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(54) SYSTEMS, METHODS AND APPARATUSES FOR ESTIMATING THE STRESS VALENCE OF AN INDIVIDUAL FROM SENSOR DATA

(71) Applicant: **Nokia Technologies Oy**, Espoo (FI)

(72) Inventors: **Marc James Ashton Bailey**, Cambridge (GB); **MD Mahbubur Rahman**, Sunnyvale, CA (US)

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A61B 5/00	(2006.01)

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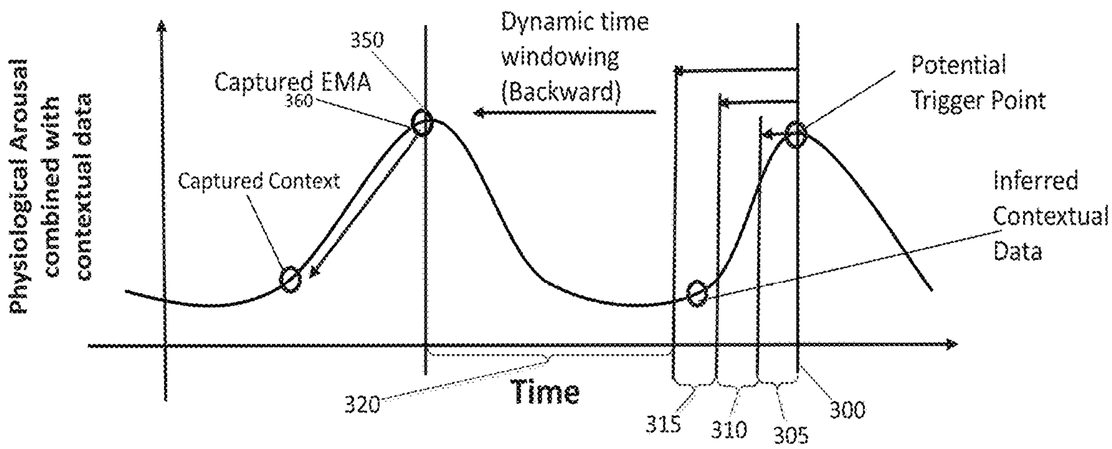
(57) **ABSTRACT**

Systems, methods, apparatuses, and computer program products for inferring the stress valence of an individual from sensor data are provided. One method includes collecting a first set of data from sensor(s) of user device(s), collecting a second set of data including a partial or complete ecological momentary assessment (EMA) response from a user, establishing a set of physiological time-series data for the user based on the first set of data and the second set of data, identifying habit information of the user based on the first set of data. Based on the first set of data and the habit information, detecting a potential trigger point for sending a subsequent EMA to the user, and, at the time of the potential trigger point, calculating an estimate of a stress valence value associated with the subsequent EMA for which an EMA response was at least partially not received.



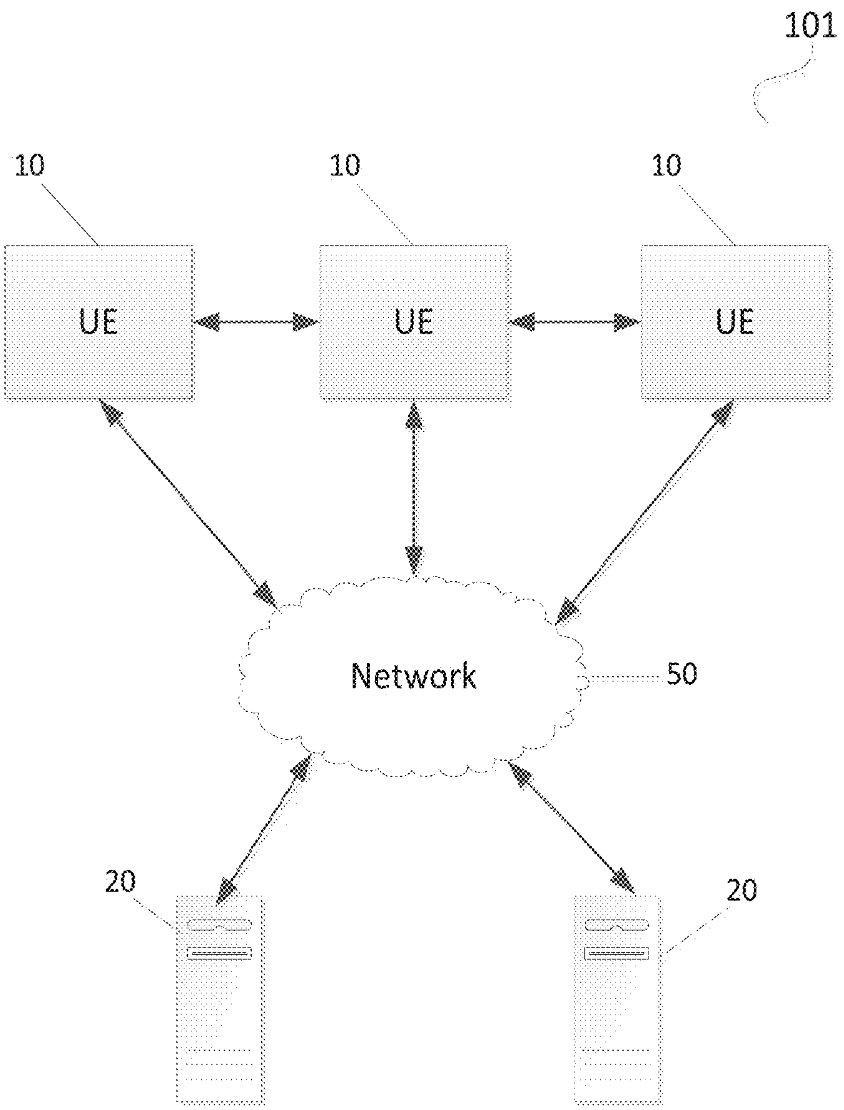


Fig. 1

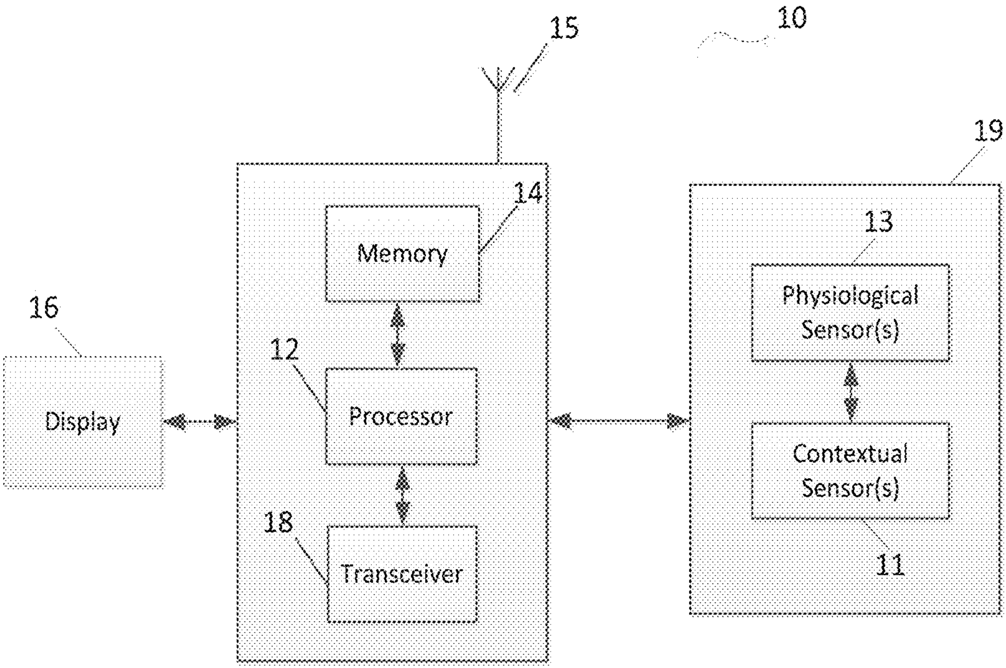

15
10
19
14
Memory
13
Physiological Sensor(s)
16
12
Display
Processor
Contextual Sensor(s)
18
Transceiver
11

