



US010517527B2

(12) **United States Patent**
Ware et al.

(10) **Patent No.:** **US 10,517,527 B2**
(45) **Date of Patent:** **Dec. 31, 2019**

- (54) **SLEEP QUALITY SCORING AND IMPROVEMENT**
- (71) Applicant: **BOSE CORPORATION**, Framingham, MA (US)
- (72) Inventors: **Laura Ware**, Boston, MA (US); **Jonathan Freed**, Milton, MA (US); **Jack Read**, Bolton, MA (US); **Debra Reich**, Arlington, MA (US); **Leela Keshavan**, Westborough, MA (US); **Brian David Mulcahey**, Sudbury, MA (US)

(58) **Field of Classification Search**
CPC A61B 5/0816; A61B 5/4812
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,228,806 A	10/1980	Lidow
5,671,733 A	9/1997	Raviv et al.
5,781,640 A	7/1998	Nicolino, Jr.

(Continued)

FOREIGN PATENT DOCUMENTS

CN	103519784 B	11/2015
CN	105231997 A	1/2016

(Continued)

OTHER PUBLICATIONS

International Search Report and Written Opinion for application No. PCT/US2017/051497 dated Dec. 8, 2017.
(Continued)

Primary Examiner — Michael J D Abreu
(74) *Attorney, Agent, or Firm* — Lando & Anastasi, LLP

(57) **ABSTRACT**

A sleep scoring device is provided for, including a contactless biometric sensor, a processor, memory, and a microphone. The sleep scoring device may detect a user's sleep state by reading signals from the contactless biometric sensor based on at least one of a detected change in heartrate, body movement, or respiration, and log the biometric information. The sleep scoring device may also generate a sleep score for a sleep session based on the latency of the sleep session, the number of detected waking events, the amount of REM sleep, the amount of deep sleep, or the number of times the snooze button was pressed during the sleep session.

22 Claims, 8 Drawing Sheets

(73) Assignee: **BOSE CORPORATION**, Framingham, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 28 days.

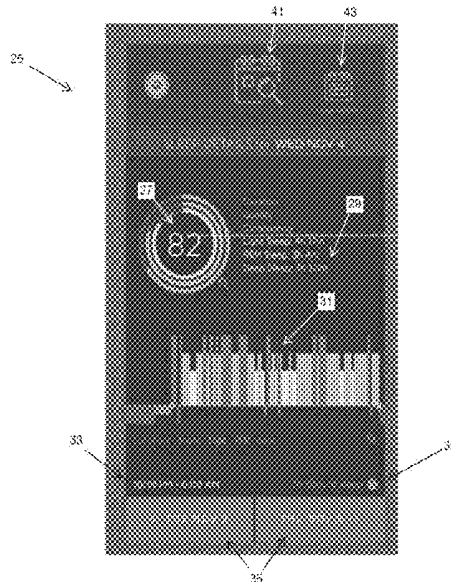
(21) Appl. No.: **15/267,464**

(22) Filed: **Sep. 16, 2016**

(65) **Prior Publication Data**
US 2018/0078197 A1 Mar. 22, 2018

(51) **Int. Cl.**
A61B 5/00 (2006.01)
A61B 5/0205 (2006.01)
A61B 7/04 (2006.01)
A61B 5/024 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **A61B 5/4815** (2013.01); **A61B 5/0205** (2013.01); **A61B 5/4809** (2013.01); **A61B 5/4812** (2013.01); **A61B 5/7278** (2013.01); **A61B 7/04** (2013.01); **A61B 5/024** (2013.01); **A61B 5/0816** (2013.01); **A61B 5/1115** (2013.01); **A61B 2560/0252** (2013.01);
(Continued)



- (51) **Int. Cl.**
A61B 5/08 (2006.01)
A61B 5/11 (2006.01)
- (52) **U.S. Cl.**
 CPC *A61B 2560/0257* (2013.01); *A61B 2560/0475* (2013.01)

2012/0092171	A1	4/2012	Hwang et al.
2012/0327748	A1	12/2012	Lee
2013/0163394	A1	6/2013	Loree, IV
2013/0234823	A1	9/2013	Kahn et al.
2013/0289419	A1	10/2013	Berezhnyy et al.
2013/0289431	A1	10/2013	Gavish et al.
2013/0338446	A1	12/2013	Van Vugt et al.
2014/0088373	A1	3/2014	Phillips et al.
2014/0334645	A1	11/2014	Yun et al.
2014/0371547	A1	12/2014	Gartenberg et al.
2014/0371635	A1	12/2014	Shinar et al.
2015/0141852	A1	5/2015	Dusanter et al.
2015/0164238	A1*	6/2015	Benson G16H 50/30 340/540

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,928,133	A	7/1999	Halyak
6,236,622	B1	5/2001	Blackman
6,662,032	B1	12/2003	Gavish et al.
6,825,769	B2	11/2004	Colmenarez et al.
6,888,779	B2	5/2005	Mollicone et al.
7,248,915	B2	7/2007	Ronnholm
7,637,859	B2	12/2009	Lindback et al.
7,850,619	B2	12/2010	Gavish et al.
8,243,937	B2	8/2012	Nicolino, Jr. et al.
8,280,067	B2	10/2012	Nicolino, Jr. et al.
8,280,068	B2	10/2012	Nicolino, Jr. et al.
8,285,344	B2	10/2012	Kahn et al.
8,379,870	B2	2/2013	Nicolino, Jr. et al.
8,485,982	B2	7/2013	Gavish et al.
8,550,978	B2	10/2013	Ullmann
8,562,526	B2*	10/2013	Heneghan A61B 5/0507 128/920
8,585,607	B2	11/2013	Klap et al.
8,731,646	B2	5/2014	Halperin et al.
8,855,334	B1	10/2014	Lavine et al.
8,870,764	B2	10/2014	Rubin
8,870,785	B2	10/2014	Muehlsteff et al.
8,964,997	B2	2/2015	Gauger, Jr.
8,992,434	B2	3/2015	Halperin et al.
9,072,437	B2	7/2015	Paalasmaa
9,192,326	B2	11/2015	Kahn et al.
9,192,333	B1	11/2015	Hayes et al.
2002/0080035	A1	6/2002	Youdenko
2002/0186618	A1	12/2002	Kirkpatrick
2003/0095476	A1	5/2003	Mollicone et al.
2003/0142591	A1	7/2003	Baweja et al.
2005/0152223	A1	7/2005	Kawakami
2006/0017558	A1	1/2006	Albert et al.
2006/0102171	A1	5/2006	Gavish
2007/0055115	A1	3/2007	Kwok et al.
2007/0083079	A1	4/2007	Lee et al.
2007/0249952	A1	10/2007	Rubin et al.
2008/0157956	A1	7/2008	Radivojevic et al.
2009/0231964	A1	9/2009	Kraft et al.
2009/0287109	A1	11/2009	Ferren et al.
2009/0292222	A1	11/2009	Ferren et al.
2010/0039399	A1	2/2010	Kim
2010/0087701	A1	4/2010	Berka et al.
2010/0162169	A1	6/2010	Skarp
2010/0226212	A1	9/2010	Gobindram
2010/0281982	A1	11/2010	Liao
2011/0004047	A1	1/2011	Braspenning et al.
2011/0144455	A1	6/2011	Young et al.
2011/0224510	A1	9/2011	Oakhill
2011/0230790	A1	9/2011	Kozlov
2011/0257772	A1	10/2011	Kerber et al.
2011/0264164	A1*	10/2011	Christopherson A61B 5/0803 607/42

2015/0173671	A1	6/2015	Paalasmaa et al.
2015/0230750	A1	8/2015	McDarby et al.
2015/0258301	A1	9/2015	Trivedi et al.
2015/0263688	A1	9/2015	Nicolino, Jr. et al.
2015/0265212	A1	9/2015	Bruekers et al.
2015/0320354	A1	11/2015	Oakhill
2015/0320588	A1	11/2015	Connor
2015/0367097	A1	12/2015	Gavish
2016/0015315	A1	1/2016	Auphan et al.
2016/0055842	A1	2/2016	DeFranks et al.
2016/0058428	A1	3/2016	Shinar et al.
2016/0151603	A1	6/2016	Shouldice et al.
2016/0217672	A1	7/2016	Yoon et al.
2016/0270718	A1	9/2016	Heneghan et al.
2016/0335886	A1	11/2016	Wei
2017/0039045	A1	2/2017	Abrahami et al.
2017/0087330	A1	3/2017	Kahn et al.
2018/0078197	A1	3/2018	Ware et al.
2018/0078198	A1	3/2018	Reich et al.
2018/0078732	A1	3/2018	Keshavan et al.
2018/0078733	A1	3/2018	Freed et al.
2018/0081527	A1	3/2018	Dolecki et al.
2018/0082550	A1	3/2018	Read et al.

FOREIGN PATENT DOCUMENTS

EP	2278507	A2	1/2011
EP	2976993	A2	1/2016
JP	2007244597	A	9/2007
WO	2005084538	A1	9/2005
WO	2012051630	A2	4/2012
WO	2013093712	A1	6/2013
WO	2013134160	A2	9/2013
WO	2015006364	A2	1/2015
WO	2015008285	A1	1/2015
WO	2015061579	A1	4/2015
WO	2016035073	A1	3/2016
WO	2016122143	A1	8/2016
WO	2016142793	A1	9/2016

OTHER PUBLICATIONS

International Search Report and Written Opinion for application No. PCT/US2017/051599 dated Jul. 6, 2018.
 Android Headlines: "Samsung Galaxy S5—How to Set an Alarm", YouTube, Apr. 28, 2014, pp. 1-3, XP054978390, Retrieved from the Internet: URL:https://www.youtube.com/watch?v=d8MT5Y5US18.

