitoring the physiological functioning of the body, such as, but not limited to, sensors for monitoring: heart rate, pulse rate, breathing rate, blood flow, heartbeat signatures, cardio-pulmonary health, organ health, metabolism, electrolyte type and concentration, physical activity, caloric intake, caloric metabolism, metabolomics, physical and psychological stress levels and stress level indicators, physiological and psychological response to therapy, drug dosage and activity (drug dosimetry), physiological drug reactions, drug chemistry in the body, biochemistry, position & balance, body strain, neurological functioning, brain activity, brain waves, blood pressure, cranial pressure, hydration level, auscultatory information, auscultatory signals associated with pregnancy, physiological response to infection, skin and core body temperature, eye muscle movement, blood volume, inhaled and exhaled breath volume, physical exertion, exhaled breath physical and chemical composition, the presence, identity, and concentration of viruses & bacteria, foreign matter in the body, internal toxins, heavy metals in the body, anxiety, fertility, ovulation, sex hormones, psychological mood, sleep patterns, hunger & thirst, hormone type and concentration, cholesterol, lipids, blood panel, bone density, body fat density, muscle density, organ and body weight, reflex response, sexual arousal, mental and physical alertness, sleepiness, auscultatory information, response to external stimuli, swallowing volume, swallowing rate, sickness, voice characteristics, tone, pitch, and volume of the voice, vital signs, head tilt, allergic reactions, inflammation response, auto-immune response, mutagenic response, DNA, proteins, protein levels in the blood, body hydration, water content of the blood, pheromones, internal body sounds, digestive system functioning, cellular regeneration response, healing response, stem cell regeneration response, and the like. Vital signs can include pulse rate, breathing rate, blood pressure, pulse signature, body temperature, hydration level, skin temperature, and the like. A physiological sensor may include an impedance plethysmograph for measuring changes in volume within an organ or body (usually resulting from fluctuations in the amount of blood or air it contains). For example, the wearable monitoring device **10** may include an impedance plethysmograph to monitor blood pressure in real-time.

[0081] An external energy sensor **12**, serving primarily as an environmental sensor, can be any compact sensor for monitoring the external environment in the vicinity of the body, such as, but not limited to, sensors for monitoring: climate, humidity, temperature, pressure, barometric pressure, pollution, automobile exhaust, soot density, airborne particle density, airborne particle size, airborne particle shape, airborne particle identity, volatile organic chemicals (VOCs), hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), carcinogens, toxins, electromagnetic energy (optical radiation, X-rays, gamma rays, microwave radiation, terahertz radiation, ultraviolet radiation, infrared radiation, radio waves, and the like), EMF energy, atomic energy (alpha particles, beta-particles, gamma rays, and the like), gravity, light properties (such as intensity, frequency, flicker, and phase), ozone, carbon monoxide, greenhouse gases, CO2, nitrous oxide, sulfides, airborne pollution, foreign material in the air, biological particles (viruses, bacteria, and toxins), signatures from chemical weapons, wind, air turbulence, sound and acoustical energy (both human audible and inaudible), ultrasonic energy, noise pollution, human voices, animal sounds, diseases expelled from others, the exhaled breath and breath constituents of others, toxins from others, bacteria & viruses from others, pheromones from others, industrial and transportation sounds, allergens, animal hair, pollen, exhaust from engines, vapors & fumes, fuel, signatures for mineral deposits or oil deposits, snow, rain, thermal energy, hot surfaces, hot gases, solar energy, hail, ice, vibrations, traffic, the number of people in a vicinity of the user, the number of people encountered throughout the day, other earpiece module users in the vicinity of the earpiece module user, coughing and sneezing sounds from people in the vicinity of the user, loudness and pitch from those speaking in the vicinity of the user, and the like.

[0082] In some embodiments, a physiological sensor **11** and/or an environmental sensor **12** may be configured to identify a person, such as biometric identification of a person, to whom the wearable monitoring device **10** is attached (or may be configured to identify other persons in the vicinity of the person wearing the monitoring device **10**).

[0083] In some embodiments, a physiological sensor **11** and/or an environmental sensor **12** may be configured to monitor physical aging rate of a person or subject. The signal processor **13** may be configured to process information from a physiological sensor and/or an environmental sensor to assess aging rate. Physiological sensors configured to assess aging rate may include pulse rate sensors, blood pressure sensors, activity sensors, and psychosocial stress sensors.

Environmental sensors configured to assess aging rate may include UV sensors and pollution sensors.

[0084] In some embodiments, a physiological sensor **11** and/or an environmental sensor **12** may be configured to be regenerated through a physical and/or chemical change. For example, it is anticipated that a wearable monitoring device **10**, or other device incorporating physiological and/or environmental sensors according to embodiments of the present invention, may be coupled to an apparatus that is configured to "recharge" or regenerate one or more environmental and/or physiological sensors via a physical process or a chemical process, etc. For example, a recharging module for recharging electric power to the wearable monitoring device **10** may also user electrical energy to reverse a chemical or physical change in one of the sensors. One example of such a sensor would be a sensor that requires the absorption or desorption of water vapor for resetting to baseline operation. Another example is a sensor that is reset (recharged) through oxidation or reduction in order to change the surface properties for monitoring vapors, such as some metal oxide sensors.

[0085] Because the wearable monitoring device **10** is capable of measuring and transmitting sensor information in real-time over a duration of time, the physiological and environmental sensors **11**, **12** can be used to sense the aforementioned parameters over time, enabling a time-dependent analysis of the user's health and environment as well as enabling a comparison between the user's health and environment. Combined with proximity or location detection, this allows an analysis for pinpointing the location where environmental stress and physical strain took place.

[0086] Proximity detection can be accomplished through GPS type devices integrated into the monitoring device **10** or a personal communication device in communication with the monitoring device **10**. Proximity detection can also be accomplished through triangulation of wireless signals; if a cellular phone is used as the personal communication device (such as **21** of FIG. **2**), proximity can be identified through existing cellular infrastructure for identifying the time and location of a phone call.

[0087] The signal processor **13** provides a means of converting the digital or analog signals from the sensors **11**, **12** into data that can be transmitted wirelessly by the transmitter **14**. The signal processor **13** may be composed of, for example, signal conditioners, amplifiers, filters, digital-to-analog and analog-to-digital converters, digital encoders, modulators, mixers, multiplexers, transistors, various switches, microprocessors, or the like. For personal communication, the signal processor **13** processes signals received by the receiver **14** into signals that can be heard or viewed by the user. The received signals may also contain protocol information for linking various telemetric modules together, and this protocol information can also be processed by the signal processor **13**.

[0088] The signal processor **13** may utilize one or more compression/decompression algorithms (CODECs) used in digital media for processing data. The transmitter **14** can be comprised of a variety of compact electromagnetic transmitters. A standard compact antenna is used in the standard Bluetooth® headset protocol, but any kind of electromagnetic antenna suitable for transmitting at human-safe electromagnetic frequencies may be utilized. The receiver **14** can also be an antenna. In some embodiments, the receiving antenna and the transmitting antenna are physically the same. The receiver/transmitter **14** can be, for example, a non-line-of-sight (NLOS) optical scatter transmission system. These systems typically use short-wave (blue or UV) optical radiation or "solar blind" (deep-UV) radiation in order to promote optical scatter, but IR wavelengths can also suffice.

[0089] Additionally, a sonic or ultrasonic transmitter can be used as the receiver/transmitter **14** of the wearable monitoring device **10**, but preferably using sounds that are higher or lower than the human hearing range. A variety of sonic and ultrasonic receivers and transmitters are available in the marketplace and may be utilized in accordance with embodiments of the present invention. If a telecommunication device **21** (FIG. **2**) receiving wireless data signal **19** from the wearable monitoring device **10** is in close proximity to the wearable monitoring device **10**, and the wearable module is an earpiece module, a variety of transmission schemes can be used. For communicating audible conversational information directly to the earpiece user, encoded telemetric conversational data received by the receiver **14** can be decoded by the signal processing module **13** to generate an electrical signal that can be converted into audible sound by the communication module **17**.

[0090] In some embodiments, the transmitter/receiver **14** is configured to transmit signals from the signal processor to the remote terminal following a predetermined time interval. For example, the transmitter may delay transmission until a certain amount of detection time has elapsed, until a certain amount of processing time has elapsed, etc. In some cases, the transmitter/receiver **14** is configured to transmit signals to the remote terminal dependent on information sensed by the sensors **11**, **12**. For example, if an unstable pulse rate is sensed, a warning message may be sent to a remote terminal to communicate a need for help at a particular location.

[0091] The power source can be any portable power source **16** capable of fitting inside the housing **18**. According to some embodiments, the power source **16** is a portable rechargeable lithium-polymer or zinc-air battery. Additionally, portable energy-harvesting power sources can be integrated into the wearable monitoring device **10** and can serve as a primary or secondary power source. For example, a solar cell module can be integrated into the wearable monitoring device **10** for collecting and storing solar energy. Additionally, piezoelectric devices or microelectromechanical systems (MEMS) can be used to collect and store energy from body movements, electromagnetic energy, and other forms of energy in the environment or from the user himself. A thermoelectric or thermovoltaic device can be used to supply some degree of power from thermal energy or temperature gradients. In some embodiments, a cranking or winding mechanism can be used to store mechanical energy for electrical conversion or to convert mechanical energy into electrical energy that can be used immediately or stored for later.

[0092] The various components described above are configured to fit within the wearable monitoring device housing **18** and/or be attached thereto. In the case where the wearable monitoring device **10** is an earpiece module, the housing **18** may be formed from any safe and comfortable solid material such as metal, rubber, wood, polymers, ceramic, organic materials, or various forms of plastic. The body attachment component **15** is attached to the housing **18** and is designed to fit around or near the ear. For example, the standard Bluetooth® headset includes an earpiece attachment that is connected to the headset housing via a double-jointed socket, to provide comfort and positioning flexibility for the user. In some embodiments, the body attachment component **15** can

be part of the housing **18**, such that the entire earpiece module is one largely inflexible, rigid unit. In such case, a counterweight may be incorporated into the wearable monitoring device **10** to balance the weight of the earpiece electronics and power source. In some embodiments, the body attachment component **15** can contain physiological and environmental sensors, and the body attachment component **15** may be detachable. In some embodiments, more than one earpiece attachment **15** can be attached to the housing **18**.