Fig. 2a

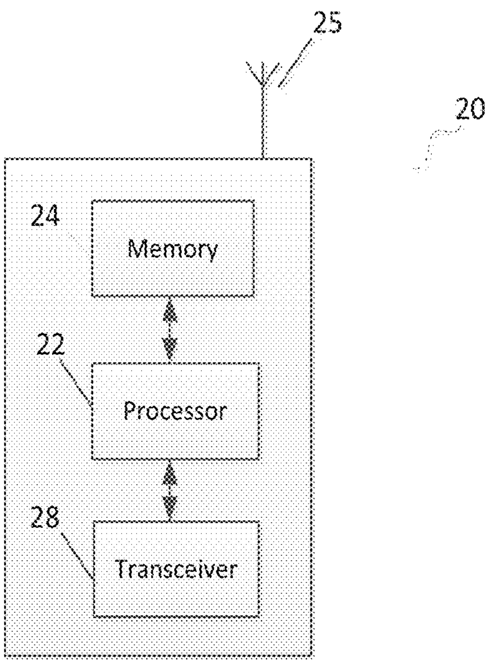

25
20
24
Memory
22
Processor
28
Transceiver

Fig. 2b

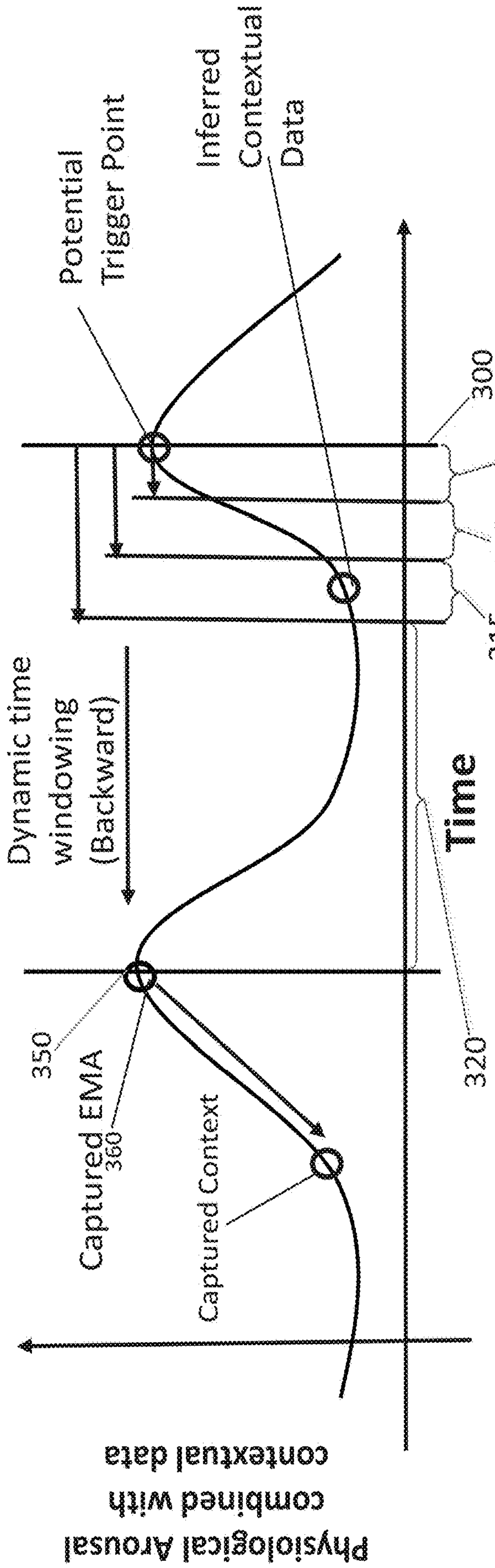

Potential Trigger Point
Inferred Contextual Data
300
305
310
315
Dynamic time windowing (Backward)
Time
320
350
Captured EMA
360
Captured Context
Physiological Arousal combined with contextual data

Fig. 3

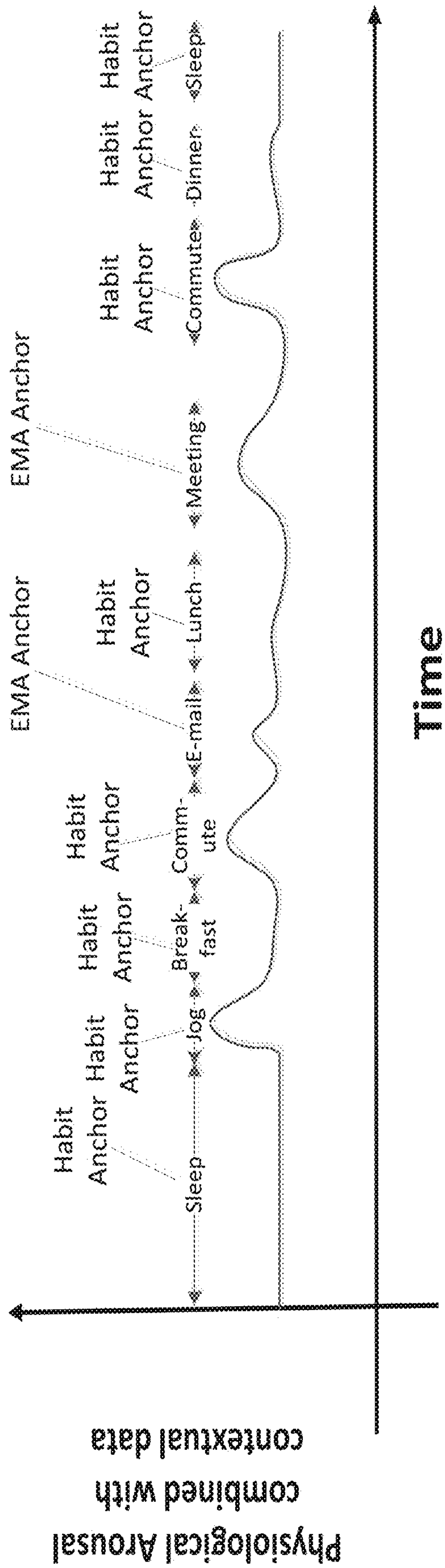

Physiological Arousal combined with contextual data
Time
Sleep
Habit Anchor
Jog
Habit Anchor
Break-fast
Habit Anchor
Comm-ute
Habit Anchor
E-mail
EMA Anchor
Lunch
Habit Anchor
Meeting
EMA Anchor
Commute
Habit Anchor
Dinner
Habit Anchor
Sleep
Habit Anchor

Fig. 4

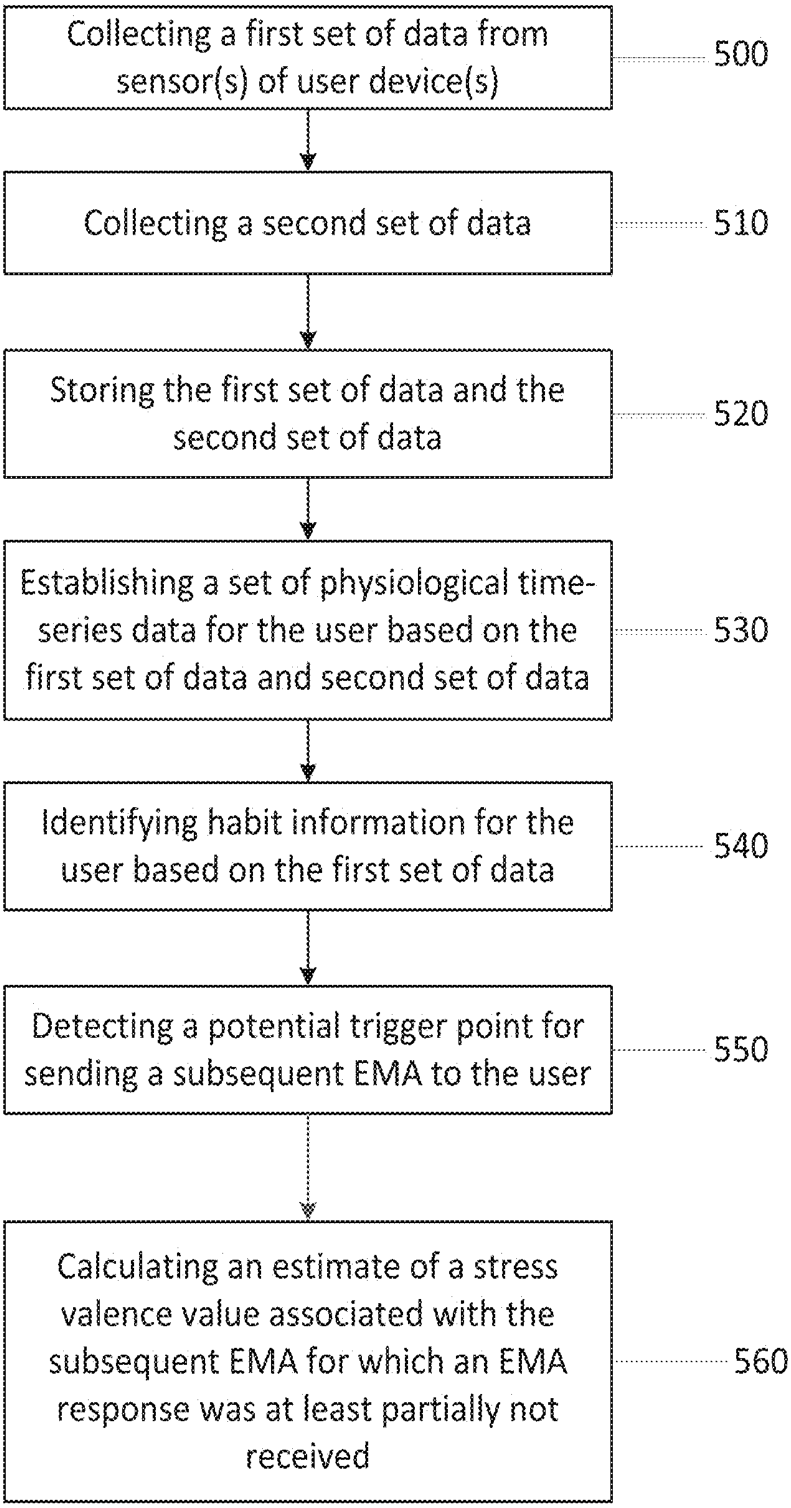

Collecting a first set of data from sensor(s) of user device(s)
500
Collecting a second set of data
510
Storing the first set of data and the second set of data
520
Establishing a set of physiological time-series data for the user based on the first set of data and second set of data
530
Identifying habit information for the user based on the first set of data
540
Detecting a potential trigger point for sending a subsequent EMA to the user
550
Calculating an estimate of a stress valence value associated with the subsequent EMA for which an EMA response was at least partially not received
560

Fig. 5

SYSTEMS, METHODS AND APPARATUSES FOR ESTIMATING THE STRESS VALENCE OF AN INDIVIDUAL FROM SENSOR DATA

BACKGROUND

Field

[0001] Certain embodiments generally relate to systems and methods for utilizing sensor data from user devices, such as smartphones and smart wearable devices, to infer or estimate the stress valence of users of such user devices.