* cited by examiner

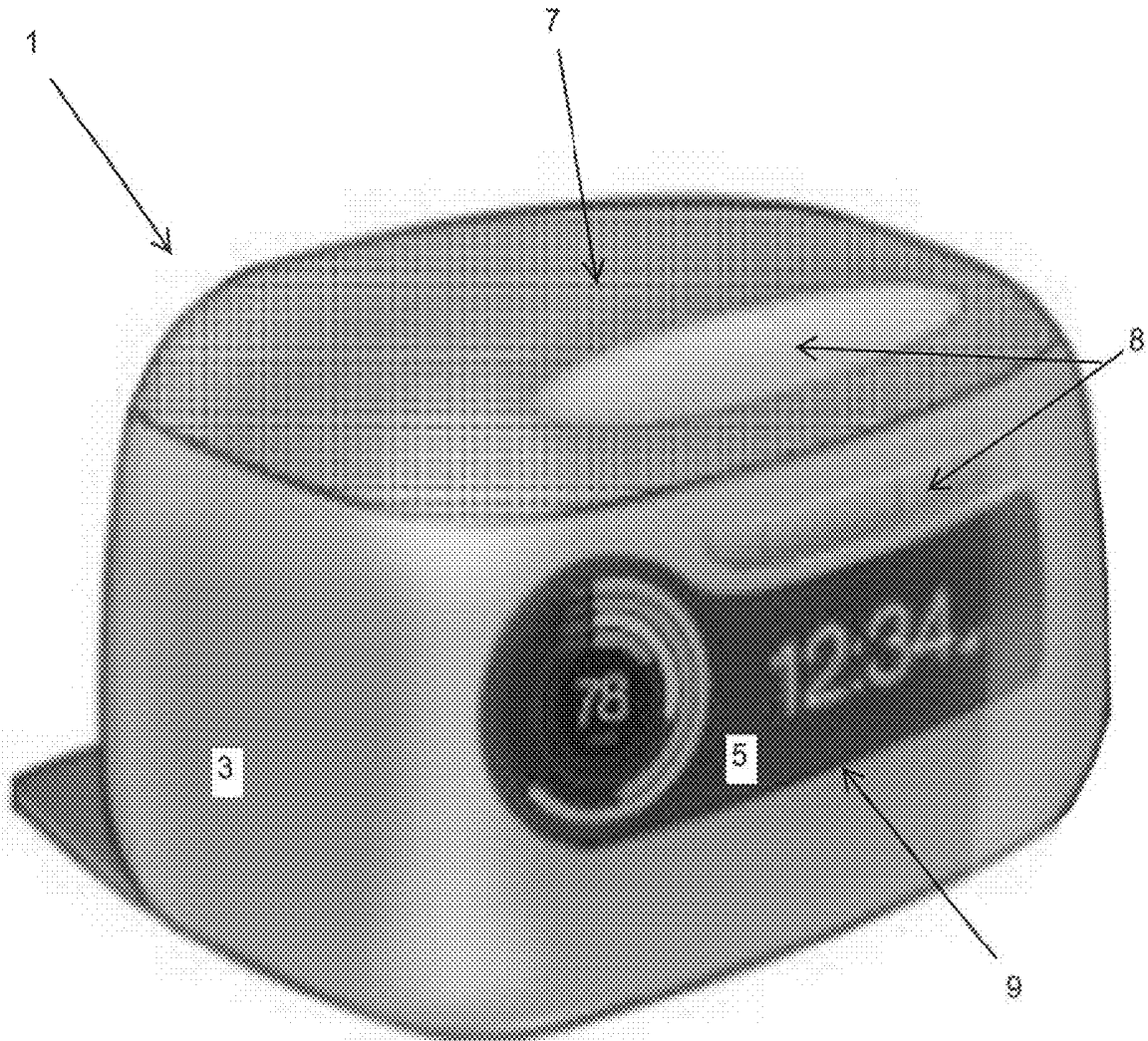


FIG. 1A

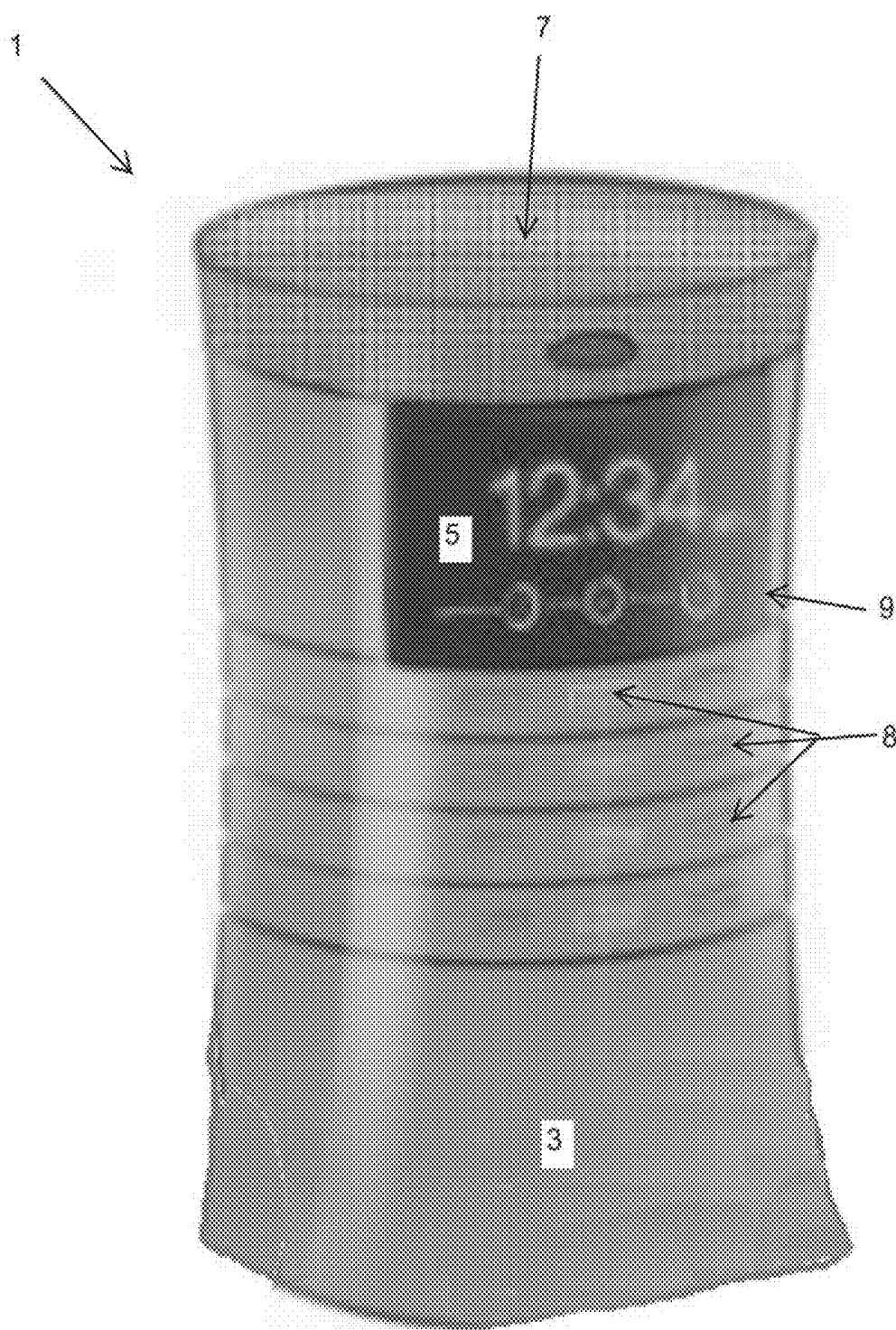


FIG. 1B

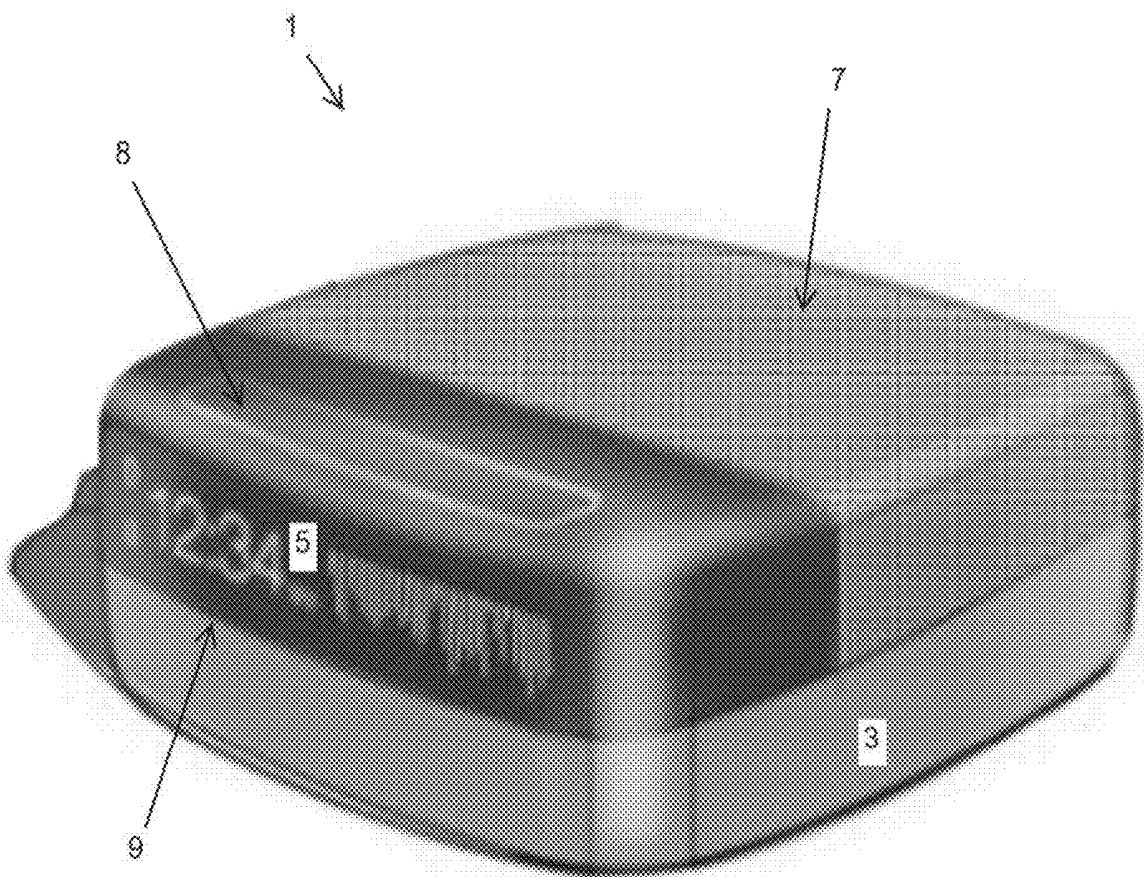


FIG. 1C

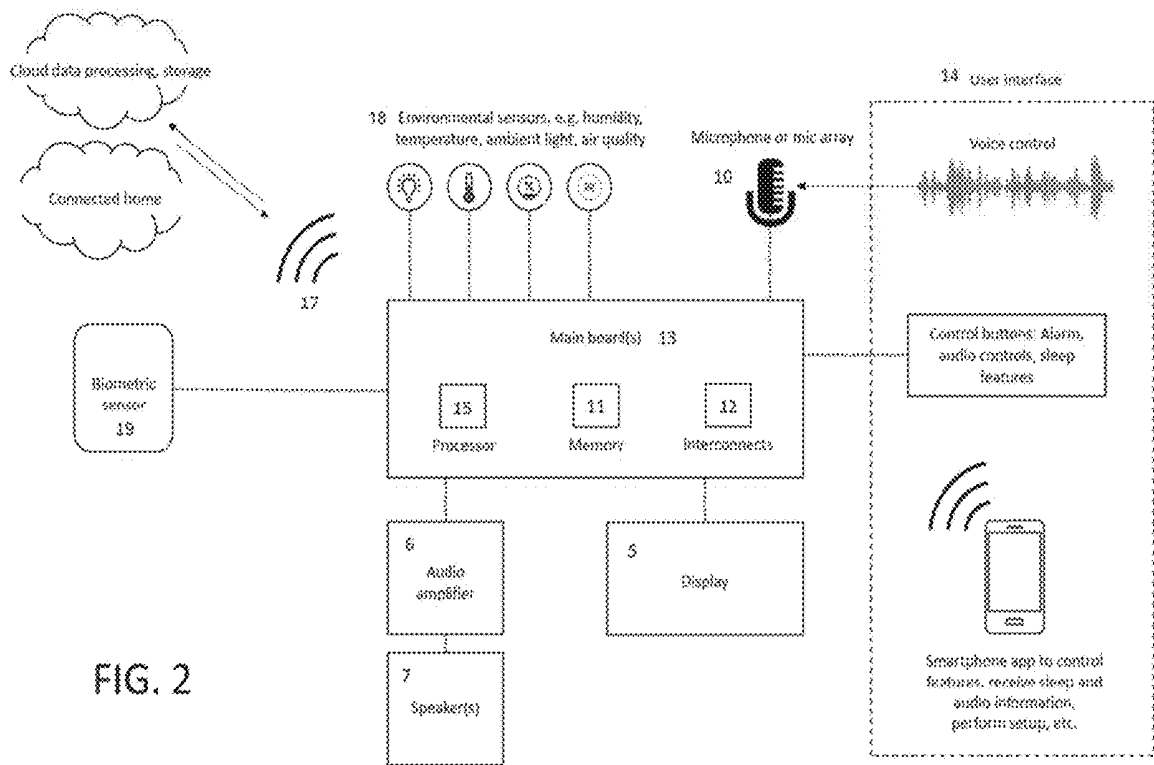


FIG. 2

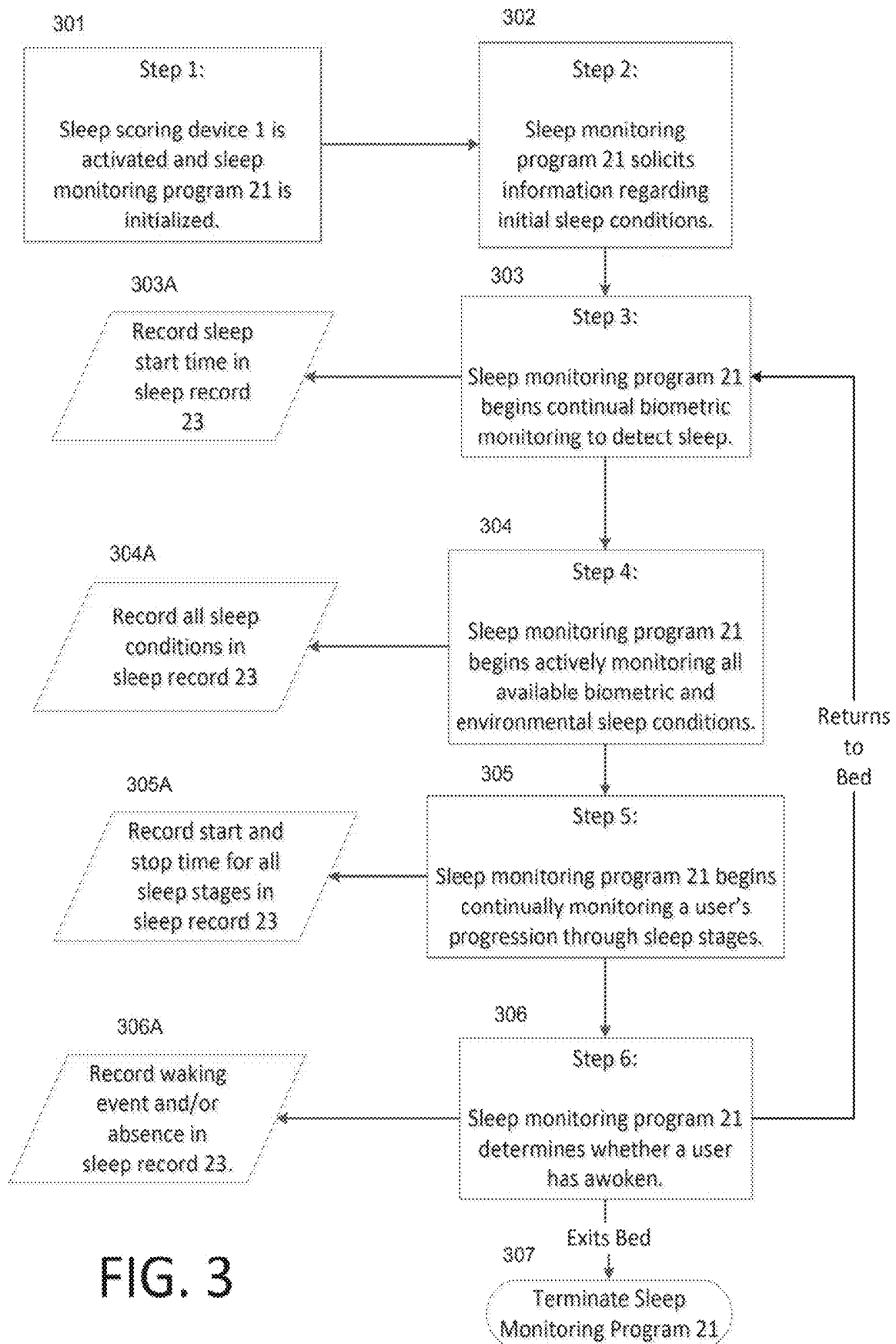


FIG. 3

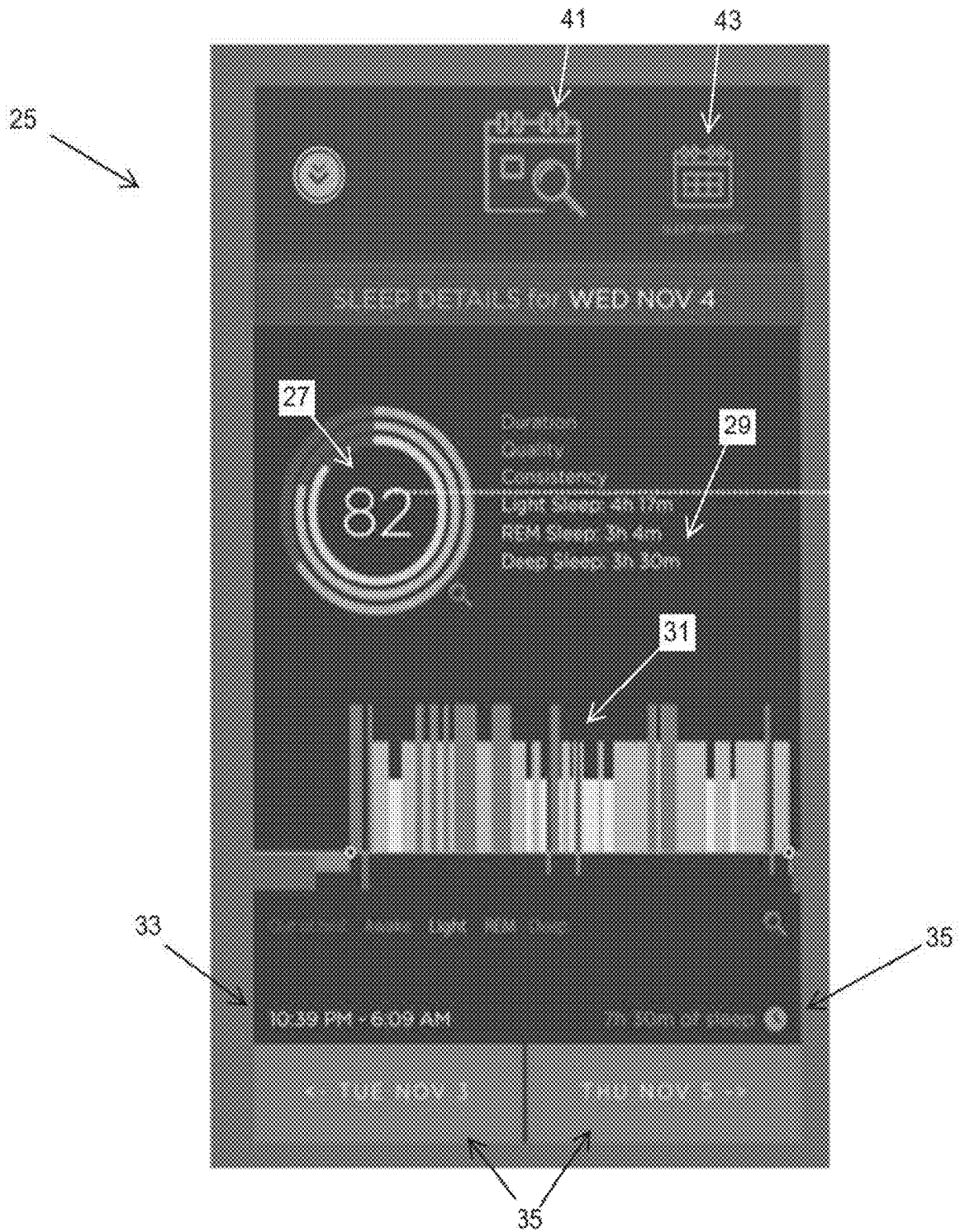


FIG. 4A

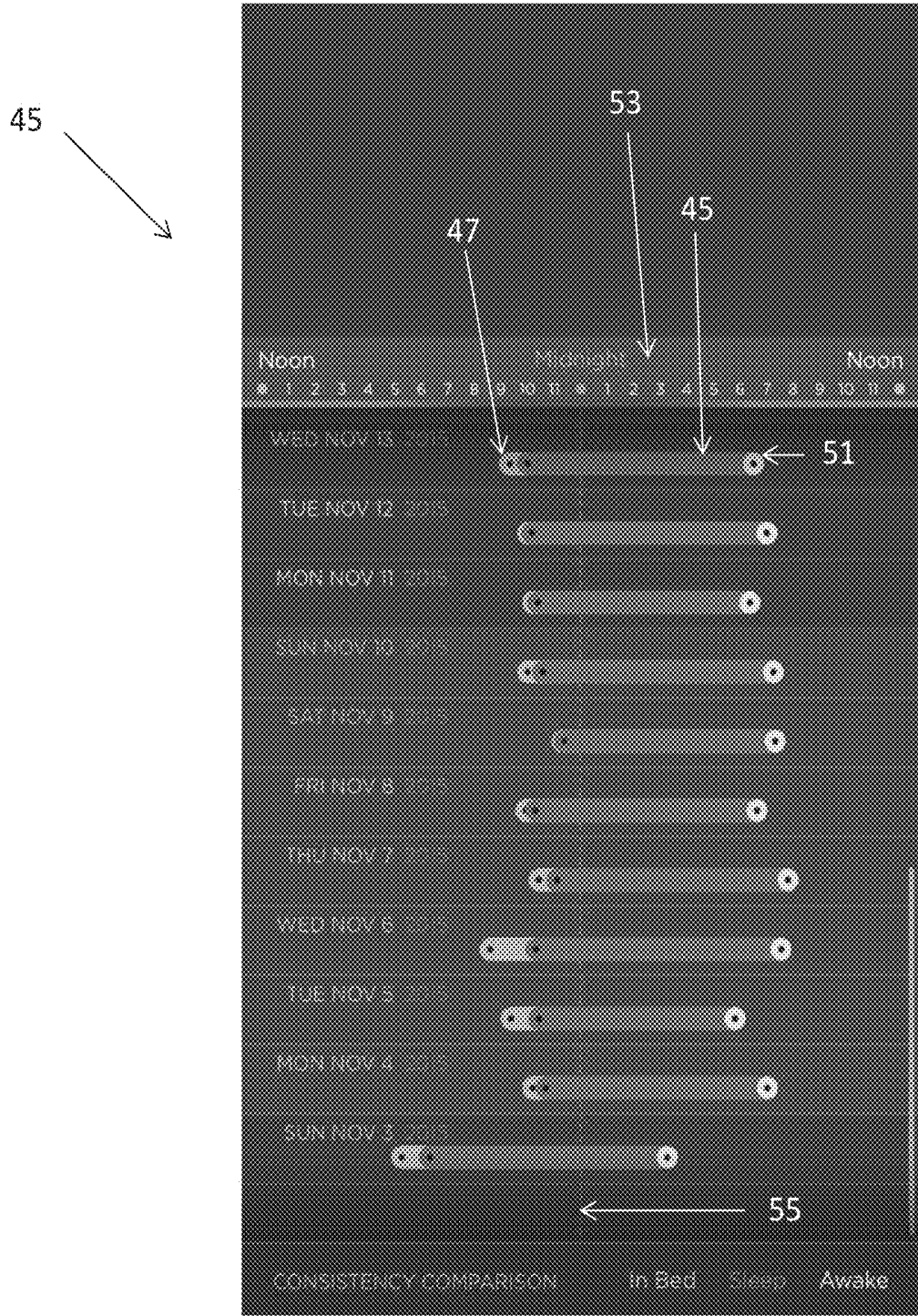


FIG. 4B

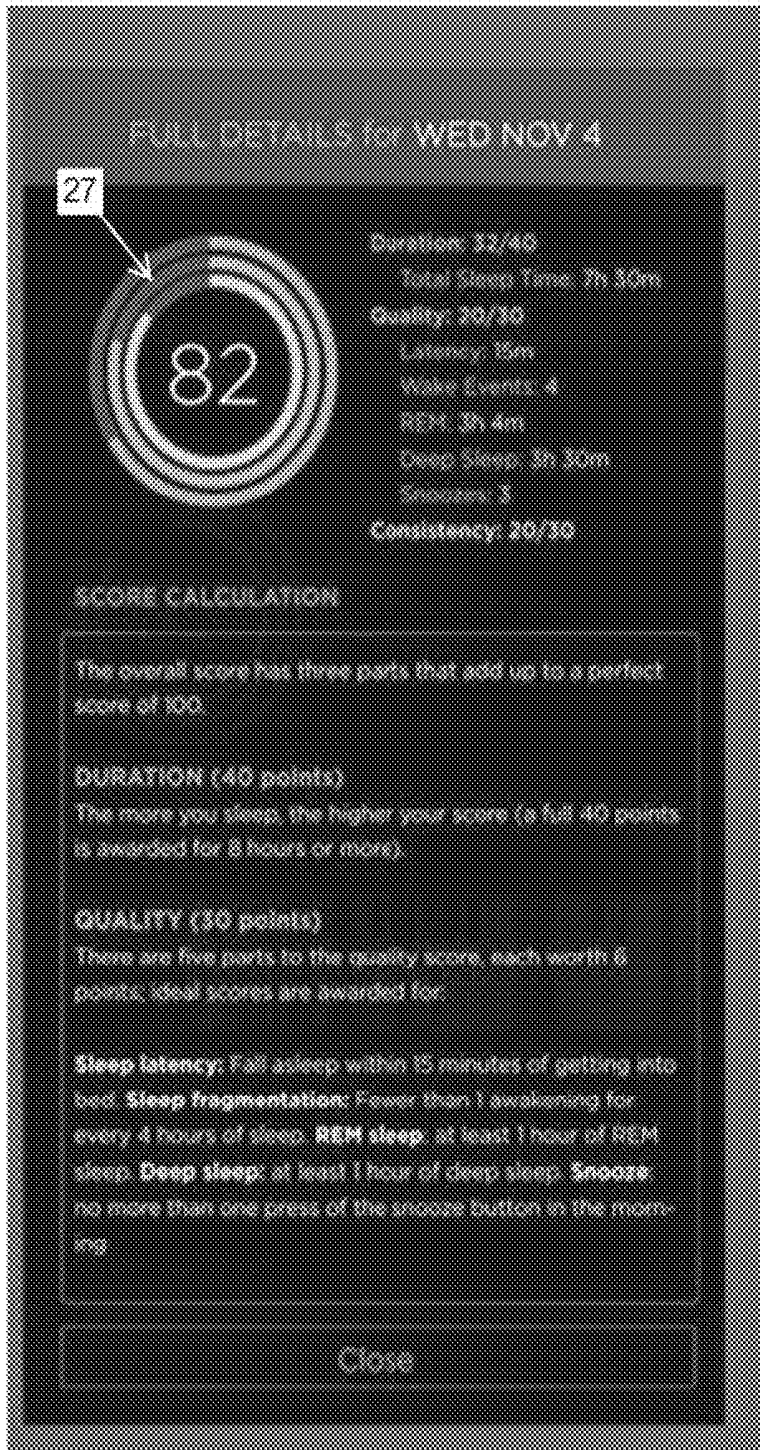


FIG. 5

SLEEP QUALITY SCORING AND IMPROVEMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application relates to U.S. patent application Ser. No. 15/267,552 entitled Intelligent Wake-Up System; U.S. patent application Ser. No. 15/267,567 entitled Sleep Assistance Device; U.S. patent application Ser. No. 15/267,848 entitled Sleep System; U.S. patent application Ser. No. 15/267,858 entitled User Interface for a Sleep System; and to U.S. patent application Ser. No. 15/267,886 entitled Sleep Assessment Using a Home Sleep System; all of which are filed on even date herewith and are incorporated herein by reference.

FIELD

This disclosure relates to systems, methods, and apparatuses for assessing the overall quality of a user's rest in order to provide objective metrics to user to help gauge the quality of their sleep and make recommendations about improving the overall quality of their sleep.

BACKGROUND

Sleeplessness and poor or interrupted sleep may significantly affect a person's health. Poor sleep may be caused by such factors as ambient noise, stress, medical conditions, or discomfort. Thus, there exists a need for a device that can track and assess the overall quality of a user's sleep and make recommendations for improving the quality of their sleep.

SUMMARY

This disclosure relates to systems, methods, and apparatuses for assessing the overall quality of a user's rest in order to provide objective metrics to user to help gauge the quality of their sleep and make recommendations about improving the overall quality of their sleep.

All examples and features mentioned below can be combined in any technically possible way.

In one example, a sleep scoring device is provided for, including a contactless biometric sensor for determining at least one of a heart rate, a respiratory rate, a presence of a user, or movement of a user; a processor; memory; and a microphone. The processor may be configured to, during a sleep session, detect a user's sleep state by reading signals from the contactless biometric sensor based on at least one of a detected change in heartrate, body movement, or respiration, and log information in a sleep record, including biometric information relating to the quality of a user's sleep and environmental factors that may affect the quality of a user's sleep. The sleep scoring device may also generate a sleep score for a sleep session based on consistency of the logged information with corresponding information logged on previous days.