[0093] The communication and entertainment module **17** (also interchangeably referred to as a "communication module") is used for, but not limited to: processing or generating an audible sound from information received via the receiver **14** (from a cell phone, computer, network, database, or the like) and/or processing or generating an electrical signal from an audible sound from the user such that the electrical signal can be transmitted telemetrically via the transmitter **14**. For example, in standard Bluetooth® protocol, communication electronics are used to convert an audible conversation into an electrical signal for telemetric conversation; communication electronics are also used to convert a digitized telemetric conversation into an audible conversation for the earpiece user. Additionally, the communication and entertainment module **17** can be used to store, process, or play analog or digital information from music, radio shows, videos, or other audible entertainment and to communicate this information to an earpiece user. In many cases, this information includes information received by the receiver **14**. In many cases, the analog or digital information is not stored in the communication and entertainment module **17** but, rather, is stored in a portable telecommunication device **21** (FIG. **2**). In such case, the communication and entertainment module **17** is used for converting the analog or digital information into audible sound for the earpiece user. The communication and entertainment module **17** may contain at least one microphone, speaker, signal processor (similar to **13**), and digital memory. In some embodiments, the communication and entertainment module **17** may apply at least one CODEC for encoding or decoding information. The communication and entertainment module may utilize non-audible forms of communication with the user, such as visual, physical, or mental (i.e., brainwaves or neural stimulation) communication with the user.

[0094] In some embodiments, an audible communicator is provided that is configured to communicate therapeutic sounds (e.g., music therapy, etc.) to a person in response to physiological or psychosocial stress. The audible communicator may be embodied in the communication and entertainment module **17** or may be a separate speaker. In some embodiments, light therapy may be provided to a person in response to physiological or psychosocial stress. In some embodiments, the communication and entertainment module **17** may be configured to communicate a treatment, therapy, and/or plan of action to the person upon detection of physiological and/or environmental concerns. For example, if it is detected that the person is being exposed to unhealthy doses of UV radiation, the communication and entertainment module **17** may audibly instruct the person to move away from the person's current location (e.g., move indoors, etc.). Mechanical vibrational therapy and electrical stimulation therapy are also examples of automated therapies that may be invoked by programs inside the monitoring device **10** in response to sensor readings from health **11** and/or environmental **12** sensors.

[0095] Like the other components of the wearable monitoring device **10** shown in FIG. **1**, the components of the communication and entertainment module **17** are not necessarily located in the same physical vicinity. The microphone and speaker of the communication module **17**, for example, may be located closer to the mouth and ear respectively. Furthermore, the signal processor **13** can be composed of several components located throughout the earpiece module. It should be understood that the word "module" does not necessarily imply a unified physical location. Rather, "module" is used to imply a unified function.

[0096] Bluetooth® devices conventionally contain a communication module, such as communication module **17**, for converting digital or analog information into audible sounds for the user. However, when combined with the health and environmental monitoring properties of a wearable monitoring device **10** according to embodiments of the present invention, the communication and entertainment module **17** can provide functionality. For the wearable monitoring device **10** can serve as a biofeedback device. As a non-limiting example, if a user is in a polluted environment, such as air filled with VOCs, the communication module **17** may notify the user to move to a new environment. As another example, if one or more of the physiological and environmental sensors **11**, **12** of the wearable monitoring device **10** pick up a high particulate density in the environment, with an elevation in core body temperature, and a change in voice pitch occurring simultaneously (or near-simultaneously) within a common timeframe, the communication module **17** may alert the user that he/she may be having an allergic response. As a further example, the user can use the communication and entertainment module **17** to execute biofeedback for willfully controlling blood pressure, breathing rate, body temperature, pulse rate, and the like. The communication module **17** may utilize audible or visible alerts if the user is meeting their physiological targets or exceeding safe physiological limits. Alerting a user by physical or electrical force, such as the sense of touch or tingling from an electric pulse or vibration, can also be utilized. Thus, although communication by audible means is often utilized, the communication module **17** can alert, signify, or communicate with the user through sound, light, electrical actuation, and physical actuation.

[0097] As a second example of this biofeedback method, basic vital signs collected by the physiological sensors **11** and processed by the signal processor **13** can be presented to the monitoring device user audibly, through the communication and entertainment module **17**. For example, the user may be able to listen to his/her breathing rate, pulse rate, and the like. Additionally, an entertaining or aggravating sound or song can be used to alert the user to favorable or unfavorable personal health and environmental factors occurring in real-time. This technique may be applied towards education, such as positive or negative feedback for educational games, learning games, or games of deception (e.g., poker, etc.). FIG. **9** illustrates the display of physiological information and environmental information collected by a monitoring device **10** via a user's cell phone, according to some embodiments of the present invention.

[0098] In some embodiments, the wearable monitoring device **10** may be configured to deliver and/or monitor drugs, as in a dosimeter. For example, a transdermal drug delivery system may be provided that is controlled by monitoring

device **10** electronics. Physiological sensors **11** can monitor the drug dosage and the physiological effects of the drug in real-time.

[0099] A health and environmental monitoring system **20** according to embodiments of the present invention that may incorporate wearable monitoring devices **10** of FIG. **1** is illustrated in FIG. **2**. Other types of wearable monitoring devices may also be utilized in the health and environmental monitoring system **20**. The wearable monitoring device **10** is utilized as a specific monitoring device **21** of the monitoring system **20**, though other modules located at various other parts of the body can be used in conjunction with, or in place of, the wearable monitoring device **10**. The terms "wearable monitoring device" and "sensor module" are used interchangeably herein in accordance with various embodiments of the present invention. The health and environmental monitoring system **20** is composed of at least one sensor module **21** (e.g., wearable monitoring device **10**) at least one portable telecommunication module **22**, at least one transmission system **23**, at least one user interface **24**, at least one personal database **25**, and at least one anonymous database **26**.

[0100] The sensor module **21** can be composed of a primary module alone or a primary module and at least one secondary module. The primary and secondary modules can be located at any location of the body, but in many cases it is preferable to be located in a region at or near the ear, and preferably the wearable monitoring device **10** serves as the primary module. In many cases, the secondary modules are not necessary. But in some cases, secondary modules may be located, for example, behind the ear (near the lymph nodes), at or near the earlobes (such as one or more earrings or ear clips), at the front of the ear (near the carotid artery), at the temples, along the neck, or other locations near the ear. In some cases the secondary modules, as with the primary module, can be located inside the body. These wearable secondary modules can be connected with either a "hard" connection to the primary module (such as an electric cable) or a "soft" connection to the primary module (such as a wireless connection). In Bluetooth® protocol, each secondary module can be simultaneously in direct wireless communication with the primary module. Primary modules and secondary modules in the same location can promote quick-donning, ease-of-use, and comfortability for the end user. Users may not be prone to accept multiple modules at multiple locations of the body.

[0101] The wearable sensor module **21** communicates wirelessly with the portable telecommunication device **22**, preferably in an open architecture configuration, such as Bluetooth® or ZigBee. The telecommunication device **22** can be any portable device, such as a cell phone (which includes a "smartphone"), PDA, laptop computer, Blackberry, another earpiece, or other portable, telemetric device. The portable telecommunication device **22** and the wearable sensor module **21** can telemetrically communicate both to and from each other. Though the main purpose of the portable telecommunication device is to transmit the local wireless signal from the sensor module **21** over longer distances unattainable by the transmitter **14** of the sensor module **21**, the telecommunication device **22** can also serve as a method of personal communication and entertainment for the earpiece user.

[0102] In some embodiments, the telecommunication device **22** transmits data in only one direction or particular directions. For example, in one embodiment, the portable telecommunication device **22** can receive telemetric information from the sensor module **21** but cannot send out signals to a transmission system **23**. The portable telecommunication device **22** may also contain an end-user graphical interface, such as a user interface **24** in the monitoring system **20**, such that data from the wearable sensor module **21** can be stored, analyzed, summarized, and displayed on the portable telecommunication device **22**. For example, charts relating health and environment, as well as real-time biofeedback and the like, can be displayed on a cell phone, media player, PDA, laptop, or other device. The telecommunication device **22** may also contain physiological and environmental sensors itself, such as sensors for blood pressure, pulse rate, air quality, pulse-oximetry, and the like. Additionally, the telecommunication device **22** can communicate with the wearable sensor module **21** to transfer commands, activate or deactivate sensors, communicate with the user, and the like.

[0103] The portable telecommunication device **22** sends/receives wireless information directly to/from a transmission system **23** for transmission to a database (such as personal database **25** and/or anonymous database **26**) for storage, analysis, and retrieval of data. The style of transmission system may depend largely on the location of the database. For example, if the database is located in a local computer, the wireless information from the telecommunication device **22** can be sent directly to the local computer. This computer may be connected with the Internet, allowing access to the database from the web. However, the database is more typically located far away from the user and telecommunication module. In this case, the wireless signal from the telecommunication device **22** can be sent to a reception tower and routed through a base station. This information can then be sent to a database through the Internet. A variety of other transmission protocols can be applied for connection between the telecommunication device **22** and the databases **25** and **26**.

[0104] The personal and anonymous databases **25**, **26** represent databases that may or may not be located on the same computer. A difference between these two databases is not the physical location of the database but rather the type of information available on each database. For example, the anonymous database **26**, containing aggregated health and environmental data from multiple indistinct monitoring device users, can be public and accessible through the Internet by various users. In contrast, the personal database **25** contains health and environmental data that is personalized for each monitoring device user, including personalized information such as name, birth date, address, and the like. Users can log-in to their personalized information in the personal database **25** through an interactive user interface **24** and compare this information with information from multiple users in the anonymous database **26** via a graphical user interface, etc. In some cases, the wearable sensor module **21** or portable telecommunication device **22** may additionally communicate information not directly related to health and environment, such as physical location, personal information, proximity to various locations or properties, etc., to either database. In some cases, this additional information may be sensed by the wearable sensor module **21** and/or by sensors and/or protocols integrated into portable communication device **22**.

[0105] The user interface **24** can be a computer monitor, a cell phone monitor, a PDA monitor, a television, a projection monitor, a visual monitor on the wearable sensor module **21**, or any method of visual display. (Audible methods and audio-visual methods can also be used for the user interface **24**, as well as mechanical methods such as automated brail displays for the blind.) For example, the user may log-in to their

personal database **25** through a computer user interface **24** and compare real-time personal health and environmental exposure data with that of other users on the monitoring system **20**. In some cases, the data from other users may be anonymous statistics. In some cases, one or more users may have agreements to view the data of one or more other users, and in other cases, users may agree to share mutual personalized data through the Internet.

[0106] A specific embodiment of a graphical user interface **30** is presented in FIG. **3**. FIG. **3** shows an example of how a computer monitor may appear to a user logging-in to their personal database **25** and comparing their own personal data with that of anonymous users in the same monitoring system **20**. In this case, data from anonymous users is averaged into certain demographics; the choice of the demographics to be displayed can be selected by the user accessing the personalized database. In the graphical user interface **30** of FIG. **3**, the user's personalized data, signified by a star, is compared with statistics from other users in an anonymous database **26**. This allows the user to compare his/her health and environment with that of others in selected demographics. FIG. **10** illustrates an exemplary user interface that a user can access to compare himself/herself to others, according to some embodiments of the present invention.

[0107] Monitoring system **20** serves not only as a source of useful information from a medical standpoint, but also as a form of entertainment for curious users. It is important to note that health and environmental information from multiple subjects may be updated regularly. In some cases, the regular updates are real-time (or "near-real-time") updates. Thus, information is always new and fresh with respect to daily changes in a group of subjects, and the plots of FIG. **3** are dynamic, changing in time with changing user health and/or environmental information.