Description of the Related Art

[0002] In wireless telecommunications systems, such as Long Term Evolution or 5th generation (5G) systems, smartphones and wearable devices (e.g., smart watches or activity trackers) may be generally referred to as user equipment (UE). In LTE or 5G systems, a UE may communicate with base stations (which may also be referred to as Node Bs or evolved Node Bs (eNBs)) to allow for connectivity between the user equipment (UE) and the core network.

[0003] Nowadays, user equipment (UE), such as smartphones and wearable devices, may incorporate sensors to monitor a user's fitness activity and physiological data. For example, many UEs include integrated pedometers for counting a user's steps and accelerometers or other sensors for calculating mileage, overall physical activity, calorie expenditure, and to monitor heart rate and quality of sleep, etc.

[0004] Outside of generally tracking activity level, an important application for these sensors is for detecting and managing stress. Stress is clearly a significant problem in modern-day medicine, and stress and stress-related symptoms are a major cause of physical and psychological illnesses. Consequently, methods and systems for monitoring and inferring the stress valence in individuals can provide significant benefits to individuals and society as a whole.

SUMMARY

[0005] One embodiment is directed to a method, which may include collecting a first set of data from at least one sensor of at least one user device. The first set of data may include at least one of physiological data or contextual data. The method may also include collecting a second set of data comprising at least one partial or complete ecological momentary assessment (EMA) response from a user of at least one user device, establishing a set of physiological time-series data for the user based on the first set of data and the second set of data, identifying habit information related to regularly occurring habits of the user based on the first set of data. The method may then include, based on at least the first set of data and the habit information, detecting a potential trigger point for sending a subsequent EMA to the user, the subsequent EMA being used to ascertain a stress valence of the user at a time of the potential trigger point. At the time of detecting the potential trigger point, the method may further include calculating an estimate of a stress valence value associated with the subsequent EMA for which an EMA response was at least partially not received. The stress valence value estimate may be calculated based on at least one of the physiological time-series data, at least one previously collected partial or complete EMA response, the first set of data, or the habit information.

[0006] Another embodiment is directed to an apparatus, which may include at least one processor and at least one memory including computer program code. The at least one memory and the computer program code may be configured, with the at least one processor, to cause the apparatus at least to collect a first set of data from at least one sensor of at least one user device, collect a second set of data comprising at least one partial or complete ecological momentary assessment (EMA) response from a user of at least one user device, establish a set of physiological time-series data for the user based on the first set of data and the second set of data, identify habit information related to regularly occurring habits of the user based on the first set of data, detect, based on at least the first set of data and the habit information, a potential trigger point for sending a subsequent EMA to the user, the subsequent EMA being used to ascertain a stress valence of the user at a time of the potential trigger point, and, at the time of the potential trigger point, calculate an estimate of a stress valence value associated with the subsequent EMA for which an EMA response was at least partially not received. The stress valence value estimate may be calculated based on at least one of the physiological time-series data, at least one previously collected partial or complete EMA response, the first set of data, or the habit information.

[0007] Another embodiment is directed to an apparatus, which may include means for collecting a first set of data from at least one sensor of at least one user device. The first set of data may include at least one of physiological data or contextual data. The apparatus may also include means for collecting a second set of data comprising at least one partial or complete ecological momentary assessment (EMA) response from a user of at least one user device, means for establishing a set of physiological time-series data for the user based on the first set of data and the second set of data, means for identifying habit information related to regularly occurring habits of the user based on the first set of data. The apparatus may then include, based on at least the first set of data and the habit information, means for detecting a potential trigger point for sending a subsequent EMA to the user, the subsequent EMA being used to ascertain a stress valence of the user at a time of the potential trigger point. At the time of detecting the potential trigger point, the apparatus may further include means for calculating an estimate of a stress valence value associated with the subsequent EMA for which an EMA response was at least partially not received. The stress valence value estimate may be calculated based on at least one of the physiological time-series data, at least one previously collected partial or complete EMA response, the first set of data, or the habit information.

[0008] Another embodiment is directed to a computer program embodied on a non-transitory computer readable medium. The computer program may be configured, when executed by a processor, to cause the processor to perform a process including collecting a first set of data from at least one sensor of at least one user device. The first set of data may include at least one of physiological data or contextual data. The process may also include collecting a second set of data comprising at least one partial or complete ecological momentary assessment (EMA) response from a user of at least one user device, establishing a set of physiological time-series data for the user based on the first set of data and the second set of data, identifying habit information related to regularly occurring habits of the user based on the first set of data. The process may then include, based on at least the first set of data and the habit information, detecting a potential trigger point for sending a subsequent EMA to the user, the subsequent EMA being used to ascertain a stress valence of the user at a time of the potential trigger point. At the time of detecting the potential trigger point, the process may further include calculating an estimate of a stress valence value associated with the subsequent EMA for which an EMA response was at least partially not received. The stress valence value estimate may be calculated based on at least one of the physiological time-series data, at least one previously collected partial or complete EMA response, the first set of data, or the habit information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For proper understanding of the present disclosure, reference should be made to the accompanying drawings, wherein:

[0010] FIG. **1** illustrates a system according to one embodiment of the present disclosure;

[0011] FIG. **2***a* illustrates an apparatus according to one embodiment;

[0012] FIG. **2***b* illustrates an apparatus according to another embodiment;

[0013] FIG. **3** illustrates an example graph depicting a process of performing dynamic temporal backtracking to infer or estimate stress valence, according to certain embodiments;

[0014] FIG. **4** illustrates an example of a graph depicting a user's activities, according to an embodiment; and

[0015] FIG. **5** illustrates a flow diagram of a method, according to one embodiment.

DETAILED DESCRIPTION

[0016] It will be readily understood that the components of the present disclosure, as generally described and illustrated in the figures herein, may be arranged and designed in a wide variety of different configurations. Thus, the following detailed description of the embodiments of systems, methods, apparatuses, and computer program products for inferring the stress valence of an individual from sensor data, is not intended to limit the scope of the present disclosure but is representative of selected embodiments of the present disclosure.

[0017] The features, structures, or characteristics of the present disclosure described throughout this specification may be combined in any suitable manner in one or more embodiments. For example, the usage of the phrases "certain embodiments," "some embodiments," or other similar language, throughout this specification refers to the fact that a particular feature, structure, or characteristic described in connection with the embodiment may be included in at least one embodiment of the present disclosure. Thus, appearances of the phrases "in certain embodiments," "in some embodiments," "in other embodiments," or other similar language, throughout this specification do not necessarily all refer to the same group of embodiments, and the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

[0018] Additionally, if desired, the different functions discussed below may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the described functions may be optional or may be combined. As such, the following description should be considered as merely illustrative of the principles, teachings and embodiments of this present disclosure, and not in limitation thereof.

[0019] As introduced above, one embodiment is directed to a method for estimating or inferring the stress valence of an individual from at least one sensor data. Stress generally refers to an individual's response to an event, environmental condition or external stimulus. Negative stress may refer to a state of mental or emotional strain or tension resulting from adverse or very demanding events or conditions. Following a stressful event, the body's way of responding to the stress may be by sympathetic nervous system activation which may result, for example, in a fight-or-flight response. Therefore, in humans, stress usually describes a negative condition that can affect a person's mental and physical well-being. However, some events or conditions may actually elicit a positive reaction or response from the body. Accordingly, physiological stress may have beneficial effects where it is termed eustress and may have negative effects where it is termed distress.

[0020] Valence, as used in the context of emotions or stress, refers to the intrinsic attractiveness (positive valence) or averseness (negative valence) of an event, object, or situation. The term can also be used to characterize specific emotions. For instance, the emotions usually referred to as "negative", such as anger and fear, have "negative valence". While positive emotions, such as joy or pleasure, have "positive valence". Thus, positively valenced emotions are evoked by positively valenced events, objects, or situations. As used herein, stress valence can refer to negative stress that may be the result of adverse conditions or to positive stress that may be the result of favorable conditions.