In some examples of the sleep scoring device, the processor is further configured to log one or more sleep start times and one or more sleep stop times within the sleep record. The processor may also be configured to detect the user's presence in a sleep space and to log the time the user entered the sleep space in said sleep record. In other examples, the processor may also be configured to detect sleep stages and to log the start time and stop time of said

sleep stages in said sleep record. The sleep stages may include at least one of REM sleep, N-REM sleep, deep sleep, light sleep, stage 1 sleep, stage 2 sleep, stage 3 sleep, or stage 4 sleep. The device may also log environmental factors, including one or more of temperature, noise levels, air pressure, air pollution, or light levels. The processor may also be configured to record detected sounds when sounds are detected at or near the same time as a detected wake-up event of a user.

In other implementations of a sleep scoring device, the processor may be configured to solicit external sleep factors from a user. The processor is may also configured to receive information regarding at least one of said environmental factors from an external database. The external database may be a weather database, a health database, a fitness database, or a calendar database.

In other examples, the processor may be configured to generate a sleep score based on at least one of the detected duration of the sleep or the quality of the sleep. The quality of the sleep can be determined based on one or more of the detected latency of the sleep session, the number of detected waking events during the sleep session, the amount of REM sleep detected during the sleep session, the amount of deep sleep detected during the sleep session, or the number of times the snooze button was pressed during the sleep session. The processor may also be configured to analyze information in the sleep record to identify potential corollaries between instances of sub-optimal sleep and said biometric information, said environmental factors, or said external sleep factors.