[0108] The monitoring system **20** can be used in medicine for a variety of important functions. As one example, a doctor can monitor the health of patients through each patient's personalized database **25**. If the wearable sensor module **21** contains a dosimeter, the doctor can even monitor the efficacy of prescribed medications, and the physiological response to medications, over time. This dosimetry approach is directly applicable to clinical studies of various treatments. For example, during a clinical trial, the wearable sensor module **21** can collect environmental data, drug dosimetry data, and physiological data from the earpiece user such that researchers can understand the epidemiology between drugs, genes, physiology, environment, and personal health.

[0109] Because of the high compliance of the wearable monitoring device **10**, primarily due to the dual-modality as a health/environmental monitor and a personal communication/entertainment device, users are prone to wear this device throughout clinical trials, providing more valuable information for drug discovery and the pharmaceuticals market.

[0110] As a further example, the health and environmental monitoring system **20** can be used by dieticians to track the caloric intake, health, and physical activity of dieters. Similarly, the monitoring system **20** can be used by athletic trainers to monitor the diet, physical activity, health, and environment of athletes. In many cases professionals are not necessary, and the user can monitor his/her own diet, activity, athletic performance, etc. through the monitoring system without professionals, parents, guardians, or friends monitoring their personal statistics.

[0111] In a specific example of the monitoring system **20**, a test subject in a clinical trial for a new treatment, such as a new drug, physical therapy, medical device, or the like, is wearing at least one monitor **21**. The subject's health and environment are monitored in real-time, and this data is stored on the wearable sensor module **21**, the portable telecommunication device **22**, the personal database **25**, and/or the anonymous database **26**. By accessing the stored data, researchers managing the clinical trial can then compare the statistics from multiple users to make correlations between user environment, health, and the effectiveness of treatment.

[0112] According to some embodiments of the present invention, a method of monitoring one or more subjects includes collecting physiological and/or environmental information from a monitoring device associated with each respective subject, storing the collected physiological and/or environmental information at a remote storage device, and comparing the stored physiological and/or environmental information with benchmark physiological and/or environmental information to identify at least one behavioral response of the one or more subjects. As described above, each monitoring device includes at least one physiological sensor and/or environmental sensor. Exemplary behavioral responses include behavioral responses to a product and/or service, behavioral responses to product and/or service marketing, behavioral responses to medical treatment, and behavioral responses to a drug.

[0113] It should be noted that algorithms for processing personal health and environmental data, diagnosing medical conditions, assessing health states, and the like do not need to be limited to the illustrated monitoring system **20**. Various algorithms can also be integrated into the wearable sensor module **21** or telecommunication device **22** according to embodiments of the present invention. A data storage component in at least one of these units allows processed signal data to be stored, analyzed, and manipulated to provide new knowledge to the user. This storage component can be any solid-state storage device, such as flash memory, random-access memory (RAM), magnetic storage, or the like. For example, the wearable sensor module **21** can be programmed to monitor certain habits, such as nail-biting. In this non-limiting example, the physiological sensors **11** may monitor internal sounds, and an algorithm can be implemented to monitor signatures of nail-biting sounds in real-time. If the habit is identified by the algorithm, the communication module **17** may instantly warn the user that the habit is occurring. Alternatively, the algorithm may count the number of times a day the habit occurred, monitor physiological and psychological stress indicators during each occurrence, log each time when the habit occurred, and store environmental data associated with the habit. This stored data can be accessed at a later time, allowing the user to determine what environmental factors cause the physiological or psychological stress associated with nail-biting. As this example shows, these algorithms can take advantage of both physiological sensor data and environmental sensor data.

[0114] According to some embodiments of the present invention, a method of supporting interpersonal relationships includes collecting physiological and/or environmental information from a monitoring device associated with a person when the person is in the presence of another person, determining a stress level of the person using the collected physiological and/or environmental information, and displaying the stress level to the person (or to others). As described

above, the monitoring device **10** includes at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from the person, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the person. The collected physiological and/or environmental information includes indicators associated with stress experienced by the person;

[0115] According to some embodiments of the present invention, physiological and/or environmental information collected from the person over a period of time can be stored and subsequently analyzed. For example, a stress level of the person over a period of time can be determined using the stored information, and can be displayed to the person (or to other persons). FIG. **11** illustrates the display of stress over time for a user, according to some embodiments of the present invention.

[0116] According to some embodiments of the present invention, physiological and/or environmental information collected from a person can be analyzed to identify a source of stress to the person, and one or more solutions for reducing stress can be recommended to the first person, for example via the monitoring device **10** (or in other ways).

[0117] A data storage component may include various algorithms, without limitation. In some embodiments, at least one algorithm is configured to focus processing resources on the extraction of physiological and/or environmental information from the various environmental and/or physiological sensors. Algorithms may be modified and/or uploaded wirelessly via a transmitter (e.g., receiver/transmitter **14** of the wearable monitoring device **10**)

[0118] The biofeedback functionality of the telemetric wearable monitoring device **10** can be applied towards various gaming applications. For example, one or more subjects can connect their wearable monitoring devices **10** to one or more gaming devices wirelessly through the open architecture network provided by Bluetooth®, ZigBee, or other such networks. This allows personal health and environmental information to be transferred wirelessly between the wearable monitoring device **10** and a gaming device. As subjects play a game, various personal health and environmental feedback can be an active component of the game. In a non-limiting embodiment, two users playing a dancing game, such as Dance Dance Revolution, can monitor their vital signs while competing in a dancing competition. In some cases, users having healthier vital signs, showing improved athletic performance, will get extra points ("Vital Points"). In another specific example, this personal health and environmental information can be sent telemetrically to a gaming device to make entertaining predictions about one or more users. Namely, the gaming device may predict someone's life expectancy, love-life, future occupation, capacity for wealth, and the like. These predictions can be true predictions, purely entertaining predictions, or a mixture of both. Sensors measuring external stressors (such as outside noise, lighting conditions, ozone levels, etc.) and sensors measuring internal stresses (such as muscle tension, breathing rate, pulse rate, etc.) integrated into the wearable monitoring device **10** can be used to facilitate predictions by the gaming device. For example, the information from the sensors can be recorded from one or more subjects wearing a sensor module **21** during a series of questions or tasks, and the information can be sent telemetrically to a gaming device. An algorithm processed in the gaming device can then generate an entertaining assessment from the information. This game can be in the form of a video game, with a graphical user interface **24**, or it can be a game "in person" through an entertainer. Other games can involve competitions between multiple wearable monitor users for health-related purposes, such as online dieting competitions, fitness competitions, activity competitions, or the like. Combining the telemetric wearable monitoring device **10** with gaming, according to embodiments of the present invention, provides seamless interaction between health and environmental monitoring and the game, through a comfortable telemetric module. Other sensor modules **21** located at various parts of the body can also be used.

[0119] An additional non-limiting embodiment of the biofeedback functionality of a wearable sensor module **21**, according to some embodiments of the present invention, include monitoring psychological and physiological stress (such as monitoring stress indicators) during a poker game. These stress indicators can be breathing rate, muscle tension, neurological activity, brain wave intensity and activity, core body temperature, pulse rate, blood pressure, galvanometric response, and the like. Users may, for example, use the wearable sensor module **21** to record or display their psychological and physiological stress during a poker game in real-time. This information can be stored or displayed on a portable telecommunication device **22** or sent wirelessly to other parts of the monitoring system **20**. The user can use this biofeedback to adjust their psychological and physiological stress (or stress indicators) through force of will. This biofeedback process allows earpiece users to self-train themselves to project a certain "poker face," such as a stoic cold look, a calm cool look, or another preferred look. Additionally, external stressors, such as light intensity and color, external sounds, and ambient temperature, can be sensed, digitized, and transmitted by the wearable monitoring device **10** to a telecommunication device (for storage), providing the user with important information about how the external environment may be affecting their stress response and, hence, poker game. In some games, the stress indicators may be displayed for outside viewers (who are not part of the poker game) as a form of entertainment when watching a group of poker players (each having earpiece modules **21**) in a casino, television, or through the Internet.

[0120] Physiological and/or environmental information collected from sensors **11**, **12** in a wearable module **21** (**10**) may be corrupted by the motion artifacts of a subject. As a specific example, when measuring pulse rate in a subject via photoplethysmography while the subject is walking, optical scatter associated with footstep-related skin vibrations may be misinterpreted as coming from a pulse. This problem can be especially difficult where footstep rates are on the order of normal human pulse rates. By measuring body motion in real-time via one or more accelerometers inside the wearable monitor **21** (**10**), sampled pulse rate data can be processed to subtract, reduce, or eliminate signals associated with footsteps. In some cases, the processor **13** may simply send a command to ignore the sampling and/or logging of pulse rate when body motion is detected. In this way, average pulse rate estimate is not convoluted with footstep information. In other cases, the processor **13** may correct for body motion in real time through dynamic feedback from the aforementioned accelerometer. A variety of other body motion sensors, such as acoustic sensors for monitoring footstep sounds and MEMS motion sensors, can also be used to monitor footsteps

and correct physiological and/or environmental data for motion artifacts. An important innovation afforded by the databases **25**, **26** is that motion artifacts in the data can be corrected by applying algorithms for reviewing the physiological and/or environmental history of each subject, identifying corruptions associated with motion artifacts, and extracting physiological and/or environmental information from corrupted data.

[0121] Information collected from one or more subjects wearing a sensor module **21** in the monitoring system **20**, can be integrated into a game for a novel gaming experience. For example, information collected from health and environmental monitors worn by a user throughout the day can be used to build a gaming character based on that user. With a group of subjects wearing such monitors throughout the day, a novel gaming environment based on a plurality of real life characters can be generated. Because information from each subject is updated on a regular basis with the monitoring system **20**, information about characters can always be fresh and dynamic, changing as the health and environment of each subject changes. Information from a group of subjects sharing a common quality can be summarized into a single character or group of characters based on the aggregated dynamic changes in the health and/or environment within the representative group.

[0122] The biofeedback approach is also directly relevant to personal education as a learning tool. For example, monitoring the physiological and psychological response to learning can be used to help users understand if they are learning efficiently. For example, in the course of reading, the wearable sensor module **21** can monitor alertness through galvanometric, brainwave, or vital sign monitoring. The user can then use this information to understand what reading methods or materials are stimulating and which are not stimulating to the earpiece user.

[0123] Biofeedback methods, according to embodiments of the present invention can be used as self-training tools for improving performance in public speaking, athletic activity, teaching, and other personal and job-related activities.