[0021] User equipment including, but not limited to, smartphones and wearable devices may include various types of sensors to obtain contextual data and physiological data from the user. The types of sensors that may incorporated into UEs can include, for example, pedometers, inertial measurement units (IMUs), accelerometers, gyroscopes, magnetometer, barometers, optical sensors, electrodes, etc. Contextual data that may be obtained from such sensors may include, for example, geographic location, time of day, altitude, external temperature, other environmental elements, or any combination thereof. Physiological data that may be obtained from such sensors may include, for example, the user's physical or biological characteristics including heart rate, pulse, core body temperature, respiration rate, blood oxygenation level, blood pressure, skin temperature, cardiac rhythm, or any combination thereof. According to one embodiment, the user equipment (or sensors therein) may continuously measure or obtain the contextual and physiological data from the user. In other embodiments, the user equipment (or sensors) may discontinuously measure or obtain the contextual and physiological data.

[0022] An additional approach for obtaining information or data from a user is by sending one or more questionnaires, such as ecological momentary assessments (EMAs). EMAs are a psychological science technique that encourages individuals to record emotional states, moods, thoughts, and actions at a particular time. In an embodiment, one or more EMA(s) may be transmitted to user equipment for display on a screen of the user equipment, for example. According to certain embodiments, responses provided by the user to the EMA(s) may be converted into machine readable and analyzable formats.

[0023] However, EMAs may impose a high burden on a user and the level or frequency of response to EMAs from users may decrease over time. This is because sending EMAs to users for feedback can be highly interruptive and onerous to the users. Certain embodiments are able to reduce the amount of interruption experienced by users thereby resulting in better user acceptance and feedback. For example, an embodiment is configured to: filter physiological arousal unrelated to stress (e.g., physical activity), trigger EMAs only when the arousal is significant (rather than triggering EMAs randomly or periodically), consider habit information to determine stressors, and to transmit EMAs at appropriate times (e.g., in case of negative valence). As a result, certain embodiments significantly reduce false triggers for sending EMAs, and increase user acceptance and feedback.

[0024] FIG. **1** illustrates a system **101** according to one embodiment of the present disclosure. In the example of FIG. **1**, system **101** may include a network **50**. The network **50** may be a radio access network, such as LTE or 5G, a local area network (LAN), a wide area network (WAN) such as the Internet, or wireless LAN (WLAN), for example. As illustrated in the example of FIG. **1**, one or more UE(s) **10** may be configured to communicate with the network **50** via wireless or wired connections. In an addition, in an embodiment, the UE(s) **10** may be configured to communicate directly with each other via wireless or wired connections. Examples of UE(s) **10** may include, but is not limited to, smartphones, wearable devices, tablets, laptop computers, desktop computers, or other mobile or stationary device. In an embodiment, system **101** may also include one or more hosts or servers **20** connected to the network **50** through wireless or wired connections. According to one embodiment, servers **20** may be implemented in or function as base stations or eNBs. In other embodiments, servers **20** may include web servers, mail servers, application servers, etc. According to certain embodiments, servers **20** may be standalone servers, networked servers, or an array of servers.

[0025] FIG. **2***a* illustrates an example of a UE or apparatus **10** according to an embodiment. In an embodiment, apparatus **10** may be a node or element in a communications network or associated with such a network, such as a mobile device, smartphone, wearable device, tablet computer, laptop computer, Internet of Things (IoT) device, or other mobile or stationary device. As described herein, apparatus **10** may alternatively be referred to as, for example, a UE, mobile station, mobile equipment, mobile unit, mobile device, user device, subscriber station, wireless terminal, tablet, smartphone, wearable device, IoT device, or the like. As one example, Apparatus **10** may be implemented in, for instance, a wireless handheld device, a wireless wearable device, a wireless plug-in accessory, or any combination thereof. In one example, apparatus **10** may correspond to UE(s) **10** depicted in FIG. **1** discussed above. It should be noted that one of ordinary skill in the art would understand that apparatus **10** may include components or features not shown in FIG. **2***a*.

[0026] As illustrated in FIG. **2***a*, apparatus **10** may include a processor **12** for processing information and executing instructions or operations. Processor **12** may be any type of general or specific purpose processor. While a single processor **12** is shown in FIG. **2***a*, multiple processors may be utilized according to other embodiments. In fact, processor **12** may include one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as examples. In some cases, the processor **12** may be remote from the apparatus **10**, such as disposed within a server like server **20** of FIG. **1**.

[0027] Processor **12** may perform functions associated with the operation of apparatus **10** which may include, for example, precoding of antenna gain/phase parameters, encoding and decoding of individual bits forming a communication message, formatting of information, and overall control of the apparatus **10**, including processes related to management of communication resources.

[0028] Apparatus **10** may further include or be coupled to a memory **14** (internal or external), which may be coupled to processor **12**, for storing information and instructions that may be executed by processor **12**. Memory **14** may be one or more memories and of any type suitable to the local application environment, and may be implemented using any suitable volatile or nonvolatile data storage technology such as a semiconductor-based memory device, a magnetic memory device and system, an optical memory device and system, fixed memory, and removable memory. For example, memory **14** can be comprised of any combination of random access memory (RAM), read only memory (ROM), static storage such as a magnetic or optical disk, hard disk drive (HDD), or any other type of non-transitory machine or computer readable media. The instructions stored in memory **14** may include program instructions or computer program code that, when executed by processor **12**, enable the apparatus **10** to perform tasks as described herein.

[0029] In some embodiments, apparatus **10** may also include or be coupled to one or more antennas **15** for transmitting and receiving signals and/or data to and from apparatus **10**. Apparatus **10** may further include or be coupled to a transceiver **18** configured to transmit and receive information. The transceiver **18** may include, for example, a plurality of radio interfaces that may be coupled to the antenna(s) **15**. The radio interfaces may correspond to a plurality of radio access technologies including one or more of LTE, 5G, WLAN, Bluetooth, near field communication (NFC), radio frequency identifier (RFID), ultrawideband (UWB), and the like. The radio interface may include components, such as filters, converters (for example, digital-to-analog converters and the like), mappers, a Fast Fourier Transform (FFT) module, and the like, to generate symbols for a transmission via one or more downlinks and to receive symbols (for example, via an uplink). As such, transceiver **18** may be configured to modulate information on to a carrier waveform for transmission by the antenna(s) **15** and demodulate information received via the antenna(s) **15** for further processing by other elements of apparatus **10**. In other embodiments, transceiver **18** may be capable of transmitting and receiving signals or data directly.

[0030] Apparatus **10** may further include a display **16**, such as a touchscreen, which may include a user interface, such as a graphical user interface. In certain embodiments, display **16** may be configured to display information or data to a user of apparatus **10**. Display **16** may also be configured to receive input from a user of apparatus **10** via a touch-screen, for example.

[0031] In an embodiment, memory **14** may store software modules that provide functionality when executed by processor **12**. The modules may include, for example, an operating system that provides operating system functionality for apparatus **10**. The memory may also store one or more functional modules, such as an application or program, to provide additional functionality for apparatus **10**. The components of apparatus **10** may be implemented in hardware, or as any suitable combination of hardware and software.

[0032] According to an embodiment, apparatus **10** may include or be connected to one or more sensors **19**. Sensors **19** may include physiological sensor(s) **13** and/or context sensor(s) **11**. Sensors **19** may include one or more of pedometers, inertial measurement units (IMUs), accelerometers, gyroscopes, magnetometer, barometers, optical sensors, electrodes, etc. Contextual data that may be obtained from context sensor(s) **11** may include, for example, geographic location, time of day, altitude, external temperature or any combination thereof. Physiological data that may be obtained from physiological sensor(s) **13** may include, for example, the user's physical or biological characteristics including heart rate, pulse, core body temperature, respiration rate, blood oxygenation level, blood pressure, skin temperature, cardiac rhythm, or any combination thereof.

[0033] In one embodiment, apparatus **10** may be a UE, mobile station, mobile equipment, mobile unit, mobile device, user device, subscriber station, wireless terminal, tablet, smartphone, wearable device, IoT device, for example. According to certain embodiments, apparatus **10** may be controlled by memory **14** and processor **12** to perform the functions associated with embodiments described herein. For example, in an embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to measure and/or collect a first set of data from at least one sensor **19**. The first set of data may include physiological data and/or contextual data, for example. According to one embodiment, apparatus **10** (or sensor(s) **19**) may be controlled by memory **14** and processor **12** to continuously measure or obtain the contextual and/or physiological data from the user. In other embodiments, apparatus **10** (or sensor(s) **19**) may be controlled to discontinuously measure or obtain the contextual and/or physiological data.