A method for monitoring and scoring sleep is also provided-for, including the steps of receiving a plurality of biometric readings of a user from a contactless biometric sensor, recording the plurality of biometric readings within a sleep record, determining the user's sleep state based on the plurality of biometric readings, recording the user's sleep state within the sleep record, receiving a plurality of environmental readings including at least one of a sound level, a light level, an air quality reading, or a temperature, recording the plurality of environmental readings in a sleep record, and determining a sleep score based, at least in part, on the recorded plurality of biometric readings, the recorded sleep state, and the plurality of environmental readings in the sleep record. Some examples of the method also include detecting the user's presence in a sleep space based on the plurality of biometric readings and recording the user's presence in the sleep record. Other examples include detecting sleep stages based on the plurality of biometric readings and recording the sleep stages in the sleep record. Sleep stages may include at least one of REM sleep, N-REM sleep, deep sleep, light sleep, stage 1 sleep, stage 2 sleep, stage 3 sleep, or stage 4 sleep. The environmental readings may include one or more of temperature, noise levels, air pressure, air pollution, or light level readings. External sleep factors may also be received and recorded in the sleep record. Some examples include analyzing information in the sleep record and identifying potential corollaries between instances of sub-optimal sleep and the plurality of environmental readings, the plurality of biometric readings, or the external sleep factors.

A sleep monitoring and scoring system is also provided-for, including a biometric sensor; a microphone; memory; and a processor, coupled to the biometric sensor, the memory, and the microphone. The processor may be configured to detect a user's sleep state by reading signals from the contactless biometric sensor based on at least one of a detected change in heartrate, body movement, or respiration,

and wherein said processor is further configured to log information in a sleep record, including biometric information relating to the quality of a user's sleep and environmental factors that may affect the quality of a user's sleep.

BRIEF DESCRIPTION OF THE DRAWINGS

Various aspects of at least one implementation of a sleep quality scoring and improvement system are discussed below with reference to the accompanying figures. The figures are provided for the purposes of illustration and explanation and are not intended as a definition of the limits of the disclosure.

FIG. 1A is a front perspective view of a sleep quality scoring and improvement device with a rectangular housing in one example of the present disclosure.