[0124] A health and environmental monitoring system **20**, according to some embodiments of the present invention, enables a variety of additional business methods for exploiting user information collected by the system **20**. For example, users can be charged a fee for downloading or viewing data from the personal and/or anonymous databases **25**, **26**. Alternatively, users may be allowed free access but may be required to register online, providing personal information with no restrictions on use, for the right to view information from the databases. In turn, this personal information can be traded or sold by the database owner(s). This information can provide valuable marketing information for various companies and government interests. The health and environmental data from the databases **25**, **26** can be of great value itself, and this data can be traded or sold to others, such as marketing groups, manufacturers, service providers, government organizations, and the like. A web page or web pages associated with a personal and anonymous database **25**, **26** may be subject to targeted advertising. For example, if a user shows a pattern of high blood pressure on a personal database **25**, a company may target blood pressure treatment advertisements on the user interface **24** (i.e., web page) while the user is logged-in to the personal database through the user interface **24**. For example, because various health and environmental statistics of subjects in the monitoring system **20** will be available on the database, this information can be used to provide a targeted advertising platform for various manufacturers. In this case, a database manager can sell information to others for targeted advertising linked to a user's personal statistics. In some cases, a database owner does not need to sell the statistics in order to sell the targeted advertising medium. As a specific example, a company can provide a database owner with statistics of interest for targeted advertising. For example, the company may request advertising a weight-loss drug to anonymous users having a poor diet, high caloric intake, and/or increasing weight. A database manager can then charge the company a fee for distributing these advertisements to the targeted users as they are logged-in to the database website(s). In this way, the users remain anonymous to the company. Because targeted advertisements can be such a lucrative market, income from these sources may eliminate the need for charging users a fee for logging-in to the databases **25**, **26**.

[0125] According to some embodiments of the present invention, a method of delivering targeted advertising to a person includes collecting physiological and/or environmental information from the person, selecting an advertisement for delivery to the person based upon the collected physiological and/or environmental information, and delivering the selected advertisement to the person. Collecting information includes receiving physiological and/or environmental information from a monitoring device associated with the person. Selecting an advertisement includes analyzing the received physiological and/or environmental information to identify a physiological condition of the person and/or environmental condition in a vicinity of the person, and selecting an advertisement for a product or service related to an identified physiological and/or environmental condition. Delivery of a selected advertisement can be via any of many different channels including, but not limited to, email, postal mail, television, radio, newspaper, magazine, the internet, and outdoor advertising.

[0126] There are many ways to profit from a health and environmental monitoring system **20**, according to embodiments of the present invention. For example, information from subjects can be used to target online advertisements or links to a particular subject or group of subjects, where these advertisements or links are tailored to information collected from each subject in the monitoring system **20** through sensor modules **21**. In some cases, a targeted online link, tailored to a subject or group of subjects, may not necessarily constitute an advertisement but rather a targeted link corresponding to a targeted good or service. Additionally, advertisements need not be limited to online advertisements. The collected information can be used for targeted mailings, television commercials, newspaper/magazine ads, billboards, and the like.

[0127] A wearable sensor module **21** and health and environmental monitoring system **20** can enable a variety of research techniques. For example, a plurality of monitoring devices **10** worn by users can be used in marketing research to study the physiological and psychological response of test subjects to various marketing techniques. This technique solves a major problem in marketing research: deciphering objective responses in the midst of human subjectivity. This is because the physiological and psychological response of the earpiece user largely represents objective, unfiltered information. For example, users that are entertained by a pilot TV program would have difficulty hiding innate vital signs in response to the program. The data generated by the wearable

sensor module **21** during market research can be transmitted through any component of the telemetric monitoring system **20** and used by marketing researchers to improve a product, service, or method.

[0128] Another method provided by the monitoring system **20** is to charge users of the monitoring system for usage and service (such as compilation service). For example, a clinical trial company may pay a fee for accessing the databases **25**, **26** of their test subjects during medical research. In this case, these companies may buy modules **21** and pay for the service, or the modules **21** may be provided free to these companies, as the database service fee can provide a suitable income itself. Similarly, doctors may pay for this service to monitor patients; fire fighters and first responders may pay for this service to monitor personnel in hazardous environments; and athletic trainers may pay for this service to monitor athletes. Also, users can pay for the database service directly themselves. Because these databases **25**, **26** are dynamic, updated regularly via a wearable sensor module **21** of each user, with data changing with time for individual users and users en mass, these databases can maintain a long-term value. In other words, there may always be new information on the databases **25**, **26**.

[0129] Another embodiment of the present invention involves methods of combining information from various sensors **11**, **12** into a meaningful real-time personal health and environmental exposure assessment in a recording device. The meaningful assessment is generated by algorithms that can be executed in the sensor module **21**, in the portable telecommunication device **22**, or through various other electronic devices and media within the monitoring system **20**. In one embodiment, raw or preprocessed data from the sensor module **21** is transmitted wirelessly to the telecommunication device **22**, and this device executes various algorithms to convert the raw sensor data (from one or more sensors) into a meaningful assessment for the user. For example, a blood pressure assessment may be processed from stored raw data on personal database **25** and/or anonymous database **26** collected from pulse rate sensors, pulse volume sensors, and blood flow sensors in the wearable sensor module **21**. In another embodiment these algorithms are executed within the sensor module **21** itself, without the need for processing in the telecommunication device **22**, through a processor **13** inside the module **21** (**10**). The output from these algorithms can be viewed as charts, graphs, figures, photos, or other formats for the user to view and analyze. Preferably, these formats display various health factors over time with respect to a particular environment, with health factor intensity on the dependent axis and time or environmental factor intensity on the independent axis. However, virtually any relationship between the physiological data and environmental data can be processed by an algorithm, and these relationships can be quantitative, qualitative, or a combination of both.

[0130] One innovation involves applying the wearable sensor module **21** towards a physical or mental health assessment method. An algorithm may combine data from health and environmental sensors **11**, **12** towards generating a personal overall health assessment for the user, conditional to a particular environment. For example breathing rate, pulse rate, and core body temperature can be compared with ozone density in the air for generating an ozone-dependent personal health assessment. In another specific example of this innovation, information from the sensors **11**, **12** can be used to monitor overall "mood" of a user in a particular environment. More particularly, algorithmic processing and analyzing of data from sensors for core body temperature, heart rate, physical activity, and lighting condition can provide a personal assessment of overall mood conditional on external lighting conditions.

[0131] Mood sensing in the wireless sensing monitoring system **20** can be implemented in a variety of novel ways. A case example is that of a girl wearing a sensor module **21**, in the form factor of a Bluetooth® headset (earpiece), embedded with sensors and a processor for monitoring overall mood. As the girl's mood changes, the headset monitor **21** senses, processes, and transmits mood to portable communication device, such as a cell phone. The cell phone may then send a text message (or other type of communication), manually or automatically via a stored program, to a boyfriend, notifying the boyfriend of a change in mood. This allows the boyfriend to respond more rapidly and efficiently to mood changes. Similarly, aggregated mood data from a variety of users wearing similar or identical monitors can be used to track mood in a population study for one or more groups of people.

[0132] An application of the health and environmental monitoring system **20** is supporting interpersonal relationships between individuals and/or groups of individuals. For example, subjects wearing a monitoring device **21** (**10**) can track stress rates when interacting with certain other subjects. As a more specific example, a subject wearing a monitoring device **21**, containing physiological and/or environmental sensors for tracking indicators associated with stress, can track their stress level in the presence of their spouse, children, coworkers, etc. through the user interface **24**. As the subject interacts throughout the day, the wearable monitoring device **21** may communicate stress updates through the wireless monitoring system **20** for storage in databases **25** and/or **26**. Through the view screen of a computer, the user can then track a history of stress levels while interacting with certain individuals. The correlation between stress level and particular individuals may be decided based on the time of day or a time mark selected by the subject wearing the monitor **21**. In some cases, the monitor **21** may be programmed to recognize other individuals audibly and/or visually or through a certain environment common to other individuals through sensors **11**, **12** integrated into the monitor **21** (**10**), and this correlation may then be transmitted wirelessly to the databases **25** and/or **26** for tracking stress with respect to a particular interpersonal relationship. The stress record stored in the databases can then be used by professionals or the individuals themselves to uncover the sources of stress and recommend solutions or therapies for reducing stress in an interpersonal relationship. In some cases, the correlation with the stress of a subject and the subject's environment may be all that is of interest, in which case detecting other individuals is not necessary.

[0133] Applying sensor information from the sensor monitoring system **20** towards predictions for individual subjects and groups of subjects is another embodiment of the present invention. Health and/or environmental information from individuals in the monitoring system can be used to predict an individual's behavior, health, the onset of a health condition, etc. Collectively, information from multiple subjects in the monitoring system **20** can be used to predict the outbreak of a disease, environmental situation, traffic conditions, mass behavior (such as market behavior), and the like. As a specific examples, sensors for monitoring physiological and/or environmental parameters associated with influenza may monitor

changes in core body temperature, voice pitch changes, pulse rate changes, etc. in a subject, or group of subjects, wearing a module **21**, and this information may be processed into a prediction of the onset of influenza for the subject or group of subjects. Indeed, the onset of a mass outbreak can be predicted. A variety of predictive techniques can be used to predict behavior based on user information from the monitoring system **20**. Predictions can be made by processing data stored in the databases **25**, **26** with predictive algorithms, such as neural network-based programs and other computer programs. In some cases, predictions can be made simply by processing trends through human analysis, computer analysis, or a combination of both. In some cases, predictions may be processed by the internal processor **13** inside the wearable health module **21** (**10**).

[0134] Information from the health and environmental monitoring system **20** can be used to track, direct, and predict the marketing, advertising, distribution, and sales of goods or services tailored towards one or more subjects or groups in the monitoring system. As an example, trends in high stress for a subject wearing a monitor **21** can be processed into information relating the specific stress-related product needs, such as medications, spas, or therapies, tailored for that specific subject. Similarly, trends in poor health may communicate corrective action to the user, through the aforementioned wireless protocol, or through medical professionals to the user. In some cases, warnings may be communicated to first responders to assist a subject. Information from groups of individuals in the monitoring system **20** may be used to track, direct, and predict the marketing, advertising, distribution, and sales of goods or services tailored towards a group or region.

[0135] Although many examples herein relate to generating profiles for individuals or groups wearing monitors **21** in a monitoring system **20**, it should be understood that embodiments of the present invention have broad applicability to users not wearing monitors **21**. Profiles can be generated for individuals not wearing monitors **21** based on similarities with one or more others who do wear monitors **21**. Namely, individuals may be targeted for advertisements, marketing, distribution, and sales for goods and services based on a relationship with subjects wearing monitors **21**. For example, individuals matching the demographics of a subject or group of subjects being monitored in the monitoring system **20** may received targeted ads, links, marketing, goods/services, and the like. Additionally, users viewing information from the anonymous database **26** may be subject to targeted or untargeted marketing and sales aspects, regardless of whether or not they wear a module **21**.

[0136] The monitoring system **20** does not require subjects to wear monitors **21** continuously to be functional. Subjects wearing modules **21** for merely a few minutes a day can provide useful information for the monitoring system **20** and for the individuals themselves.