[0034] According to certain embodiments, apparatus **10** may be further controlled by memory **14** and processor **12** to collect a second set of data that includes one or more partial or complete ecological momentary assessment (EMA) response(s) from a user of apparatus **10**. In one embodiment, ecological momentary assessments (EMAs) may refer to a questionnaire that requests certain information from individuals, such as their emotional states, moods, thoughts, and actions at a particular time. Accordingly, an EMA response may contain information on the stress of a user including, for example, the stress valence (i.e., positive or negative stress) at the time of the EMA response. In an embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to provide or display one or more EMA(s) on a screen such as the display **16** of the apparatus **10**, for example, at appropriate times. According to certain embodiments, responses provided by the user to the EMA(s) may be converted into machine readable and analyzable formats.

[0035] According to an embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to store the first set of data and the second set of data in memory **14**. In one embodiment, the first set of data may be continuous data that contains information on a level of arousal or stimulation of the user, such as heart rate and heart rate variation data. In an embodiment, information contained in an EMA response from a user may be considered as discontinuous data that contains information on the stress of the user, such as valence (i.e., positive or negative stress reported in the EMA response).

[0036] In one embodiment, apparatus **10** may be further controlled by memory **14** and processor **12** to establish a set of physiological time-series data for a user of apparatus **10** based on the first set of data and the second set of data. For example, in an embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to establish the set of physiological time-series data by combining, integrating and/or synchronizing the first set of data (e.g., the physiological and contextual data) and the second set of data (e.g., one or more EMA responses) to create the set of physiological time-series data for the user. According to an embodiment, the combining, integrating and/or synchronizing of the first set of data and the second set of data may include establishing consistency among the sets of data, which may be collected from different sources, and the continuous harmonization of the sets of data over time. The physiological time-series data may be a representation of the user's physical and/or emotional state at a given time based on the contextual data, physiological data, and/or EMA response data collected. For example, in one embodiment, the physiological time-series data may include a representation of the user's physiological stimulation (e.g., elevated heart rate) combined with contextual data (e.g., time or location).

[0037] In another embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to transmit the first set of data (e.g., the physiological and contextual data) and the second set of data (e.g., one or more EMA responses) to a node, host or server of a network. According to this embodiment, the network node may be configured to establish the set of physiological time-series data for a user of apparatus **10** based on the received first set of data and second set of data. For instance, in this embodiment, the network node may establish the set of physiological time-series data by combining, integrating and/or synchronizing the first set of data and the second set of data to create the set of physiological time-series data for the user. As discussed in the foregoing, the combining, integrating and/or synchronizing of the first set of data and the second set of data may include establishing consistency among the sets of data, which may be collected from different sources, and the continuous harmonization of the sets of data over time.

[0038] In one embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to identify habit information related to regularly occurring habits of the user based on the first set of data (e.g., physiological and contextual data). In an embodiment, habit information refers to information representative of regularly occurring habits or routines that make up a user's day. In other words, as one example, habits refer to a repeated series of activities that an individual performs on a regular day or basis. For example, habits for an average individual may include sleeping, eating meals, commuting, working, exercising, etc. According to one embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to place a habit anchor within the physiological time-series data to identify periods of time during which the regularly occurring habits are happening.

[0039] FIG. **4** is an example of a graph depicting a user's activities during the twenty four hours of a day. In the example of FIG. **4**, the x-axis depicts the time of day and the y-axis depicts the physiological arousal of the user. FIG. **4** shows several daily habits which may be repeated over workdays at similar times. FIG. **4** also shows the physiological change in the user, their time, duration, and when a physiological change may coincide with the habits, throughout the day. FIG. **4** further illustrates some other events, such as checking e-mail or attending meetings, which may occur irregularly or sporadically throughout a day. These irregular events may also cause physiological changes, as shown in FIG. **4**. In the example of FIG. **4**, habit anchors may be placed at periods where habits usually occur, such as during times of sleep, jogging, eating breakfast, commuting to work, eating lunch, commuting back home, and eating dinner, for instance. In an embodiment, EMA anchors may be placed during the times of other events (e.g., meetings or checking e-mail). Thus, stress valence during habits may be captured via habit anchor, and during other events via EMA anchor. Once the habit information is captured, apparatus **10** can determine whether a habit creates positive or negative stress, or if it has a neutral effect on the user. It is noted that FIG. **4** is merely one example and many other possibilities or examples are applicable according to certain embodiments of the present disclosure.

[0040] According to one embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to determine or detect, based on at least the first set of data (e.g., physiological and contextual data) and the habit information, a potential trigger point for sending an EMA to the user. In an embodiment, the EMA may be used, in part, to ascertain the stress valence of the user at the time of the potential trigger point. According to one embodiment, the potential trigger point may be a point in time where the first set of data shows a significant change in level that is above or below a pre-defined threshold. As one example, if the physiological sensor **13** detects that the user's heart rate has moved above 100 beats per minute (BPM) and the habit information does not reflect a reason for the elevated heart rate, then apparatus **10** may be controlled to determine that this is a potential trigger point for sending the EMA to the user. However, if the physiological sensor **13** detects that the user's heart rate has moved above 100 beats per minute (BPM) but the habit information indicates that the user is likely exercising (i.e., this is the time of day the user normally exercises or the user location is at the gym), then apparatus **10** may determine that this is not a potential trigger point for sending the EMA to the user. In other words, apparatus **10** may use the habit information to disregard physiological stimulation or arousal unrelated to psychological stress. It is noted that heart rate is merely one example of physiological or contextual data that may cause apparatus **10** to detect a potential trigger point, as any physiological or contextual data can similarly be used according to other embodiments.

[0041] In one embodiment, at the time of the potential trigger point, apparatus **10** may be controlled by memory **14** and processor **12** to compute or calculate an estimate of the stress valence value associated with the EMA for which an EMA response was at least partially not received (e.g., either because the EMA was not sent or because the user did not provide a response to the EMA). According to an embodiment, the stress valence value estimate may be calculated based on at least one of the physiological time-series data, at least one previously collected partial or complete EMA response, the first set of data, the habit information, or any combination thereof.

[0042] According to certain embodiments, the computing or calculating of the estimate of the stress valence value may include apparatus **10** being controlled by memory **14** and processor **12** to perform dynamic temporal backtracking to identify past trends in the physiological time-series data of the user. For example, according to an embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to iteratively apply an increasing retrospective time window beginning from the time of the potential trigger point until a previously captured EMA response is found representing a change in physiological data, contextual data, or any combination thereof, that is similar to the significant change in the first set of data that caused the detection of the potential trigger point. In this embodiment, when the previously captured EMA response is found that shows the similar change, apparatus **10** may be controlled by memory **14** and processor **12** to use the stress valence determined from the previously captured EMA response as the estimated stress valence value for the user at the potential trigger point.

[0043] As noted above, the detection of a potential trigger point does not necessarily mean that an EMA will be sent to the user. However, in one embodiment, upon detection of the potential trigger point, apparatus **10** may be controlled by memory **14** and processor **12** to send the EMA to the display **16** so that the user can provide an EMA response. In an embodiment, apparatus **10** may then be controlled by memory **14** and processor **12** to receive the EMA response from the user and to use the EMA response to determine the stress valence of the user. In another embodiment, a response to the EMA may not be provided by the user. According to an embodiment, apparatus **10** may then be controlled by memory **14** and processor **12** to calculate the estimate of the stress valence value associated with the EMA when a response to the subsequent EMA is not received.

[0044] FIG. **3** illustrates an example graph depicting how apparatus **10** may perform dynamic temporal backtracking to infer or estimate stress valence, according to certain embodiments. The example of FIG. **3** illustrates how stress valence may be determined using retrospective time window (s) to capture the most similar valence response (i.e., EMA response) in terms of physiological arousal/stimulation, context(s) (e.g., time of day), while accounting for habit information (e.g., exercising, commuting, etc.).

[0045] As illustrated in the example of FIG. **3**, the potential trigger point is detected at **300** because of a spike or change in the level of the first set of data (i.e., physiological and context data) that exceeds a predetermined threshold. For example, in an embodiment, the potential trigger point may be an initiation event defined as a period of protracted arousal as measured by the first set of data (e.g., physiological and contextual data). As discussed above, the first set of data may show changes in arousal throughout a day that are unrelated to stress (e.g., from exercising); however, in an embodiment, the potential trigger point **300** is detected based on a protracted period of arousal that exceeds a pre-determined threshold. The duration of the protracted time period may vary for each individual, for example based on level of health or any pre-existing health conditions.

[0046] Thus, according to an embodiment, beginning at the potential trigger point **300**, apparatus **10** may be controlled to track backwards in time to identify the start of the event that may have caused the change in the level of the first set of data. For example, in one embodiment, apparatus **10** may be controlled to iteratively apply retrospective time windows **305**, **310**, **315**, **320** of increasing duration to, in effect, look back over the preceding time with progressively longer windows and averaging arousal to confirm that it is unchanging over a time period. The duration of the time windows may vary empirically based on the amount and type of data collected or measured. This process of retrospective averaging may stop when the earliest time stamp coincides with the completion time of an EMA response addressing stress valence of the user. This EMA response could then be integrated with the first set of data to determine if the stress observed is positive or negative.