FIG. 1B is a front perspective view of a sleep quality scoring and improvement device with a cylindrical housing in one example of the present disclosure.

FIG. 1C is a front perspective view of a sleep quality scoring and improvement device with a square housing in one example of the present disclosure.

FIG. 2 is a schematic of the components of a sleep quality scoring and improvement device in one example of the present disclosure.

FIG. 3 is a flowchart showing a potential sequence of steps for a sleep quality scoring program in one example of the present disclosure.

FIG. 4A is a sleep details report in one example of the present disclosure.

FIG. 4B is a sleep consistency report in one example of the present disclosure.

FIG. 5 is a full sleep details report in one example of the present disclosure.

DETAILED DESCRIPTION

It should be understood that the following descriptions are not intended to limit the disclosure to an exemplary implementation. To the contrary, it is intended to cover alternatives, modifications, and equivalents as may be included within the spirit and scope of the described subject matter.

FIGS. 1A-1C are front perspective views of a sleep scoring device 1 in three examples of the present disclosure. As shown, a sleep scoring device 1 may include a housing 3, a display screen 5, speakers 7, and buttons 8 or a touchscreen 9 for inputting information into the sleep scoring device. A wide variety of forms may be utilized for a sleep scoring device, including a rectangular shape (e.g. FIG. 1A), an elongate cylindrical tower (e.g. FIG. 1B), or a flat square shape (e.g. FIG. 1C). However, as one of ordinary skill in the art will appreciate, any suitable form factor may be utilized that may be suitable for being placed nearby a user while sleeping, such as on a night stand, for example. In such examples, housing 3 may be formed into a suitable shape from any rigid materials, including plastics, metals, wood, or composites.

In some examples, display screen 5 may provide biometric or sleep information gathered by sleep scoring device 1 that may be of interest to a user. Such information may include information regarding the user's biometrics observed during sleep periods, such as information regarding the user's presence, heart rate, heart rate variability, respiratory rate, ambient temperature, movement, snoring, or sleep state over time. This may be direct information or derived information. In some examples, display screen 5 may also include a clock as shown, in FIGS. 1A-1C.