[0137] An earpiece/headset form factor for a wearable sensor module **21** can be utilized for monitoring or predicting traffic-related conditions for automobiles and other vehicles. As a specific example, a wearable earpiece module **21**, containing physiological and environmental sensors, can provide information about the stress of a subject while driving, as well as the speed of the subject, environmental conditions surrounding the subject, alertness of the subject, and the like. This can be accomplished by monitoring heart rate, breathing rate, core body temperature, acceleration, the weather conditions, air quality, and the like with sensors **11**, **12**. Information from multiple subjects can be used to track and study the stress of a group of individuals with certain traffic-related conditions. Additionally, predictions about traffic jams, road accidents, traffic flow can be estimated based on processed information stored in the remote databases **25**, **26**. This information can also be used to assist infrastructure decisions that will reduce the stress of drivers, improve traffic flow, and prevent automotive accidents. In some cases, this information may be used in studies to understand the interaction between stress, road conditions, environment, and the like.

[0138] In some embodiments, information from sensors in a sensor monitoring system **20** can be used to generate real-time maps related to physiological and/or environmental conditions of groups of subjects over a geographical landscape. For example, a real-time health/stress map (see, for example, FIG. **12**) or real-time air quality map can be generated through a user interface **24** for informational or entertainment value to one or more viewers. Aggregated data stored in the anonymous database **26** can be processed into a map by correlating the location of each subject with physiological and environmental data measured by sensors **11**, **12** integrated into a wearable monitor **21** worn by the each subject. Location information can be provided through the existing cellular infrastructure, through the triangulation of wireless signals related to each subject, or through location sensors integrated into the monitor **21** or portable telecommunication device **22** (such as GPS sensors), or the like. These maps can be dynamic and real-time based on wireless updates from each subject. These maps can be local, regional, state-wide, national, world-wide, and the like.

[0139] Earpiece monitoring devices described herein need not be embodied within headsets only. For example, an wearable earpiece module **10** according to embodiments of the present invention can be a hearing aid, an earplug, an entertaining speaker, the earpiece for an IPOD®, Walkman®, or other entertainment unit, a commercial headset for a phone operator, an earring, a gaming interface, or the like. A wearable earpiece module **10** covers the broad realm of earpieces, ear jewelry, and ear apparatuses used by persons for entertainment, hearing, or other purposes both inside and outside of health and environmental monitoring.

[0140] Moreover, two earpiece modules **10** may be utilized, according to some embodiments of the present invention; one for each ear of a person. In some cases, dual-ear analysis can be performed with a single headset having dual earpieces. Dual-ear analysis with two earpiece modules can be used, for example, to compare the core temperature of each tympanic membrane in order to gauge brain activity comparing each brain hemisphere. In another case, acoustical energy, including ultrasonic energy, can be passed from one earpiece module to the other, with acoustic absorption and reflection being used to gauge various physiological states. For example, this technique can be used to gauge hydration level in the head or brain by estimating the acoustical energy absorption rate and sound velocity through the head of the user.

[0141] A variety of form factors for wearable monitoring devices **10** may be used in the present invention. The form-factor of a wrist-watch, belt, article of clothing, necklace, ring, body piercing, bandage, electrode, headband, glasses or sunglasses, cast (i.e., for broken bones), tooth filling, etc. are but a few examples. A variety of earpiece styles, shapes, and architectures can be used for the case of where a wearable monitoring device **10** is an earpiece module, according to

embodiments of the present invention. A non-limiting embodiment of an earpiece module is illustrated in FIG. **4**. The illustrated earpiece **40** fits over the ear of a person and is held in place by an ear support **41** (also called the "earpiece attachment component" **15**). The illustrated earpiece module **40** also includes an earpiece body **42**, an earpiece fitting **43**, and an optional earlobe clip **44**. The earpiece may also contain an adjustable mouthpiece **52** (FIG. **5**B) and/or a pinna cover **53** (FIGS. **5**A-**5**B) described below. The earpiece **40** connects with the ear canal of a person through an earpiece fitting **43** located on the backside **45** of the earpiece **40**. The earpiece fitting **43** transmits sound to the inner ear and eardrum. Health and environmental sensors are integrated primarily within or along the earpiece body **42**, including the earpiece backside **45**. However, an earlobe clip **44** can contain various health and environmental sensors as well. In some cases, health and environmental sensors can be integrated within or along the ear support **41**, the adjustable mouthpiece **52**, the earpiece fitting **43**, or the pinna cover **53**. Raw or processed data **46** from these sensors can be wirelessly transferred to a recording device or a portable telecommunication device **22** (FIG. **2**). In some embodiments of the present invention, a recording device can be located within or about the earpiece **40** itself. In some cases, this recording device is flash memory or other digitized memory storage. The types of health and environmental factors which may be monitored have been previously described above for the wearable monitoring device **10**.

[0142] It should be understood that the earpiece body **42** can be any shape and size suitable for wear around or near the ear. In some cases, the earpiece body and earpiece fitting can be one and the same structure, such that the earpiece body-fitting is a small fitting inside the ear. In many cases, it is desirable to seal off or partially seal off the ear canal so as to prevent sounds from entering or leaving the ear such that auscultatory signal can more easily be extracted from the ear canal through devices (such as microphones) in the earpiece body-fitting.

[0143] It should be noted that the invention is not limited to the exemplary earpiece **40** of FIG. **4**. Other earpiece configurations are also capable of integrating health and environmental sensors for portable, noninvasive, real-time health monitoring according to embodiments of the present invention. For example, the earlobe clip can be modified to reach other surfaces along or near a person's ear, head, neck, or face to accommodate electrical or optical sensing. Similarly, more than one clip may be integrated into the earpiece. Sensors can be integrated into the earpiece-fitting. In such embodiments, the sensors may be integrated into a module in the earpiece-fitting. Environmental sensors are preferably located on the outside of the earpiece through a region on the earpiece frontside. This allows access to air in the vicinity of the earpiece user. However, environmental sensors can be located anywhere along the earpiece module **40**.

[0144] FIGS. **5**A-**5**B illustrate an embodiment of an earpiece module **50** with an adjustable mouthpiece **52** and a pinna cover **53**. The earpiece **50** contains a region where an adjustable mouthpiece **52** can be swiveled, extended, pulled, extracted, flipped, or ejected towards the mouth. A microphone at the end of the mouthpiece **52** can be used to improve personal communication through the earpiece **50**. Sensors integrated into the mouthpiece **52** can be used to monitor, for example, exhaled breath for respirometry and inhalation/exhalation monitoring. Carbon dioxide, oxygen, nitrogen, water vapor, and other respired gases and vapors can be monitored, providing an overall assessment of health. Additionally, VOC's and other vapors exhaled by the breath can be monitored for diagnosing various disease states, such as diabetes, obesity, diet, metabolism, cancer, hepatic or renal health, organ functioning, alcoholism, halitosis, drug addiction, lung inflammation, voice analysis, voice distinction, and the like. The mouthpiece **52** is in a retracted or stored position in FIG. **5**A and is in an extended or operative position in FIG. **5**B.

[0145] Another multifunctional earpiece module **60**, according to embodiments of the present invention, is illustrated in FIG. **6**. The illustrated earpiece module **60** includes the embodiments described with respect to FIGS. **4** and **5**A-**5**B, such as a pinna cover **62**, an ear support **63**, a mouthpiece **64**, an earpiece body **65**, and the like. Additionally, the earpiece module **60** may contain an extension **66** with sensors for monitoring jaw motion, arterial blood flow near the neck, or other physiological and environmental factors near the jaw and neck region.

[0146] The person illustrated in FIG. **6** is also wearing an earring monitor **67** according to some embodiments of the present invention. Because at least one portion of an earring may penetrate the skin, earring monitor **67** may contain sensors and telemetric circuitry that provide access to various blood analytes through iontophoresis and electrochemical sensing that may not be easily accessible by the other portions of the earpiece module **60**. Additionally, the earring **67** may provide a good electrical contact for ECG or skin conductivity.

[0147] Embodiments of the present invention are not limited to earpiece modules. Other types of modules may be utilized that attach to other portions of a person's body. For example, a temple module **70** having a similar design as the earpiece module design **10** can also be employed, as illustrated in FIG. **7**. A temple module **70** has the benefit of being close to physiological areas associated with stress, intracranial pressure, brain activity, and migraines. Additionally, a temple module can monitor physiological activity associated with the onset of a stroke, such as increased or decreased blood flow and/or oxygen flow to the brain.

[0148] FIG. **8** illustrates a monitoring device **10**, according to some embodiments of the present invention, that is integrated into a telemetric Bluetooth® module. Though a Bluetooth® module is illustrated, it should be understood that other telemetric modules can be used. Telemetric modules according to some embodiments of the present invention may operate in open architecture protocols, allowing multiple telemetric devices to communicate with each other. A Bluetooth® module (including the monitoring device) according to some embodiments of the present invention is integrated into a wearable earpiece module (i.e., monitoring device **10** described above). The monitoring device illustrated in FIG. **8** contains one or more sensors, and is mounted onto a Bluetooth® module. In one embodiment, the sensor module is directly soldered onto the Bluetooth® module. In another embodiment, the sensor module is elevated from the Bluetooth® module with spacers, and a cable or electrical wires connect between the sensor module and the Bluetooth® module. The module may be elevated in embodiments where the sensors need to be exposed to the environment. For example, the sensors may need to be exposed through the frontside region of an earpiece module, and the Bluetooth® module may fit too deeply into the earpiece module to provide sensor access to the external environment. In some cases, contact leads or vias may connect between the sensor module and an

extended sensor or an additional sensor module. This allows the extended sensor or sensor module to be flexibly mounted anywhere inside, along, outside, or about the wearable sensor module **10**. Extended sensors can be especially useful for 4-point galvanometric monitoring of skin conductance, pulse oximetry, and volatile organic compound monitoring.

[0149] Pulse oximetry is a standard noninvasive technique of estimating blood gas levels. Pulse oximeters typically employ 2 or more optical wavelengths to estimate the ratio of oxygenated to deoxygenated blood. Similarly, various types of hemoglobin, such as methemoglobin and carboxyhemoglobin can be differentiated by measuring and comparing the optical absorption at key red and near-infrared wavelengths. Additional wavelengths can be incorporated and/or replace conventional wavelengths. For example, by adding additional visible and infrared wavelengths, myoglobin, methemoglobin, carboxyhemoglobin, bilirubin, SpCO2, and blood urea nitrogen (BUN) can be estimated and/or monitored in real-time in addition to the conventional pulse oximetry SpO2 measurement.

[0150] Blood hydration can also be monitored optically, as water selectively absorbs optical wavelengths in the mid-IR and blue-UV ranges, whereas water can be more transparent to the blue-green wavelengths. Thus, the same optical emitter/detector configuration used in earpiece pulse oximetry can be employed for hydration monitoring. However, mid-IR or blue optical emitters and detectors may be required. Additionally, monitoring the ratio of blue-green to other transmitted or reflected wavelengths may aid the real-time assessment of blood hydration levels. Blood hydration can also be monitored by measuring changes in capacitance, resistance, or inductance along the ear in response to varying water-content in the skin tissues or blood. Similarly, hydration can be estimated by monitoring ions extracted via iontophoresis across the skin. Additionally, measuring the return velocity of reflected sound (including ultrasound) entering the head can be used to gauge hydration. These hydration sensors can be mounted anywhere within or along an earpiece or other monitoring device **10**. It should be noted that other hydration sensors can also be incorporated into a module.