[0047] In the example of FIG. **3**, apparatus **10** may be controlled to iteratively apply the retrospective time windows until time **350** where a previous EMA response **360** was captured when there was a spike or change in the set of first data that is similar to the change detected at the potential trigger point **300**. In one embodiment, apparatus **10** may be controlled to use the stress valence determined from the previously captured EMA response **360** as the estimated stress valence value for the user at the potential trigger point **300**.

[0048] In one embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to provide a user interface for a user to review auto-generated triggers with associated meaningful contexts in offline or online modes, and to provide users with the opportunity to provide feedback on the accuracy of the triggers. Certain embodiments are then able to adapt the user feedback and improve its accuracy in determining stress valance and triggering EMA (s). Moreover, in an embodiment, apparatus **10** may be controlled by memory **14** and processor **12** to accept priority rules defined by a user to avoid interruptions whenever they want.

[0049] FIG. **2***b* illustrates an example of an apparatus **20** according to another embodiment. In an embodiment, apparatus **20** a node, host, or server in a communications network or serving such a network. For example, apparatus **20** may be a base station, a node B, an evolved node B, 5G node B or access point, next generation node B (NG-NB), WLAN access point, mobility management entity (MME), or subscription server associated with a radio access network, such as a GSM network, LTE network or 5G radio access technology. For instance, in an embodiment, apparatus **20** may correspond to network node **20** illustrated in FIG. **1** discussed above. It should be noted that one of ordinary skill in the art would understand that apparatus **20** may include components or features not shown in FIG. **2***b*.

[0050] As illustrated in FIG. **2***b*, apparatus **20** may include or be coupled to a processor **22** for processing information and executing instructions or operations. Processor **22** may be any type of general or specific purpose processor. While a single processor **22** is shown in FIG. **2***b*, multiple processors may be utilized according to other embodiments. In fact, processor **22** may include one or more of general-purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), and processors based on a multi-core processor architecture, as examples.

[0051] Processor **22** may perform functions associated with the operation of apparatus **20** including, without limitation, precoding of antenna gain/phase parameters, encoding and decoding of individual bits forming a communication message, formatting of information, and overall control of the apparatus **20**, including processes related to management of communication resources.

[0052] Apparatus **20** may further include or be coupled to a memory **24** (internal or external), which may be coupled to processor **22**, for storing information and instructions that may be executed by processor **22**. Memory **24** may be one or more memories and of any type suitable to the local application environment, and may be implemented using any suitable volatile or nonvolatile data storage technology such as a semiconductor-based memory device, a magnetic memory device and system, an optical memory device and system, fixed memory, and removable memory. For example, memory **24** can be comprised of any combination of random access memory (RAM), read only memory (ROM), static storage such as a magnetic or optical disk, or any other type of non-transitory machine or computer readable media. The instructions stored in memory **24** may include program instructions or computer program code that, when executed by processor **22**, enable the apparatus **20** to perform tasks as described herein.

[0053] In some embodiments, apparatus **20** may also include or be coupled to one or more antennas **25** for receiving a downlink signal and for transmitting via an uplink from apparatus **20**. Apparatus **20** may further include a transceiver **28** configured to transmit and receive information. The transceiver **28** may also include a radio interface (e.g., a modem) coupled to the antenna **25**. The radio interface may correspond to a plurality of radio access technologies including one or more of GSM, LTE, LTE-A, 5G, WLAN, IoT, Bluetooth, NFC, RFID, UWB, and the like. The radio interface may include other components, such as filters, converters (for example, digital-to-analog converters and the like), symbol demappers, signal shaping components, an Inverse Fast Fourier Transform (IFFT) module, and the like, to process symbols, such as OFDMA symbols, carried by a downlink or an uplink.

[0054] For instance, transceiver **28** may be configured to modulate information on to a carrier waveform for transmission by the antenna(s) **25** and demodulate information received via the antenna(s) **25** for further processing by other elements of apparatus **20**. In other embodiments, transceiver **28** may be capable of transmitting and receiving signals or data directly. Apparatus **20** may further include a user interface, such as a graphical user interface or touchscreen.

[0055] In an embodiment, memory **24** stores software modules that provide functionality when executed by processor **22**. The modules may include, for example, an operating system that provides operating system functionality for apparatus **20**. The memory may also store one or more functional modules, such as an application or program, to provide additional functionality for apparatus **20**. The components of apparatus **20** may be implemented in hardware, or as any suitable combination of hardware and software.

[0056] According to one embodiment, apparatus **20** may be a network node or server, such as a base station, node B, eNB, 5G node B or access point, or next generation node B (NG-NB), for example. According to certain embodiments, apparatus **20** may be controlled by memory **24** and processor **22** to perform the functions associated with embodiments described herein. According to an embodiment, apparatus **20** may be controlled by memory **24** and processor **22** to receive and/or collect a first set of data from one or more sensors of one or more user devices. The first set of data may include physiological data and/or contextual data, for example. According to one embodiment, apparatus **20** may be controlled by memory **24** and processor **22** to continuously receive or obtain the contextual and/or physiological data from the sensor(s) of the user device(s). Thus, in one embodiment, the first set of data may be continuous data that contains information on a level of arousal or stimulation of the user, such as heart rate and heart rate variation data. In other embodiments, apparatus **20** may be controlled to discontinuously receive or obtain the contextual and/or physiological data.

[0057] According to certain embodiments, apparatus **20** may be controlled by memory **24** and processor **22** to receive and/or collect a second set of data that includes one or more partial or complete ecological momentary assessment (EMA) response(s) from a user of the user device(s). As discussed above, in one embodiment, ecological momentary assessments (EMAs) may refer to a questionnaire that requests certain information from individuals, such as their emotional states, moods, thoughts, and actions at a particular time. As such, an EMA response may contain information on the stress of a user including, for example, the stress valence (i.e., positive or negative stress) at the time of the EMA response.

[0058] In an embodiment, apparatus **20** may be controlled by memory **24** and processor **22** to transmit one or more EMA(s) to the user device(s) for display on a screen of the user device(s), for example, at appropriate times. According to certain embodiments, apparatus **20** may be controlled by memory **24** and processor **22** to receive responses provided by the user to the EMA(s) and to convert the responses into machine readable and analyzable formats. In an embodiment, information contained in an EMA response from a user may be considered as discontinuous data that contains information on the stress of the user, such as valence (i.e., positive or negative stress reported in the EMA response). According to an embodiment, apparatus **20** may be further controlled by memory **24** and processor **22** to store the first set of data and the second set of data in memory **24**. In other embodiments, the user device may be configured to itself trigger display of one or more EMA(s), for example, on the screen of the user device, without involvement of apparatus **20**.

[0059] In one embodiment, apparatus **20** may be further controlled by memory **24** and processor **22** to establish a set of physiological time-series data for a user of the user device, for example, based on the first set of data and the second set of data. For example, in an embodiment, apparatus **20** may be controlled by memory **24** and processor **22** to establish the set of physiological time-series data by combining, integrating and/or synchronizing the first set of data (e.g., the physiological and contextual data) and the second set of data (e.g., one or more EMA responses) to create the set of physiological time-series data for the user. According to an embodiment, the combining, integrating and/or synchronizing of the first set of data and the second set of data may include establishing consistency among the sets of data, which may be collected from different sources, and the continuous harmonization of the sets of data over time.

[0060] For instance, in an embodiment, the first set of data may need to be synchronized together since the first set of data may include measurements taken from different sensors at different times. As one example, the first set of data may include motion measured by an accelerometer and heart rate measured by a physiological sensor. Accordingly, apparatus **20** may be controlled to synchronize and integrate the motion measurement with the heart rate measurement. In addition, the first set of data may need to be synchronized with the second set of data (e.g., an EMA response), for example based on collection times. In other embodiments, the processing, combining, integrating and/or synchronizing of the first set of data (e.g., the physiological and contextual data) and the second set of data (e.g., EMA response(s)) may be performed either in the user device (e.g., smartphone) or the apparatus **20** connected in the network, or any combination thereof. Similarly, the EMA may be triggered either from the apparatus **20** to the user device, or by the user device alone.

[0061] In an embodiment, the physiological time-series data may be a representation of the user's physical and/or emotional state at a given time based on the contextual data, physiological data, and/or EMA response data collected. For example, in one embodiment, the physiological time-series data may include a representation of the user's physiological stimulation (e.g., elevated heart rate) combined with contextual data (e.g., time or location).

[0062] In one embodiment, apparatus **20** may be further controlled by memory **24** and processor **22** to identify habit information related to regularly occurring habits of the user based on the first set of data (e.g., physiological and contextual data). As discussed above, in one example, habits may refer to a repeated series of activities that an individual performs on a regular day or basis, such as sleeping, eating meals, commuting, working, exercising, etc. According to one embodiment, apparatus **20** may be further controlled by memory **24** and processor **22** to place a habit anchor within the physiological time-series data to identify periods of time during which the regularly occurring habits are happening.

[0063] As described above in connection with FIG. **4**, in an embodiment, habit anchors may be placed at periods where habits usually occur, such as during times of sleep, jogging, eating breakfast, commuting to work, eating lunch, commuting back home, and eating dinner, for instance. According an embodiment, EMA anchors may be placed during the times of other events (e.g., meetings or checking e-mail). Thus, stress valence during habits may be captured via habit anchor, and during other events via EMA anchor. Once the habit information is captured, apparatus **20** may be controlled to determine whether a habit creates positive or negative stress, or if it has a neutral effect on the user.