Speakers 7 may comprise any suitable speaker system for generating sounds, as may be familiar to one of ordinary skill in the art. In some examples, speakers 7 may comprise an upwards firing driver along with an acoustic deflector, to provide an omni-directional acoustical experience. Such configurations may be helpful for providing non-directional, room-filling sounds for a soundscape or a white noise while a user is sleeping. Omni-directional sounds systems may be particularly helpful to achieve soothing sounds, a natural wake-up experience, or a consistent listening experience throughout the room. As one of ordinary skill in the art will appreciate, any acceptable sound system for speakers 7 may be employed for producing room-filling sounds, however.

Touchscreen 9 or buttons 8 may comprise any suitable means for delivering inputs to sleep scoring device 1, including a tactile sensor coupled to a surface of housing 3 for detecting the presence of a user's fingers and for detecting pressure, such as when a virtual button on touchscreen 9 is being pressed by a user. Virtual buttons may be displayed on touchpad 9 in a manner familiar to one of ordinary skill in the art in order to allow an operating system to accept input commands from a user. In this manner, sleep scoring device 1 may be configured to accept input commands in a variety of ways and in a variety of contexts, by providing a programmable user interface that may present options and choices to a user via touchpad 9. In other examples, touchscreen 9 may present a permanent display of fixed virtual buttons or include fixed physical buttons 8 for receiving inputs from a user.

In some examples, display screen 5 and a touchscreen 9 may not be necessary or may be reduced in function because a user's smartphone or other external computing device may be used for linking with sleep scoring device 1, displaying information from sleep scoring device 1, accepting inputs, and delivering them to sleep scoring device 1 in order to control its functions. In such a configuration, the display screen 5 and touchscreen 9, if any, may display and control only typical bedside clock-related functions, such as time, alarm, and music selection, or a simplified component of the sleep score, such as just a total score value, may be displayed.

FIG. 2 provides an exemplary schematic of a sleep scoring device, showing its components. As shown, sleep scoring device 1 may include one or more main board(s) 13, including a processor 15, memory 11, and interconnects 12. Main board 13 controls the operation of several other connected components, such as a microphone 10, display screen 5, audio amplifier 6, speakers 7, and buttons 8 or a touchscreen 9 for inputting information into the sleep scoring device. Communications hardware 17 may include any wired or wireless communication means suitable for use with a sleep scoring device, such as WiFi, Bluetooth, USB, micro USB, or any suitable wired or wireless communications technologies known to one of ordinary skill in the art. Main board 13 also receives information from biometric sensor 19 as well as any number of environmental sensors 18, for detecting environmental conditions, such as temperature, humidity, ambient light, and air quality. Main board 13 also receives inputs based on a user's interactions with a user interface 14, which may include voice-activated commands detected by microphone 10; various audio, alarm, and sleep control inputs received from buttons 8 or touchscreen 9; or inputs received from a companion application running on a user's smart phone or other external computing device. The communications hardware 17 may also provide communications with external data sources, such as weather reports,

and connected home services providing access to such things as lights, thermostat, locks, and any of the sensors **18**.

Microphone **10** may be any suitable microphone for detecting and sampling sounds within a user's bedroom or sleep space, as is known to one of ordinary skill in the art. In some examples, microphone **10** may be an arrayed microphone that is suitable for distinguishing between sounds produced by sleep scoring device **1** and sounds produced externally within the user's bedroom or sleep space. In examples where microphone **10** comprises an arrayed microphone, it may comprise a plurality of omnidirectional microphones, directional microphones, or any mixture thereof, distributed about sleep scoring device **1**. Microphone **10** may be coupled to processor **15** for simultaneous processing of the signals from each individual microphone in a manner familiar to one of ordinary skill in the art in order to distinguish between sounds produced by sleep scoring device **1** and other sounds within the room and to analyze any external noises for use with sound-masking subroutine **27**, as discussed below. Microphone **10** may employ beamforming or other techniques to achieve directionality in a particular direction, for example, towards a sound to be analyzed. Microphone **10** may be employed both for monitoring the user's sleep and for receiving spoken user interface commands.

Biometric sensor **19** remotely detects information about a nearby user, including bed presence, respiration rate, heart rate, or a sleep state among other biometric indicators. In some examples, biometric sensor **19** may be a contactless biometric sensor which may use an RF sensor for directing RF signals towards a user, measuring the strength of the backscattered signal, and analyzing the backscattered signal to determine the state of various vital signs of a user over time. Other contactless biometric techniques may include lasers for measuring minor skin deflections caused by a user's heart rate and blood pressure; or image-based monitoring systems, whereby skin deflections caused by heartbeats and blood pressure may be observed and analyzed over time through a camera. Biometric sensor **19** may be configured to report detected biometric information to processor **15** for storage in memory **11** and to be analyzed for use in the various subroutines described herein.

In other examples, sleep scoring device **1** may also employ a direct biometric sensor as is known to one of ordinary skill in the art. A direct biometric sensor may include probes or contact pads, that may be disposed on or under the user's body or within their mattress or sheets in order to mechanically detect biometric information, such as movement, respiration, heart rate, heart rate variability, blood pressure, and temperature, among others. Such sensors may include accelerometers, other motion sensors, or mechanical sensors such as piezoelectric sensors or other vibration sensors. The biometric information detected by the probes may then be communicated to sleep scoring device **1** using a wired or wireless connection in a manner known to one of ordinary skill in the art. In some examples, a biometric sensor may be placed within earbuds worn by a user. Other implementations may combine both contactless and direct biometric sensors. Mechanical sensors that measure the body through an intervening medium, such as bedding, are included in the category of "contactless" biometric sensors.

Referring now to FIG. **3**, in some examples, processor **15** may initiate a sleep monitoring program **21** that includes a series of steps or subroutines to monitor, analyze, and record metrics regarding a user's sleep during sleep sessions. In a first step (box **301** in FIG. **3**), sleep scoring device **1** is

activated, along with processor **15**, which may initialize sleep monitoring program **21**. Sleep monitoring program **21** may run on a continuous basis or by default. In some examples, a user may be able to selectively deactivate sleep monitoring program **21** when it is not necessary. In a second step (box **302**), processor **15** may determine whether a user is present within their bed or sleep space, which information, along with the relevant time, may be logged in a sleep record **23**. Sleep record **23** may be a database for storing and retrieving information relating to a user's sleep throughout a sleep session. Information regarding a user's presence in bed may be useful for providing metrics regarding time spent awake in bed versus time spent sleeping. In other implementations it may be advantageous to periodically monitor only for a user's presence in order to maintain sleep scoring device **1** in a dormant mode in order to expend less power when continual biometric readings are not necessary. Preferably, a user's presence may be detected passively and without the need for a user to manually indicate that they are preparing for sleep (e.g. by pressing a button).

Once a user's presence has been detected, processor **15** may cause user interface screen **5** or an external computing device to solicit user information about their initial sleep conditions in a second step. For example, information regarding the current state of the user or the sleep space may be solicited in a form or via dropdown menus and the like. For example, processor **15** may solicit information regarding what the user ate or drank during the day or before bed, whether the bedroom windows are open, whether a user has showered, whether a user has brushed their teeth, whether the user has recently watched television or read a book, or any other situational information which may be relevant to a user's sleep quality. Any information received by processor **15** through the solicitation process may be logged within sleep record **23**. In some instances a user may not wish to fill out a questionnaire regarding their pre-sleep conditions. However, in such instances, processor **15** may employ a user's default settings or simply disregard any omitted initial sleep conditions within sleep record **23** for the current sleep session. Processor **15** may also receive initial sleep conditions either sporadically or consistently without adversely impacting the functionality of the device, but it may be advantageous to input particular information with more diligence during periods when a user is deliberately experimenting with pre-sleep habits, as such information may be useful for providing more effecting sleep coaching, as discussed below. Once baseline information is determined or stable routines are established, it may be preferable to minimize user interaction with the system at the time the user is going to bed. It may also be preferable to minimize interaction when first using the system, so that the user becomes comfortable with the system and develops the habit of allowing it to operate.

In other examples, processor **15** may communicate with external systems, at step **2**, in order to retrieve information relevant to a user's day or habits that may be relevant to sleep quality. For example, processor **15** may communicate with exercise tracking applications, such as a database associated with a wearable exercise-tracking device, or other databases for tracking eating habits or other daily activities, such as an online calendar. Home automation systems may also provide information about the state of any windows, the internal temperature, and light levels, to name a few examples. External information may also be gathered and recorded, such as the time of sunset at the user's location and

the weather for the day. Any information potentially relevant to sleep quality may be downloaded and stored within sleep record **23** for later analysis.

Once a user's presence has been detected, processor **15** may also begin actively monitoring a user's biometrics on a continual basis in a third step (box **303**) in order to determine when a user has fallen asleep. To do so, processor **15** may read signals from biometric sensor **19** to determine whether there has been a measurable change in heart rate, respiration, body movements, or any other biometric indicator of sleep known to one of ordinary skill in the art. Once sleep has been detected, processor **15** may log the time of sleep initiation in sleep record **23** (box **303A**).

Once the user has fallen asleep, processor **15** may begin actively monitoring the current sleep conditions throughout the sleep session in a fourth step (box **304**). Current sleep conditions may comprise any combination of biometric and environmental variables relevant to sleep which may be measured throughout a sleep session. A user's biometrics may be received from biometric sensor **19** on a continual basis in order to record any relevant variables for tracking the overall quality of a user's sleep over time. For example, variables affecting or indicative of the quality of a user's sleep may include the user's heartrate, respiration rate, any bodily movement, body temperature, blood pressure, or any other biometric information that may be relevant to sleep quality may be monitored by biometric sensor **19** and recorded in sleep record **23** throughout a sleep session (box **304A**).