[0151] A variety of techniques can be used for monitoring blood metabolites via an earpiece module, such as wearable monitoring device **10**. For example, glucose can be monitored via iontophoresis at the surface of the skin combined with enzyme detection. Blood urea nitrogen (BUN) can be monitored by monitoring UV fluorescence in blood (through the skin) or by monitoring visible and mid-IR light absorption using the pulse oximetry approach described above. Various ions such as sodium, potassium, magnesium, calcium, iron, copper, nickel, and other metal ions, can be monitored via selective electrodes in an earpiece module following iontophoresis through the skin.

[0152] Cardiopulmonary functioning can be evaluated by monitoring blood pressure, pulse, cardiac output, and blood gas levels via earpiece modules, and other monitoring apparatus in accordance with some embodiments of the present invention. Pulse rate and intensity can be monitored through pulse oximetry (described above) as well as by sensing an increase in oxygenated blood with time. Pulse rate and blood flow may also be assessed through impedance measurements via galvanometry near a blood vessel. Additionally, pulse rate and blood flow may be assessed through a fast-response thermal energy sensor, such as a pyroelectric sensor. Because moving blood may temporarily increase or decrease the localized temperature near a blood vessel, a pyroelectric sensor will generate an electrical signal that is proportional to the total blood flow in time.

[0153] Blood pressure can be monitored along an earlobe, for example. According to some embodiments of the present invention, a digital blood pressure meter is integrated into an earpiece module, such as earpiece **40** of FIG. **4**. A compact clip containing actuators and sonic and pressure transducers, can be placed along the earlobe, and systolic and diastolic pressure can be measured by monitoring the pressure at which the well-known Korotkoff sound is first heard (systolic), then disappears (diastolic). This technique can also be used to monitor intra-cranial pressure and other internal pressures. Blood pressure may also be measured by comparing the time between pulses at different regions of the body. For example, sensors for monitoring pulse rate and blood volume can be located in front of the ear and behind the ear or at the earlobe, and the time between the detection of each pulse from each sensor, as well as the volume of blood passed, can be processed by a signal processor **13** into an indication of blood pressure.

[0154] Electrodes within or about an earpiece can also be utilized to monitor blood gases diffused through the skin, giving an indication of blood gas metabolism. For example, a compact Severinghaus electrode can be incorporated within an earpiece module for the real-time monitoring of CO2 levels in the blood, for example, through an earlobe connector, a sensor region of an earpiece fitting, or along or about an ear support. These Severinghaus-type electrodes can also be used to monitor other blood gases besides CO2, such as oxygen and nitrogen.

[0155] Organ function monitoring includes monitoring, for example, the liver, kidneys, pancreas, skin, and other vital or important organs. Liver quality can be monitored noninvasively by monitoring optical absorption and reflection at various optical wavelengths. For example, optical reflection from white LEDs or selected visible-wavelength LEDs can be used to monitor bilirubin levels in the skin and blood, for a real-time assessment of liver health.

[0156] Monitoring neurological functioning can be accomplished via electrodes placed at the ear, near the ear, or along another surface of the body. When such electrodes are placed along the forehead, this process is described as electroencephalography, and the resulting data is called an electroencephalogram (EEG). These electrodes can be either integrated into an earpiece module or connected to an earpiece module, according to some embodiments of the present invention. For example, an earlobe clip (e.g., **44**, FIG. **4**) can be modified to conform with EEG electrodes or other electrodes for measuring brain waves or neurological activity. For monitoring neurological functioning, a temple earpiece (e.g., **70**, FIG. **7**) may also be used. Electrodes may be positioned in a temple earpiece region near the temples of a user for direct contact with the skin. In some embodiments, direct contact is not necessary, and the neurological functioning can be monitored capacitively, inductively, electromagnetically, or a combination of these approaches. In some embodiments, brain waves may couple with low frequency acoustical sensors integrated into an earpiece module.

[0157] A person's body motion and head position can be monitored by integrating a motion sensor into an earpiece module (e.g., **40**, FIG. **4**) Two such compact motion sensors include gyroscopes and accelerometers, typically mechanical or optical in origin. In some embodiments, an accelerometer

may be composed of one or more microelectromechanical systems (MEMS) devices. In some embodiments, an accelerometer can measure acceleration or position in 2 or more axes. When the head is moved, a motion sensor detects the displaced motion from the origin. A head position monitor can be used to sense convulsions or seizures and relay this information wirelessly to a recording device. Similarly, head position monitoring may serve as a feedback mechanism for exercise and athletic training were head positioning with respect to the body is important. Additionally, the head position monitoring can be used to monitor when someone has fallen down or is not moving.

[0158] Body temperature, including core and skin temperature, can be monitored in real-time by integrating compact infrared sensors into an earpiece module, according to some embodiments of the present invention. Infrared sensors are generally composed of thermoelectric/pyroelectric materials or semiconductor devices, such as photodiodes or photoconductors. Thermistors, thermocouples, and other temperature-dependent transducers can also be incorporated for monitoring body temperature. These sensors can be very compact and thus can be integrated throughout an earpiece module. In some embodiments, these sensors may be mounted along the backside of an earpiece body, as illustrated in FIG. **4**, where the earpiece connects with the ear canal. Temperature sensors aimed at the tympanic membrane may be more accurate than sensors aimed in other directions.

[0159] In some embodiments of the present invention, a pedometer can be integrated into an earpiece module to measure the number of steps walked during a day. Pedometers that can be integrated into an earpiece module include, but are not limited to, mechanical pedometers (usually implementing a metallic ball or spring), microelectromechanical systems (MEMS) pedometers, inertial sensor pedometers, accelerometer-based pedometers, accelerometry, gyroscopic pedometers, and the like.

[0160] In some embodiments of the present invention, a pedometer for an earpiece module employs an acoustic sensor for monitoring the characteristic sounds of footsteps channeled along the ear canal. For example, an acoustic sensor can be integrated into an earpiece housing (e.g., **42**, FIG. **4**) along the backside thereof (e.g., **45**, FIG. **4**) and/or within an earpiece fitting thereof. The sounds generated from footsteps can be detected and analyzed with a signal processor using a noise cancellation or signal extraction approach to identify footstep sounds in the midst of convoluting physiological noise. In this embodiment, digitized electrical signals from footstep sounds from outside the body are compared with digitized electrical signals from footstep sounds traveling through the body (and ear canal), and only the spectral features associated with both types of digitized signals are amplified. This provides a new signal that contains cleaner information about footsteps.

[0161] Breathing characteristics can be monitored in a manner similar to that of acoustic pedometry (described above) via auscultatory signal extraction. In some embodiments, an acoustic sensor in an earpiece module is used to sense sounds associated with breathing. Signal processing algorithms are then used to extract breathing sounds from other sounds and noise. This information is processed into a breathing monitor, capable of monitoring, for example, the intensity, volume, and speed of breathing. Another method of monitoring breathing is to employ pressure transducers into an earpiece module. Changes in pressure inside or near the ear associated with breathing can be measured directly and, through signal processing, translated into a breathing monitor. Similarly, optical reflection sensors can be used to monitor pressure in or near the ear by monitoring physical changes in the skin or tissues in response to breathing. For monitoring the physical changes of the tympanic membrane in response to breathing, and hence ascertaining breathing rate, an optical signal extraction approach may be employed. At least one color sensor, or colorimetric sensor, can be employed to monitor changes in color associated with breathing and other health factors.

[0162] It should be noted that some embodiments of the present invention incorporate health sensors that do not employ chemical or biological reagents for monitoring various health factors. This is because such sensors have traditionally required larger instrumentation (not suitable for portability) and/or disposable samplers (not acceptable to most end users). However, sensors employing chemical or biological reagents may be incorporated into earpiece modules, according to some embodiments of the present invention. For example, the diffusion of analyte through the skin can be monitored electrically or optically by selective binding to enzymes or antibodies contained in the health sensors integrated into an earpiece module. In some cases, iontophoresis, agitation, heat, or osmosis may be required to pull ions from the skin or blood into the sensor region for monitoring health factors. In some cases, these analytes may be tagged with markers for electromagnetic, electrical, nuclear, or magnetic detection.

[0163] Caloric intake, physical activity, and metabolism can be monitored using a core temperature sensor, an accelerometer, a sound extraction methodology, a pulse oximeter, a hydration sensor, and the like. These sensors can be used individually or in unison to assess overall caloric metabolism and physical activity for purposes such as diet monitoring, exercise monitoring, athletic training, and the like. For example, a sound extraction methodology can be used to extract sounds associated with swallowing, and this can give an indication of total food volume consumed. Additionally, a core temperature sensor, such as a thermopile, a pyroelectric sensor, a thermoelectric sensor, or a thermistor, or a tympanic membrane extraction technique, can be used to assess metabolism. In one case, the core temperature is compared with the outdoor temperature, and an estimate of the heat loss from the body is made, which is related to metabolism.

[0164] Environmental temperature can be monitored, for example, by thermistor, thermocouple, diode junction drop reference, or the like. Electrical temperature measurement techniques are well known to those skilled in the art, and are of suitable size and power consumption that they can be integrated into a wireless earpiece module without significant impact on the size or functionality of the wireless earpiece module.

[0165] Environmental noise can be monitored, for example, by transducer, microphone, or the like. Monitoring of environmental noise preferably includes, but is not limited to, instantaneous intensity, spectral frequency, repetition frequency, peak intensity, commonly in units of decibels, and cumulative noise level exposures, commonly in units of decibel-hours. This environmental noise may or may not include noise generated by a person wearing an earpiece module. Sound made by a person wearing an earpiece module may be filtered out, for example, using analog or digital noise cancellation techniques, by directional microphone head shap-

ing, or the like. The environmental noise sensor may or may not be the same sensor as that used for the intended purpose of wireless communication. In some embodiments, the environmental noise sensor is a separate sensor having broader audible detection range of noise level and frequency, at the possible sacrifice of audio quality.

[0166] Environmental smog includes VOC's, formaldehyde, alkenes, nitric oxide, PAH's, sulfur dioxide, carbon monoxide, olefins, aromatic compounds, xylene compounds, and the like. Monitoring of the aforementioned smog components can be performed using earpiece modules and other wearable apparatus, according to some embodiments of the present invention, and in a variety of methods. All smog components may be monitored. Alternatively, single smog components or combinations of smog components may be monitored. Photoionization detectors (PID's) may be used to provide continuous monitoring and instantaneous readings. Other methods of detecting smog components according to embodiments of the present invention include, but are not limited to, electrocatalytic, photocatalytic, photoelectrocatalytic, calorimetric, spectroscopic or chemical reaction methods. Examples of monitoring techniques using the aforementioned methods may include, but are not limited to, IR laser absorption spectroscopy, difference frequency generation laser spectroscopy, porous silicon optical microcavities, surface plasmon resonance, absorptive polymers, absorptive dielectrics, and calorimetric sensors. For example, absorptive polymer capacitors inductors, or other absorptive polymer-based electronics can be incorporated into an earpiece module (e.g., **10**, FIG. **1**) according to embodiments of the present invention. These polymers change size or electrical or optical properties in response to analyte(s) from the environment (such as those described above). The electrical signal from these absorptive polymer electronic sensors can be correlated with the type and intensity of environmental analyte. Other techniques or combinations of techniques may also be employed to monitor smog components. For example, a smog component may be monitored in addition to a reference, such as oxygen, nitrogen, hydrogen, or the like. Simultaneous monitoring of smog components with a reference analyte of known concentration allows for calibration of the estimated concentration of the smog component with respect to the reference analyte within the vicinity of an earpiece user.