[0064] According to one embodiment, apparatus **20** may be further controlled by memory **24** and processor **22** to determine or detect, based on at least the first set of data (e.g., physiological and contextual data) and the habit information, a potential trigger point for sending an EMA to the user. In an embodiment, the EMA may be used, in part, to ascertain the stress valence of the user at the time of the potential trigger point. According to one embodiment, the potential trigger point may be a point in time where the first set of data shows a significant change in level that is above or below a pre-defined threshold. In an embodiment, apparatus **20** may use the habit information to disregard physiological stimulation or arousal unrelated to stress.

[0065] In one embodiment, at the time of the potential trigger point, apparatus **20** may be further controlled by memory **24** and processor **22** to compute or calculate an estimate of the stress valence value associated with the EMA for which an EMA response was at least partially not received (e.g., either because the EMA was not sent or because the user did not provide a response to the EMA). According to an embodiment, the stress valence value estimate may be calculated based on at least one of the physiological time-series data, at least one previously collected partial or complete EMA response, the first set of data, or the habit information.

[0066] According to certain embodiments, the computing or calculating of the estimate of the stress valence value may include apparatus **20** being controlled by memory **24** and processor **22** to perform dynamic temporal backtracking to identify past trends in the physiological time-series data of the user. For example, as discussed above in connection with FIG. **3**, apparatus **20** may be further controlled by memory **24** and processor **22** to iteratively apply an increasing retrospective time window beginning from the time of the potential trigger point until a previously captured EMA response is found representing a change in physiological data, contextual data, or any combination thereof, that is similar to the significant change in the first set of data that caused the detection of the potential trigger point. In this embodiment, when the previously captured EMA response is found that shows the similar change, apparatus **20** may be further controlled by memory **24** and processor **22** to use the stress valence determined from the previously captured EMA response as the estimated stress valence value for the user at the potential trigger point.

[0067] As noted above, the detection of a potential trigger point does not necessarily result in an EMA being sent to the user. However, in one embodiment, upon detection of the potential trigger point, apparatus **20** may be further controlled by memory **24** and processor **22** to send the EMA to the user device(s) so that the user can provide an EMA response. In an embodiment, apparatus **20** may be further controlled by memory **24** and processor **22** to receive the EMA response from the user and to use the EMA response to determine the stress valence of the user. In another embodiment, a response to the EMA may not be provided by the user. According to an embodiment, apparatus **10** may then be controlled by memory **14** and processor **12** to calculate the estimate of the stress valence value associated with the EMA when a response to the subsequent EMA is not received.

[0068] FIG. **5** illustrates an example flow diagram of a method, according to one embodiment. In an embodiment, the method of FIG. **5** may be performed by a user device, such as a UE, smartphone, wearable device, or by a network node, such as a server, base station, node B, eNB, or by any combination thereof.

[0069] As illustrated in the example of FIG. **5**, the method may include, at **500**, measuring and/or collecting a first set of data from one or more sensors of one or more user devices. The first set of data may include physiological data and/or contextual data, for example. According to one embodiment, the collecting **500** may include continuously measuring or obtaining the contextual and/or physiological data from the user device(s). In other embodiments, the collecting **500** may include discontinuously measuring or obtaining the contextual and/or physiological data.

[0070] According to certain embodiments, the method may further include, at **510**, measuring and/or collecting a second set of data that includes one or more partial or complete ecological momentary assessment (EMA) response(s) from a user of the user device(s). In one embodiment, an EMA response may contain information on the stress of a user including, for example, the stress valence (i.e., positive or negative stress) at the time of the EMA response. In an embodiment, the method may include providing or displaying one or more EMA(s) on a screen of the user device(s), for example, at appropriate times. According to certain embodiments, the method may include receiving response(s) provided by the user to the EMA(s) and converting the EMA responses into machine readable and analyzable formats.

[0071] According to an embodiment, the method may also include, at **520**, storing the first set of data and the second set of data in memory. In one embodiment, the first set of data may be continuous data that contains information on a level of arousal or stimulation of the user, such as heart rate and heart rate variation data. In an embodiment, information contained in an EMA response from a user may be considered as discontinuous data that contains information on the stress of the user, such as valence (i.e., positive or negative stress reported in the EMA response).

[0072] In one embodiment, the method may then include, at **530**, establishing a set of physiological time-series data for the user based on the first set of data (e.g., the physiological and contextual data) and the second set of data (e.g., one or more EMA responses). For example, in an embodiment, the establishing of the set of physiological time-series data may include combining, integrating and/or synchronizing the first set of data and the second set of data to create the set of physiological time-series data for the user. The physiological time-series data may be a representation of the user' s physical and/or emotional state at a given time based on the contextual data, physiological data, and/or EMA response data collected. For example, in one embodiment, the physiological time-series data may include a representation of the user's physiological stimulation (e.g., elevated heart rate) combined with contextual data (e.g., time or location).

[0073] In another embodiment, the method may include transmitting the first set of data (e.g., the physiological and contextual data) and the second set of data (e.g., one or more EMA responses) to a node, host or server of a network. According to this embodiment, the network node may be configured to combine and synchronize the first set of data and the second set of data to create the set of physiological time-series data for the user.

[0074] In one embodiment, the method may also include, at **540**, identifying habit information related to regularly occurring habits of the user based on the first set of data (e.g., physiological and contextual data). In an embodiment, habit information refers to information representative of regularly occurring habits or routines that an individual performs on a regular day or basis. According to one embodiment, the method may include placing a habit anchor within the physiological time-series data to identify periods of time during which the regularly occurring habits are happening.

[0075] According to one embodiment, the method may further include, at **550**, determining or detecting, based on at least the first set of data (e.g., physiological and contextual data) and the habit information, a potential trigger point for sending an EMA to the user. In an embodiment, the EMA may be used, in part, to ascertain the stress valence of the user at the time of the potential trigger point. According to one embodiment, the potential trigger point may be a point in time where the first set of data shows a significant change in level that is above or below a pre-defined threshold. In an embodiment, the detecting **550** may include using the habit information (e.g., time and duration of regular physical exercises) to disregard physiological stimulation or arousal unrelated to stress.

[0076] In one embodiment, at the time of the potential trigger point, the method may include, at **560**, computing or calculating an estimate of the stress valence value associated with the EMA for which an EMA response was at least partially not received (e.g., either because the EMA was not sent or because the user did not provide a response to the EMA). According to an embodiment, the calculating **560** may include calculating the stress valence value estimate based on at least one of the physiological time-series data, at least one previously collected partial or complete EMA response, the first set of data, or the habit information.

[0077] According to certain embodiments, the calculating **560** of the estimate of the stress valence value may include performing dynamic temporal backtracking to identify past trends in the physiological time-series data of the user. For example, according to an embodiment, performing the dynamic temporal backtracking may include iteratively apply an increasing retrospective time window beginning from the time of the potential trigger point until a previously captured EMA response is found representing a change in physiological data, contextual data, or any combination thereof, that is similar to the significant change in the first set of data that caused the detection of the potential trigger point. In this embodiment, when the previously captured EMA response is found that shows the similar change, the calculating **560** may include using the stress valence determined from the previously captured EMA response as the estimated stress valence value for the user at the potential trigger point.

[0078] As noted above, the detection of a potential trigger point does not necessarily mean that an EMA will be sent to the user. However, in one embodiment, upon detection of the potential trigger point, the method may include sending the EMA to the user device(s) so that the user can provide an EMA response. In this embodiment, the method may include receiving the EMA response from the user and then the calculating **560** may include using the EMA response to determine the stress valence of the user. In another embodiment, a response to the EMA may not be provided by the user. According to an embodiment, the method may include calculating the estimate of the stress valence value associated with the EMA when a response to the subsequent EMA is not received.

[0079] In view of the above, embodiments of the present disclosure may provide several advantages, technical improvements and/or technical effects. For example, certain embodiments improve the functioning of user equipment (UEs), such as smart phones and wearable devices, by making these devices more intuitive and allowing the devices to learn daily habits of users in order to provide feedback or output that is less intrusive and more beneficial to users. As such, embodiments of the present disclosure can improve the performance of network nodes including, for example, UEs, mobile devices, smart phones, wearable devices, network servers, base stations, eNBs, etc. Accordingly, the use of embodiments of the present disclosure results in improved functioning of communications networks and their nodes.

[0080] In some embodiments, the functionality of any of the methods, processes, signaling diagrams, or flow charts described herein may be implemented by software and/or computer program code or portions of code stored in memory or other computer readable or tangible media, and executed by a processor.

[0081] In certain embodiments, an apparatus may be included or be associated with at least one software application, module, unit or entity configured as arithmetic operation(s), or as a program or portions of it (including an added or updated software routine), executed by at least one operation processor. Programs, also called program products or computer programs, including software routines, applets and macros, may be stored in any apparatus-readable data storage medium and may include program instructions to perform particular tasks.