Bedroom environmental variables potentially affecting sleep may also be continually monitored and logged. For example, processor **15** may utilize microphone **10** for monitoring the noise levels or sound attributes within a room or sleep space and may continually log such information in sleep record **23**. Microphone **10** may also be utilized by processor **15** to monitor and log any instances of snoring, suspected sleep apnea, sleep talking, or any other events detectable by sound during a sleep session. Instances of such detected noise events may also be detected by processor **15**, characterized (in terms of noise level or magnitude), and logged within sleep record **23**. Processor **15** may also be configured to record the associated sound(s) for later playback by a user in order to identify any sleep-disruptive sounds and potentially prevent them from reoccurring.

Processor **15** may also receive information from environmental sensors **18**, regarding temperature, humidity, ambient light, or other atmospheric conditions within the bedroom. In other examples, environmental sensors **18** may provide information regarding air quality monitors in order to assess the levels of any detectable air pollutants within the sleep space. In other implementations, such information regarding environmental or climate conditions may be gathered through integration with a home-automation system, which may also track and communicate information to processor **15** regarding the temperature readings or thermostat settings within a bedroom or sleep space, along with any other potentially relevant information regarding the home which may impact sleep. Environmental factors may also be gathered from publicly available sources, such as online databases containing local weather, pollution, pollen, seasonal information, or moon phases. Any potentially relevant environmental factors may be received by processor **15** and stored within sleep record **23**.

Processor **15** may also accept mechanical indicators of sleep quality. For example, any interactions with the sleep scoring device, itself, may be monitored and logged in sleep record **23**, such as instances when a snooze button is

depressed or any other settings are adjusted during periods of light sleep or wakefulness. Any interactions with linked, external devices, such as a phone or external computing device, or adjustable aspects of the bed, such as firmness or the temperature of a heating pad, may likewise be monitored by sleep scoring device **1** and any interactions may similarly be logged.

While a user is sleeping, processor **15** may also continually receive information regarding a user's progression through various sleep stages in a fifth step (box **305**). As one of ordinary skill in the art will appreciate, sleepers typically progress through five stages—stages 1, 2, 3, and 4 (often referred to collectively as non-rapid eye movement or “N-REM” sleep) and rapid eye movement or “REM sleep.” Throughout a sleep session, biometric sensor **19** may continually monitor a user's progression through these sleep stages either through direct observation or by determining the likely present sleep stage through observation of other biometric factors, such as heartrate, respiration, and blood pressure. As a user progresses through each sleep cycle, processor **15** may continue to log the present sleep stage over time (box **305A**). In other examples, sleep scoring device **1** may not be able to differentiate fully between the above-referenced sleep stages and may instead monitor for and record instances of “light” or “deep” sleep, which may be determined based on analysis of the available biometric indicators in any manner known to one of ordinary skill in the art.

At a sixth step, processor **15** may determine whether a user has awoken, based on the same information used to determine that a user has fallen asleep, such as a measurable change in heart rate, respiration, body movements, or any other biometric indicator of sleep known to one of ordinary skill in the art (box **306**). Once a user is detected as having awoken, processor **15** may log the time of waking in sleep record **23** (box **306A**) and sleep monitoring program **21** may return to the third step, described above, and begin monitoring whether a user returns to sleep. If processor **15** detects that a user has left the bed or sleep space for more than a brief period of time without returning, the processor may terminate sleep monitoring program **21** and return to an inactive mode whereby biometric sensor **19** only periodically checks to determine whether a user is present.

Once a sleep session has concluded, processor **15** may generate a sleep details report **25**, which may be viewable on user interface screen **5** or an external computing device. FIG. **4A** is an example of sleep detail report in one example of the present disclosure. As shown, processor **15** may provide a sleep details report, including a graphical sleep score **27**, depicting the overall quality of a user's sleep on that date, as recorded by the system. In some examples graphical sleep score **27** may have color-coded bars representing sleep criteria, such as the duration of the sleep, the quality of the sleep, or the consistency of the sleep, which may all contribute to an overall sleep score. Where available, sleep statistics **29** may also be displayed, such as the amount of light sleep, REM sleep, or deep sleep observed during the prior sleep session. Processor **15** may also include a hypnogram **31** within sleep details report **25**, which may provide another graphical depiction of the depth of a user's sleep throughout the night. In some examples hypnogram **31** may be presented by a color-coded time graph representing periods of absence, waking, light sleep, REM sleep, or deep sleep along an x-axis. Different heights along a y-axis may correspond to the relative depth of the sleep during that timeframe. Processor **15** may also include basic information regarding the sleep session within sleep details report **25**,

such as the sleep timeframe **33** or a sleep duration **35**. Where available, buttons **37** may be used to view sleep details reports for other available days recorded within sleep record **23**. In other examples, a user may select a date range encompassing a plurality of sleep sessions in order to view relevant sleep statistics within that range, such as the average sleep score, duration, or quality, among others. For example, button **41** may allow users to view sleep details for a single day, whereas button **43** may allow users to see comparative sleep data over multiple days. The data may be available from the sleep system itself, stored in the device implementing the user interface, or retrieved on-demand from a networked resource.

FIG. **4B** shows an example of a sleep consistency report **45** in an example of the present disclosure that may be an example of a report spanning multiple days, which may be accessed by selecting button **43** in FIG. **4A**, as previously discussed. In this example, a sleep consistency report **45** provides a graphical representation of a user's observed sleep patterns over multiple days. For example, each sleep session is depicted for multiple days in rows corresponding to separate dates. The sleep sessions are depicted as lines with multiple segments, including an in-bed segment **47** which corresponds to times where the user was detected as being in bed, a sleeping segment **49**, which corresponds to times when a user was detected as being asleep, and an waking segment, **51**, which corresponds to times when a user was detected as waking from sleep. In some examples, these line segments may be color-coded lines representing the duration of each sleep segment. In this example, the actual colors used and are not shown; color is only used to help visually distinguish the sleep segments, and is redundant with their relative position.

A horizontal time bar **53** may also be included within sleep consistency report **45** to depict the timeframe for any given sleep event or sleep segment within the consistency report. To aid the user in quickly assessing their sleep consistency across multiple days, a vertical time line **55** may also be depicted, which traverses the sleep segments and allows for visual comparison of a user's detected sleep state at the same time on multiple nights. In some implementations, the time line may be fixed at the middle of time bar **53** and the time line **55** may be moved by either dragging the time bar **53** to a desired position or touching a specific hour within the time bar.

In some examples, processor **15** may also provide a full details report **39**, as shown in FIG. **5**, which may be accessed by selecting a button or link within sleep details report **25**. In some examples, graphical sleep score **27** may serve as a link to a full details report **39**. Processor **15** may present a user with further details regarding the data and methodology supporting their sleep score for the selected sleep session in full details report **39**. As shown in FIG. **5**, a sleep score may be based, in some examples, on three basic sleep criteria, including duration, quality, and consistency. Processor **15** may calculate sleep duration based on the elapsed time of a user's sleep session, with a perfect score reserved for the upper limit of medically recommended amounts of sleep, which may be eight or nine hours or more. Processor **15** determine sleep quality based on several sub-factors, such as latency (e.g. the speed with which a user falls asleep), the number of observed waking events, the amount of observed REM sleep, the amount of observed deep sleep, or any observed mechanical interactions, such as snoozes. These factors may contribute to an overall sleep score using any suitable methodology for scoring and weighting these or any other relevant sleep quality criteria. Finally, processor **15**

may calculate sleep consistency based on the overall similarities between sleeping and waking times of a user or any other sleep factors which may be compared night-to-night, based on information stored in sleep record **23**. While the present disclosure depicts sleep scoring based on the criteria of duration, quality, and consistency, any combinations of sleep criteria known to one of ordinary skill in the art may be evaluated to determine an overall sleep score.

Any available information may also be viewed, reported, access, compared, or exported from sleep record **23** in any suitable manner known to one of ordinary skill in the art. For example, processor **15** may generate additional reports from sleep record **23** on a daily, weekly, monthly, or yearly basis and may provide a graphical depiction of a user's sleep score alongside any other tracked information stored in sleep record **23**, such as recorded sound levels, average caffeine consumption, daily exercise or calorie intake. Such graphical representations of a user's sleep score alongside information relating to a user's environmental factors or habits may allow a user to identify factors that may be adversely affecting sleep. These reports may be selectively generated for a user or may be periodically communicated to a user via user interface **5**, email, or via a companion application on an external computing device.