[0167] In some embodiments of the present invention, environmental air particles can be monitored with a flow cell and a particle counter, particle sizer, particle identifier, or other particulate matter sensor incorporated as part of an earpiece module (e.g., **10**, FIG. **1**) or externally attached to an earpiece module. Non-limiting examples of particles include oil, metal shavings, dust, smoke, ash, mold, or other biological contaminates such as pollen. In some embodiments of the present invention, a sensor for monitoring particle size and concentration is an optical particle counter. A light source is used (e.g., a laser or a laser diode), to illuminate a stream of air flow. However, a directional LED beam, generated by a resonant cavity LED (RCLED), a specially lensed LED, or an intense LED point source, can also be used for particle detection. The optical detector which is off-axis from the light beam measures the amount of light scattered from a single particle by refraction and diffraction. Both the size and the number of particles can be measured at the same time. The size of the monitored particle is estimated by the intensity of the scattered light. Additionally, particles can be detected by ionization detection, as with a commercial ionization smoke detector. In this case, a low-level nuclear radiation source, such as americium-241, may be used to ionize particles in the air between two electrodes, and the total ionized charge is detected between the electrodes. As a further example, piezoelectric crystals and piezoelectric resonator devices can be used to monitor particles in that particles reaching the piezoelectric surface change the mass and hence frequency of electromechanical resonance, and this can be correlated with particle mass. If the resonators are coated with selective coatings, certain types of particles can attach preferentially to the resonator, facilitating the identification of certain types of particles in the air near a person wearing an earpiece module. In some embodiments, these resonators are solid state electrical devices, such as MEMS devices, thin film bulk acoustic resonators (FBARs), surface-acoustic wave (SAW) devices, or the like. These compact solid state components may be arrayed, each arrayed element having a different selective coating, for monitoring various types of particles.

[0168] In some embodiments of the present invention, environmental air pressure or barometric pressure can be monitored by a barometer. Non-limiting examples of barometric pressure measurement include hydrostatic columns using mercury, water, or the like, foil-based or semiconductor-based strain gauge, pressure transducers, or the like. In some embodiments of the present invention, semiconductor-based strain gauges are utilized. A strain gauge may utilize a piezoresistive material that gives an electrical response that is indicative of the amount of deflection or strain due to atmospheric pressure. Atmospheric pressure shows a diurnal cycle caused by global atmospheric tides. Environmental atmospheric pressure is of interest for prediction of weather and climate changes. Environmental pressure may also be used in conjunction with other sensing elements, such as temperature and humidity to calculate other environmental factors, such as dew point. Air pressure can also be measured by a compact MEMS device composed of a microscale diaphragm, where the diaphragm is displaced under differential pressure and this strain is monitored by the piezoelectric or piezoresistive effect.

[0169] In some embodiments of the present invention, environmental humidity, relative humidity, and dew point can be monitored by measuring capacitance, resistivity or thermal conductivity of materials exposed to the air, or by spectroscopy changes in the air itself. Resistive humidity sensors measure the change in electrical impedance of a hygroscopic medium such as a conductive polymer, salt, or treated substrate. Capacitive humidity sensors utilize incremental change in the dielectric constant of a dielectric, which is nearly directly proportional to the relative humidity of the surrounding environment. Thermal humidity sensors measure the absolute humidity by quantifying the difference between the thermal conductivity of dry air and that of air containing water vapor. Humidity data can be stored along with pressure monitor data, and a simple algorithm can be used to extrapolate the dew point. In some embodiments of the present invention, monitoring humidity is performed via spectroscopy. The absorption of light by water molecules in air is well known to those skilled in the art. The amount of absorption at known wavelengths is indicative of the humidity or relative humidity. Humidity may be monitored with a spectroscopic method that is compatible with the smog monitoring spectroscopic method described above.

[0170] When environmental factors such as the aforementioned are monitored continuously in real-time, a user's total

exposure level to an environmental factor can be recorded. When a representative volume of air a user has been exposed to is monitored or estimated, the volumetric concentration of the analytes can be calculated or estimated. In order to estimate the volume of air a person wearing an earpiece has been exposed to, a pedometer or accelerometer or air flow sensor can also be integrated into an earpiece module. Pedometers and accelerometers can be integrated into an earpiece module via mechanical sensors (usually implementing a mechanical-electrical switch), MEMS devices, and/or gyroscopic technologies. The technologies required for these types of pedometers and accelerators are well known to those skilled in the art. The incorporated pedometer or accelerometer (or more than one pedometer or accelerometer) is used to gage the distance a person has traveled, for use in the estimation of the volume of air to which a person has been exposed, and the subsequent estimate of the volumetric concentration of monitored analytes.

[0171] The health and environmental sensors utilized with earpiece modules and other wearable monitoring apparatus, according to embodiments of the present invention, can operate through a user-selectable switch on an earpiece module. However, health and environmental sensors can also be run automatically and independently of the person wearing the apparatus. In other embodiments, the person may control health and environmental monitoring through a device wirelessly coupled to an earpiece module, such as a portable telecommunication device. For example, health and environmental sensors in or about an earpiece module can be controlled wirelessly through, for example, a cell phone, laptop, or personal digital assistant (PDA).

[0172] A wearable monitoring device **10** may be configured such that user preferences can be "downloaded" wirelessly without requiring changes to the earpiece monitor hardware. For example, an earpiece concerned about a heart condition may wish to have the signal processor **13** focus on processing pulse signature, at the expense of ignoring other physiological or environmental parameters. The user may then use the portable telecommunication device **22** to download a specialized algorithm through the web. This may be accomplished through existing wireless infrastructure by text-messaging to a database containing the algorithm. The user will then have an earpiece module suited with analysis software specialized to the needs and desires of the user.

[0173] Health and environmental monitors, according to embodiments of the present invention, enable low-cost, real-time personal health and environmental exposure assessment monitoring of various health factors. An individual's health and environmental exposure record can be provided throughout the day, week, month, or the like. Moreover, because the health and environmental sensors can be small and compact, the overall size of an apparatus, such as an earpiece, can remain lightweight and compact.

[0174] The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.

That which is claimed is:

1. A method of monitoring a subject, comprising:

receiving physiological and/or environmental information from the subject via a portable monitoring device associated with the subject, wherein the monitoring device has at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from the subject, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the subject; and

analyzing the received information to identify and/or predict one or more health and/or environmental issues associated with the subject.

2. The method of claim **1**, wherein physiological information and/or environmental information is received and analyzed at a location geographically remote from the subject.

3. The method of claim **1**, further comprising communicating corrective action information to the subject in response to identifying one or more health and/or environmental problems associated with the subject.

4. The method of claim **1**, further comprising communicating corrective action information for the subject to a third party in response to identifying one or more health and/or environmental problems associated with the subject.

5. The method of claim **1**, further comprising analyzing the received information to identify and/or predict the aging rate of the subject.

6. The method of claim **1**, further comprising analyzing the received information to identify and/or predict environmental changes in the vicinity of the subject.

7. The method of claim **1**, further comprising analyzing the received information to identify and/or predict psychological and/or physiological stress for the subject.

8. The method of claim **1**, further comprising creating a geographical map illustrating health-related and/or environmental conditions associated with the subject.

9. A health and environmental monitoring system, comprising:

a plurality of portable monitoring devices, each comprising at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from a respective subject, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the respective subject;

a plurality of portable communication devices, wherein each communication device is in communication with a respective monitoring device and is configured to transmit data from the monitoring device to remote data storage; and

a processor configured to analyze data within the remote data storage and to identify and/or predict health and/or environmental issues associated with each subject.

10. The system of claim **9**, wherein the processor is configured to communicate corrective action information to each respective subject.

11. The system of claim **9**, wherein the processor communicates corrective action information for a subject to a third party.

12. The system of claim **9**, wherein the processor communicates corrective action information to each subject via the monitoring device associated with each respective subject.

13. The system of claim **9**, wherein the remote data storage comprises a private portion and a public portion, wherein the private portion contains health and environmental data that is personalized for each subject, and wherein the public portion contains anonymous health and environmental data and is accessible by third parties.

14. The system of claim **9**, wherein the processor is configured to identify and/or predict the aging rate of one or more subjects.

15. The system of claim **9**, wherein the processor is configured to identify and/or predict environmental changes in the vicinity of one or more subjects.

16. The system of claim **9**, wherein the processor is configured to identify and/or predict psychological and/or physiological stress for one or more subjects.

17. The system of claim **9**, wherein the processor is configured to create a geographical map illustrating health and/or environmental conditions associated with one or more subjects.

18. The system of claim **9**, wherein each monitoring device is configured to be attached to a body of a respective subject.

19. The system of claim **9**, wherein one or more of the monitoring devices are each configured to be attached to an ear of a respective subject.

20. A method of delivering targeted advertising to a person, comprising:

collecting physiological and/or environmental information from a person;

selecting an advertisement for delivery to the person based upon the collected physiological and/or environmental information; and

delivering the selected advertisement to the person.

21. The method of claim **20**, wherein the collecting step comprises receiving physiological and/or environmental information from a monitoring device associated with the person, wherein the monitoring device includes at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from the person, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the person.

22. The method of claim **21**, wherein the selecting step comprises:

analyzing the received physiological and/or environmental information to identify a physiological condition of the person and/or environmental condition in a vicinity of the person; and

selecting an advertisement for a product or service related to an identified physiological and/or environmental condition.

23. The method of claim **21**, wherein the monitoring device is attached to a body of the person.

24. The method of claim **21**, wherein the monitoring device is attached to an ear of the person.

25. The method of claim **20**, wherein the delivering step comprises delivering the selected advertisement to the person via one or more of the following delivery channels: email, postal mail, television, radio, newspaper, magazine, the internet, and outdoor advertising.

26. A system for delivering targeted advertising, comprising:

a plurality of portable monitoring devices, each comprising at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from a respective person, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of a respective person; and

a remotely located advertisement selection device that receives physiological and/or environmental information from the monitoring devices, selects advertisements based upon the collected physiological and/or environmental information, and delivers selected advertisements to the monitored persons.

27. The system of claim **26**, wherein the advertisement selection device receives physiological and/or environmental information from each monitoring device via a communication device associated with each respective monitoring device.