[0082] A computer program product may comprise one or more computer-executable components which, when the program is run, are configured to carry out certain embodiments. The one or more computer-executable components may include software code or portions of it. Modifications and configurations required for implementing the functionality of an embodiment may be performed as routine(s), which may be implemented as added or updated software routine(s). In certain embodiments, software routine(s) may be downloaded into an apparatus.

[0083] Software or computer program code or portions of code may be in a source code form, object code form, or in some intermediate form, and may be stored in some type of carrier, distribution medium, or computer readable medium, which may be any entity or device capable of carrying the program. Such carriers include a record medium, computer memory, read-only memory, photoelectrical and/or electrical carrier signal, telecommunications signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital computer or it may be distributed amongst a number of computers. The computer readable medium or computer readable storage medium may be a non-transitory medium.

[0084] In other embodiments, the functionality of any method or process described herein may be performed by hardware, for example through the use of an application specific integrated circuit (ASIC), a programmable gate array (PGA), a field programmable gate array (FPGA), or any other combination of hardware and software. In yet another embodiment, the functionality may be implemented as a signal, a non-tangible means that can be carried by an electromagnetic signal downloaded from the Internet or other network.

[0085] According to an embodiment, an apparatus, such as a node, device, or a corresponding component, may be configured as a computer or a microprocessor, such as single-chip computer element, or as a chipset, including at least a memory for providing storage capacity used for arithmetic operations and an operation processor for executing the arithmetic operations.

[0086] One having ordinary skill in the art will readily understand that the present disclosure as discussed above may be practiced with steps in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although the present disclosure has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the present disclosure. In order to determine the metes and bounds of the present disclosure, therefore, reference should be made to the appended claims.

We claim:

1. A method, comprising:

collecting a first set of data from at least one sensor of at least one user device, wherein the first set of data comprises at least one of physiological data or contextual data;

collecting a second set of data comprising at least one partial or complete ecological momentary assessment (EMA) response from a user of the at least one user device;

establishing a set of physiological time-series data for the user based on the first set of data and the second set of data;

identifying habit information related to regularly occurring habits of the user based on the first set of data;

based on at least the first set of data and the habit information, detecting a potential trigger point for sending a subsequent EMA to the user, the subsequent EMA being used to ascertain a stress valence of the user at a time of the potential trigger point; and

at the time of the potential trigger point, calculating an estimate of a stress valence value associated with the subsequent EMA for which an EMA response was at least partially not received, wherein the stress valence value estimate is calculated based on at least one of the physiological time-series data, the at least one previously collected partial or complete EMA response, the first set of data, or the habit information.

2. The method according to claim **1**, wherein the potential trigger point comprises a point in time where the first set of data shows a significant change in level that is above or below a pre-defined threshold.

3. The method according to claim **2**, wherein the calculating of the estimate of the stress valence value comprises performing backtracking to identify past trends in the physiological time-series data of the user.

4. The method according to claim **3**, wherein the performing comprises iteratively applying an increasing retrospective time window beginning from the time of the potential trigger point until a previously captured EMA response is found representing a change in physiological data, contextual data, or any combination thereof, that is similar to the significant change in the first set of data at the potential trigger point, and wherein the calculating further comprises using a stress valence determined from the previously captured EMA response as the estimated stress valence value for the subsequent EMA.

5. The method according to claim **1**, the method further comprising placing a habit anchor within the physiological time-series data to identify periods of time during which the regularly occurring habits are happening.

6. The method according to claim **1**, wherein the detecting of the potential trigger point further comprises using the habit information to disregard physiological arousal unrelated to stress.

7. The method according to claim **1**, wherein the contextual data comprises at least one of geographical location, time of day, altitude, external temperature, or any combination thereof.

8. The method according to claim **1**, wherein the physiological data comprises the user's physical or biological characteristics including at least one of heart rate, pulse, core body temperature, respiration rate, blood oxygenation level, blood pressure, skin temperature, cardiac rhythm, or any combination thereof.

9. The method according to claim **1**, wherein the method further comprises, upon detection of the potential trigger point, sending the subsequent EMA to the at least one user device, and wherein the calculating comprises calculating the estimate of the stress valence value associated with the subsequent EMA when a response to the subsequent EMA is not received.

10. An apparatus, comprising:

at least one processor; and

at least one memory including computer program code,

the at least one memory and the computer program code configured, with the at least one processor, to cause the apparatus at least to

collect a first set of data from at least one sensor of at least one user device, wherein the first set of data comprises at least one of physiological data or contextual data;

collect a second set of data comprising at least one partial or complete ecological momentary assessment (EMA) response from a user of the at least one user device;

establish a set of physiological time-series data for the user based on the first set of data and the second set of data;

identify habit information related to regularly occurring habits of the user based on the first set of data;

detect, based on at least the first set of data and the habit information, a potential trigger point for sending a subsequent EMA to the user, the subsequent EMA being used to ascertain a stress valence of the user at a time of the potential trigger point; and

at the time of the potential trigger point, calculate an estimate of a stress valence value associated with the subsequent EMA for which an EMA response was at least partially not received, wherein the stress valence value estimate is calculated based on at least one of the physiological time-series data, the at least one previously collected partial or complete EMA response, the first set of data, or the habit information.

11. The apparatus according to claim **10**, wherein the potential trigger point comprises a point in time where the first set of data shows a significant change in level that is above or below a pre-defined threshold.

12. The apparatus according to claim **11**, wherein the at least one memory and the computer program code are further configured, with the at least one processor, to cause the apparatus at least to perform backtracking to identify past trends in the physiological time-series data of the user in order to estimate the stress valence value associated with the subsequent EMA.

13. The apparatus according to claim **12**, wherein the dynamic temporal backtracking comprises iteratively applying an increasing retrospective time window beginning from the time of the potential trigger point until a previously captured EMA response is found representing a change in physiological data, contextual data, or any combination thereof, that is similar to the significant change in the first set of data at the potential trigger point, and wherein the stress valence determined from the previously captured EMA response is used as the estimated stress valence value for the subsequent EMA.

14. The apparatus according to claim **10**, wherein the at least one memory and the computer program code are further configured, with the at least one processor, to cause the apparatus at least to place a habit anchor within the physiological time-series data to identify periods of time during which the regularly occurring habits are happening.

15. The apparatus according to claim **10**, wherein the at least one memory and the computer program code are further configured, with the at least one processor, to cause the apparatus at least to detect the potential trigger point at least by using the habit information to disregard physiological arousal unrelated to stress.

16. The apparatus according to claim **10**, wherein the contextual data comprises at least one of geographical location, time of day, altitude, external temperature, or any combination thereof.

17. The apparatus according to claim **10**, wherein the physiological data comprises the user's physical or biological characteristics including at least one of heart rate, pulse, core body temperature, respiration rate, blood oxygenation level, blood pressure, skin temperature, cardiac rhythm, or any combination thereof.

18. The apparatus according to claim **10**, wherein the at least one user device comprises at least one of a smart phone, smart watch, fitness tracker, other wearable device, or any combination thereof.

19. The apparatus according to claim **10**, wherein, upon detection of the potential trigger point, the at least one memory and the computer program code are further configured, with the at least one processor, to cause the apparatus at least to send the subsequent EMA to the at least one user device, and to calculate the estimate of the stress valence value associated with the subsequent EMA when a response to the subsequent EMA is not received.

20. A computer program, embodied on a non-transitory computer readable medium, the computer program configured to control a processor to perform a process, comprising:

collecting a first set of data from at least one sensor of at least one user device, wherein the first set of data comprises at least one of physiological data or contextual data;

collecting a second set of data comprising at least one partial or complete ecological momentary assessment (EMA) response from a user of the at least one user device;

storing the first set of data and the second set of data;

establishing a set of physiological time-series data for the user based on the first set of data and the second set of data;

identifying habit information related to regularly occurring habits of the user based on the first set of data;

based on at least the first set of data and the habit information, detecting a potential trigger point for sending a subsequent EMA to the user, the subsequent EMA being used to ascertain a stress valence of the user at a time of the potential trigger point; and

at the time of the potential trigger point, calculating an estimate of a stress valence value associated with the subsequent EMA for which an EMA response was at least partially not received, wherein the stress valence value estimate is calculated based on at least one of the physiological time-series data, the at least one previously collected partial or complete EMA response, the first set of data, or the habit information.

* * * * *

patsnap

专利名称(译)	用于根据传感器数据估计个体的应力效价的系统，方法和设备		
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摘要(译)

提供了用于从传感器数据推断个体的压力效价的系统，方法，装置和计算机程序产品。一种方法包括从用户设备的传感器收集第一组数据，收集第二组数据，包括来自用户的部分或完整的生态瞬时评估（EMA）响应，建立一组生理时间 - 基于第一组数据和第二组数据的用户的系列数据，基于第一组数据识别用户的习惯信息。基于第一组数据和习惯信息，检测用于向用户发送后续EMA的潜在触发点，并且在潜在触发点时，计算与后续EMA相关联的应力价值的估计。对此至少部分未收到EMA回复。