In some examples of this disclosure, processor **15** may also execute a "sleep coaching" engine **41**. Through sleep coaching engine **41**, processor **15** may periodically analyze the user's sleep history (including biometric, environmental, and user-input variables) in order to identify potential correlations between such variables and instances of diminished or sub-optimal sleep scoring. Processor **15** may also compare observations against publicly available databases of known conditions that may influence sleep in order to identify potential sleep conditions or known solutions to sleep problems. After periodically analyzing the user's sleep data, processor **15** may communicate its findings or suggestions for changes a user can make to improve their sleep, for example through adjusting settings of sleep scoring device **1**, itself, adjusting other aspects of the environment, such as thermostat settings, or by recommending that the user alter behaviors that may be adversely affecting sleep. In other instances of the sleep coaching engine **41**, processor **15** may proactively assess sleep conditions at the beginning of a sleep session or using publicly available information about upcoming environmental factors to make emergency recommendations when a user is preparing to sleep. For example, if a user or a home automation system indicates that a window is open and other information indicates that rain or a high pollen count is predicted during the upcoming sleep session, processor **15** may send an emergency warning to a user to shut their window. Of course, such periodic interactions may be limited or deactivated by a user according to their preferences.

One of skill in the art will appreciate that the systems, methods and apparatuses outlined above may include various hardware and operating software, familiar to those of skill in the art, for running software programs as well as communicating with and operating any devices, including, for example, a biometric sensor, environmental sensors, a user interface, a computer network, a sound system, and any other internal or external devices. Such computerized systems may also include memory and storage media, and other internal and external components which may be used for carrying out the operations of this disclosure. Moreover, such computer systems may include one or more processors for processing and controlling the operation of the computer system, thus, embodying the processes of this disclosure. To

that end, the processor, associated hardware and communications systems may carry out the various examples presented herein.

While the disclosed subject matter is described herein in terms of certain exemplary implementations, those skilled in the art will recognize that various modifications and improvements can be made to the disclosed subject matter without departing from the scope thereof. As such, the particular features claimed below and disclosed above can be combined with each other in other manners within the scope of the disclosed subject matter such that the disclosed subject matter should be recognized as also specifically directed to other implementations having any other possible permutations and combinations. It will be apparent to those skilled in the art that various modifications and variations can be made in the systems and methods of the disclosed subject matter without departing from the spirit or scope of the disclosed subject matter. Thus, it is intended that the disclosed subject matter include modifications and variations that are within the scope of the appended claims and their equivalents.

What is claimed:

1. A sleep scoring device comprising:
 - a contactless biometric sensor for determining at least one of a heart rate, a respiratory rate, a presence of a user, or movement of the user;
 - a processor;
 - memory; and
 - a microphone;
 wherein said processor is configured to, during a sleep session, detect the user's sleep state by reading signals from said contactless biometric sensor based on at least one of a detected change in heartrate, body movement, or respiration, log information in a sleep record, including biometric information relating to the quality of the user's sleep and environmental factors that may affect the quality of the user's sleep, generate and display a numerical sleep score for said sleep session based on consistency of the logged information with corresponding information logged on previous days, and generate a sleep consistency report based on the sleep record, the sleep consistency report illustrating comparative sleep data of the user over multiple days as graphical representations of sleep patterns of the user, each graphical representation being representative of sleep patterns of the user in a single sleep session.
2. The sleep scoring device of claim 1, wherein said processor is further configured to detect sleep stages and to log a start time and a stop time of said sleep stages in said sleep record.
3. The sleep scoring device of claim 2, wherein said sleep stages comprise at least one of REM sleep, N-REM sleep, deep sleep, light sleep, stage 1 sleep, stage 2 sleep, stage 3 sleep, or stage 4 sleep.
4. The sleep scoring device of claim 3, wherein said environmental factors comprise one or more of temperature, noise levels, air pressure, air pollution, or light levels.
5. The sleep scoring device of claim 4, wherein said processor is further configured to record detected sounds when sounds are detected at or near a same time as a detected wake-up event of the user.
6. The sleep scoring device of claim 1, wherein said processor is further configured to log one or more sleep start times and one or more sleep stop times.

7. The sleep scoring device of claim 6, wherein said processor is further configured to detect the user's presence in a sleep space and to log a time the user entered the sleep space in said sleep record.

8. The sleep scoring device of claim 1, wherein said processor is further configured to receive information regarding at least one of said environmental factors from an external database.

9. The sleep scoring device of claim 8, wherein said external database comprises a weather database, a health database, a fitness database, or a calendar database.

10. The sleep scoring device of claim 1, wherein said processor is further configured to generate the sleep score based on at least one of a detected duration of the sleep or the quality of the sleep.

11. The sleep scoring device of claim 10, wherein the quality of the sleep is determined based on one or more of a detected latency of the sleep session, a number of detected waking events during the sleep session, an amount of REM sleep detected during the sleep session, an amount of deep sleep detected during the sleep session, or a number of times a snooze button was pressed during the sleep session.

12. The sleep scoring device of claim 1, wherein said processor is further configured to solicit external sleep factors from the user.

13. The sleep scoring device of claim 1, wherein said processor is further configured to analyze information in said sleep record and to identify potential corollaries between instances of sub-optimal sleep and said biometric information, said environmental factors, or external sleep factors.

14. The sleep scoring device of claim 1, wherein said processor is further configured to generate the sleep score based on at least on a number of times a snooze button was pressed during the sleep session.

15. A method for monitoring and scoring sleep comprising:

- receiving a plurality of biometric readings of a user from a contactless biometric sensor;
- recording said plurality of biometric readings within a sleep record;
- determining said user's sleep state based on said plurality of biometric readings;
- logging said user's sleep state within said sleep record;
- determining and displaying a numerical sleep score based, at least in part, on consistency of the logged information with corresponding information logged on previous days; and
- generating a sleep consistency report based on the sleep record, the sleep consistency report illustrating comparative sleep data of the user over multiple days, the sleep consistency report including graphical representations of sleep patterns of the user for multiple respective days, each graphical representation being representative of sleep patterns of the user in a single sleep session.

16. The method for monitoring and scoring sleep of claim 15, further comprising detecting said user's presence in a sleep space based on said plurality of biometric readings and recording the user's presence in said sleep record.

17. The method for monitoring and scoring sleep of claim 16, further comprising detecting sleep stages based on said plurality of biometric readings and recording said sleep stages in said sleep record.

18. The method for monitoring and scoring sleep of claim 17, wherein said sleep stages comprise at least one of REM

13

sleep, N-REM sleep, deep sleep, light sleep, stage 1 sleep, stage 2 sleep, stage 3 sleep, or stage 4 sleep.

19. The method for monitoring and scoring sleep of claim 15, further comprising:

- receiving a plurality of environmental readings including at least one of a sound level, a light level, an air quality reading, or a temperature; and
- recording said plurality of environmental readings in the sleep record.

20. The method for monitoring and scoring sleep of claim 19, further comprising receiving external sleep factors and recording them in said sleep record.

21. The method for monitoring and scoring sleep of claim 20, further comprising analyzing information in said sleep record and identifying potential corollaries between instances of sub-optimal sleep and said plurality of environmental readings, said plurality of biometric readings, or said external sleep factors.

- 22. A sleep monitoring and scoring system comprising: a biometric sensor; a microphone; memory; and

14

a processor, coupled to the biometric sensor, the memory, and the microphone, the processor being configured to detect a user's sleep state during a sleep session by reading signals from said contactless biometric sensor based on at least one of a detected change in heartrate, body movement, or respiration, and wherein said processor is further configured to log information in a sleep record, including biometric information relating to the quality of a user's sleep and environmental factors that may affect the quality of a user's sleep, to generate and display a numerical sleep score for said sleep session based on consistency of the logged information with corresponding information logged on previous days, and to generate a sleep consistency report based on the sleep record, the sleep consistency report illustrating comparative sleep data of the user over multiple days, the sleep consistency report including graphical representations of sleep patterns of the user for multiple respective days, each graphical representation being representative of sleep patterns of the user in a single sleep session.

* * * * *

专利名称(译)	睡眠质量评分和改善		
公开(公告)号	US10517527	公开(公告)日	2019-12-31
申请号	US15/267464	申请日	2016-09-16
[标]申请(专利权)人(译)	伯斯有限公司		
申请(专利权)人(译)	Bose公司		
当前申请(专利权)人(译)	Bose公司		
[标]发明人	WARE LAURA FREED JONATHAN READ JACK REICH DEBRA KESHAVAN LEELA MULCAHEY BRIAN DAVID		
发明人	WARE, LAURA FREED, JONATHAN READ, JACK REICH, DEBRA KESHAVAN, LEELA MULCAHEY, BRIAN DAVID		
IPC分类号	A61B5/00 A61B5/0205 A61B7/04 A61B5/024 A61B5/11 A61B5/08		
CPC分类号	A61B5/4815 A61B5/0205 A61B7/04 A61B5/4812 A61B5/4809 A61B5/7278 A61B5/0816 A61B5/1115 A61B5/024 A61B2560/0257 A61B2560/0475 A61B2560/0252 A61B5/02055 A61B5/113 A61B7/003 A61B2560/0242 G16H15/00 G16H40/63 G16H50/20 G16H50/30		
其他公开文献	US20180078197A1		
外部链接	Espacenet		

摘要(译)

提供一种睡眠计分装置，用于包括非接触式生物统计传感器，处理器，存储器和麦克风。睡眠计分装置可以通过基于检测到的心率变化，身体运动或呼吸变化中的至少一种，从非接触式生物统计传感器读取信号来检测用户的睡眠状态，并记录生物信息。睡眠计分设备还可以基于睡眠会话的等待时间，检测到的唤醒事件的数量，REM睡眠的数量，深度睡眠的数量或贪睡按钮的次数来生成睡眠会话的睡眠分数。在睡眠过程中被按下。