28. The system of claim **27**, wherein the communication device is selected from the group consisting of PDAs, cell phones, laptop computers, and other portable telemetric devices.

29. The system of claim **27**, wherein one or more of the monitoring devices communicate wirelessly with respective communication devices.

30. The system of claim **26**, further comprising a database that stores the physiological and/or environmental information received from the monitoring devices.

31. The system of claim **26**, wherein each monitoring device is configured to be attached to a body of a respective person.

32. The system of claim **26**, wherein one or more of the monitoring devices are each configured to be attached to an ear of a respective person.

33. The system of claim **26**, wherein the advertisement selection device comprises an ad server configured to deliver online advertisements.

34. The system of claim **26**, wherein the advertisement selection device comprises an email server configured to deliver advertisements via email.

35. The system of claim **26**, wherein the advertisement selection device is configured to communicate with a third party service that can deliver the selected advertisement via one or more of the following delivery channels: postal mail, television, radio, newspaper, magazine, the internet, and outdoor advertising.

36. The system of claim **26**, wherein the advertisement selection device is configured to select an advertisement for a product and/or service related to a physiological condition of a person.

37. The system of claim **26**, wherein the advertisement selection device is configured to select an advertisement for a product and/or service related to an environmental condition in a vicinity of a person.

38. A method of supporting interpersonal relationships, comprising:

collecting physiological and/or environmental information from a monitoring device associated with a first person when the first person is in the presence of a second person, wherein the monitoring device includes at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from the first person, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the first person, and wherein

the collected physiological and/or environmental information includes indicators associated with stress experienced by the first person;

determining a stress level of the first person using the collected physiological and/or environmental information; and

displaying the stress level to the first person.

39. The method of claim **38**, further comprising transmitting the stress level of the first person to a third person.

40. The method of claim **38**, wherein the monitoring device is attached to a body of the first person.

41. The method of claim **38**, further comprising storing physiological and/or environmental information collected from the first person over a period of time.

42. The method of claim **41**, wherein storing physiological and/or environmental information collected from the first person comprises transmitting collected physiological and/or environmental information to a remote storage device.

43. The method of claim **41**, further comprising:

determining a stress level of the first person over the period of time; and

displaying the stress level over the period of time to the first person.

44. The method of claim **38**, further comprising identifying the second person via the monitoring device.

45. The method of claim **41**, further comprising:

analyzing the physiological and/or environmental information collected from the first person over the period of time to identify a source of stress; and

recommending a solution for reducing stress to the first person.

46. A system for supporting interpersonal relationships, comprising:

a portable monitoring device that collects physiological and/or environmental information from a first person when the first person is in the presence of a second person, wherein the monitoring device comprises at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from the first person, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the first person, and wherein the collected physiological and/or environmental information includes indicators associated with stress experienced by the first person; and

a processor that receives physiological and/or environmental information from the monitoring device, determines a stress level of the first person using the collected physiological and/or environmental information, and transmits and/or displays the stress level to the first person.

47. The system of claim **46**, wherein the processor receives physiological and/or environmental information from the monitoring device via a communication device associated with the monitoring device.

48. The system of claim **47**, wherein the communication device is selected from the group consisting of PDAs, cell phones, laptop computers, and other portable telemetric devices.

49. The system of claim **46**, further comprising a database that stores the physiological and/or environmental information received from the monitoring device.

50. The system of claim **46**, wherein the monitoring device is configured to be attached to a body of the first person.

51. The system of claim **46**, wherein the processor is configured to transmit the stress level of the first person to a third person.

52. The system of claim **46**, wherein the monitoring device is configured to identify the second person.

53. The system of claim **46**, wherein the processor is configured to analyze the physiological and/or environmental information collected from the first person to identify a source of stress, and to recommend a solution for reducing stress to the first person.

54. A method of supporting interpersonal relationships, comprising:

collecting physiological and/or environmental information from a monitoring device associated with a first person, wherein the monitoring device includes at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from the first person, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the first person, and wherein the collected physiological and/or environmental information includes indicators associated with one or more moods of the first person; and

determining a mood of the first person using the collected physiological and/or environmental information.

55. The method of claim **54**, further comprising communicating the mood of the first person to a second person.

56. The method of claim **55**, wherein communicating the mood of the first person to a second person comprises communicating via a communication network.

57. The method of claim **54**, wherein the monitoring device is attached to a body of the first person.

58. A system for supporting interpersonal relationships, comprising:

a portable monitoring device that collects physiological and/or environmental information from a first person, wherein the monitoring device comprises at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from the first person, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the first person, and wherein the collected physiological and/or environmental information includes indicators associated with a mood of the first person; and

a processor that receives physiological and/or environmental information from the monitoring device, and determines a mood of the first person using the collected physiological and/or environmental information.

59. The system of claim **58**, wherein the processor receives physiological and/or environmental information from the monitoring device via a communication device associated with the monitoring device.

60. The system of claim **59**, wherein the communication device is selected from the group consisting of PDAs, cell phones, laptop computers, and other portable telemetric devices.

61. The system of claim **58**, further comprising a database that stores the physiological and/or environmental information received from the monitoring device.

62. The system of claim **58**, wherein the processor is configured to communicate the mood of the first person to a second person.

63. A method of monitoring one or more subjects, comprising:

collecting physiological and/or environmental information from a monitoring device associated with each respective subject, wherein the monitoring device includes at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from a subject, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of a subject;

storing the collected physiological and/or environmental information at a remote storage device, and

comparing the stored physiological and/or environmental information with benchmark physiological and/or environmental information to identify at least one behavioral response of the one or more subjects.

64. The method of claim **63**, wherein the at least one behavioral response is a behavioral response to a product and/or service.

65. The method of claim **63**, wherein the at least one behavioral response is a behavioral response to product and/or service marketing.

66. The method of claim **63**, wherein the at least one behavioral response is a behavioral response to medical treatment.

67. The method of claim **63**, wherein the at least one behavioral response is a behavioral response to a drug.

68. The method of claim **63**, wherein each monitoring device is attached to the body of a respective subject.

69. The method of claim **63**, wherein each monitoring device is attached to an ear of a respective subject.

70. A system for monitoring one or more subjects, comprising:

a plurality of portable monitoring devices, wherein each monitoring device is associated with a respective subject, wherein each monitoring device includes at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to collect physiological information from a subject, and wherein each environmental sensor is configured to collect environmental conditions in a vicinity of a subject; and

a processor that compares collected physiological and/or environmental information with benchmark physiological and/or environmental information to identify at least one behavioral response of the one or more subjects.

71. The system of claim **70**, wherein the at least one behavioral response is a behavioral response to a product and/or service.

72. The system of claim **70**, wherein the at least one behavioral response is a behavioral response to product and/or service marketing.

73. The system of claim **70**, wherein the at least one behavioral response is a behavioral response to medical treatment.

74. The system of claim **70**, wherein the at least one behavioral response is a behavioral response to a drug.

75. The system of claim **70**, wherein each monitoring device comprises a dosimeter configured to measure a dose of a drug taken by a respective subject.

76. The system of claim **70**, wherein each monitoring device is attached to the body of a respective subject.

77. The system of claim **70**, wherein the processor receives physiological and/or environmental information from each monitoring device via a respective communication device associated with each monitoring device.

78. The system of claim **77**, wherein the communication device is selected from the group consisting of PDAs, cell phones, laptop computers, and other portable telemetric devices.

79. The system of claim **77**, wherein each monitoring device communicates wirelessly with a respective communication device.

80. The system of claim **70**, further comprising a database that stores the physiological and/or environmental information received from each monitoring device.

81. The system of claim **70**, wherein each monitoring device is configured to be attached to an ear of a respective person.

82. A method of monitoring patients, wherein attached to each patient is a monitoring device that includes at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from the patient, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the patient, the method comprising:

collecting physiological and/or environmental information from each patient monitoring device for each respective patient; and

analyzing the collected information to determine caloric intake, health, and physical activity of each patient.

83. The method of claim **82**, wherein each monitoring device is configured to be attached to an ear of a respective patient.

84. A system for monitoring patients, comprising:

a plurality of portable monitoring devices, wherein each monitoring device is attached to a body of a respective patient, wherein each monitoring device includes at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from a patient, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of a patient; and

a processor that receives physiological and/or environmental information from each monitoring device, and determines caloric intake, health, and physical activity of each patient.

85. The system of claim **84**, wherein the processor receives physiological and/or environmental information from each monitoring device via a respective communication device associated with each monitoring device.

86. The system of claim **85**, wherein the communication device is selected from the group consisting of PDAs, cell phones, laptop computers, and other portable telemetric devices.

87. The system of claim **85**, wherein each monitoring device communicates wirelessly with a respective communication device.

88. The system of claim **84**, further comprising a database that stores the physiological and/or environmental information received from each monitoring device.

89. The system of claim **84**, wherein each monitoring device is configured to be attached to an ear of a respective person.

90. An entertainment system, comprising:

a gaming device; and

a plurality of portable monitoring apparatuses in communication with the gaming device, wherein each monitoring apparatus is configured to transmit physiological information and/or environmental information to the gaming device;

wherein the gaming device is configured to display physiological information and/or environmental information received from each monitoring apparatus.

91. The system of claim **90**, wherein each monitoring apparatus comprises at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from a respective subject, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the respective subject.

92. An entertainment system, comprising:

a gaming device; and

a plurality of portable, wearable monitoring apparatuses in communication with the gaming device, wherein each monitoring apparatus is configured to transmit physiological information and/or environmental information wirelessly to the gaming device;

wherein the gaming device is configured to integrate into the gaming strategy physiological information and/or environmental information received from each monitoring apparatus.

93. The system of claim **92**, wherein each monitoring apparatus comprises at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from a respective subject, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the respective subject.

94. The system of claim **92** wherein at least one monitoring apparatus is configured to be worn on or around the ear.

95. A method of interacting with an electronic game, comprising:

collecting physiological and/or environmental information from a monitoring device associated with a person, wherein the monitoring device includes at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from the person, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the person;

analyzing the collected information to identify one or more health and/or environmental issues associated with the person;

sending the identified one or more health and/or environmental issues to a gaming device; and

incorporating the identified one or more health and/or environmental issues into a strategy of a game executing on the gaming device.

96. The method of claim **95**, further comprising creating a gaming character based on the person using the identified one or more health and/or environmental issues.

97. The method of claim **95**, further comprising providing biofeedback to the person for improving at least one skill associated with the electronic game.

98. A method of monitoring a participant in an activity, comprising:

collecting physiological and/or environmental information from a monitoring device associated with a participant in an activity, wherein the monitoring device includes at least one physiological sensor and/or environmental sensor, wherein each physiological sensor is configured to detect and/or measure physiological information from the participant, and wherein each environmental sensor is configured to detect and/or measure environmental conditions in a vicinity of the participant;

analyzing the collected physiological and/or environmental information to identify one or more health-related and/or environmental issues associated with the participant; and

providing feedback to the participant, wherein the feedback is relevant to a skill utilized by the participant in the activity.

* * * * *