EEG monitoring apparatus and method for presenting messages therein

The present invention relates to a portable EEG monitoring apparatus, in particular but not exclusively a portable EEG monitoring apparatus adapted to be carried continuously by a person being monitored. The invention furthermore relates to a method of presenting messages in such a portable EEG monitoring device.

EEG is the commonly used abbreviation for Electro Encephalo-Gram, which is generally speaking a method of electrically monitoring brain activity of a person. Systems for monitoring EEGs have been known for many years. However with the general technological development, EEG monitoring systems, which may be carried or worn continuously by a person to be monitored, have been devised.

One such system is known from the document WO-A-2006/066577, where blood sugar levels are monitored in a person suffering from diabetes in order to warn against hypoglycaemic attacks. Low blood sugar levels have severe influences on the brain activity and too low blood sugar levels may lead to unconsciousness and even death. The system disclosed WO-A-2006/066577 is a fully implanted subcutaneous system. The implanted electrodes are via electrical leads connected to a monitoring device capable of detecting the brainwaves characteristic for an imminent hypoglycaemic attack, and issuing a warning in the form of a vibration of the subcutaneous monitoring device. In WO-A-2006/066577 it is furthermore suggested that the implant may wirelessly communicate with an external unit, which may contain the more power demanding parts of the electronics, so as to obtain a long battery service life of the implanted subcutaneous parts. It is stated that this will also allow an acoustic warning, but WO-A-2006/066577 does not disclose any details on how.

Based on this prior art it is the overall object of the present invention, to provide an improved system vis-à-vis the prior art system, in particular regarding the acoustic warning of the person carrying the apparatus.

According to a first aspect of the invention this object is achieved by a portable EEG monitoring apparatus, said apparatus comprising: EEG pick-up means adapted for measuring at least one EEG signal from the person carrying the apparatus, a signal processing means for analysing said at least one EEG signal and adapted to identify or predict predetermined biological incidents in said person based on said analysis, a decision means adapted to decide when information is to be presented to said person, a message selection means for selecting a voice message providing said person with information, and an acoustic transducer adapted for presenting the selected voice message to the person.

According to a second aspect of the invention there is provided a method for presenting voice messages in a portable EEG monitoring apparatus, said method comprising measuring at least one EEG signal from the person carrying the apparatus using an EEG pick-up means, analysing said at least one EEG signal using a signal processing means adapted to identify or predict predetermined biological incidents in said person based on said analysis, deciding, using a decision means, when information is to be presented to said person, selecting, using a message selection means, a voice message providing said person with information, and presenting the selected voice message to the person using an acoustic transducer.

Using a voice message rather than, e.g. a simple warning tone, has many advantages. A major advantage, however, is that a voice message, such as a spoken warning is far more pervasive in getting the attention of the person addressed, and far easier for the person to respond correctly to. Bearing in mind that the purpose of the EEG monitoring is in first instance to warn the person about threatening biological incidents such as imminent hypoglycaemic seizure, it is very likely that the warning issued by the apparatus is issued at a time where the person is already no longer at his full mental capacity or even on the verge of unconsciousness. An voice message is in this situation not only far more efficient in alerting the person, but may moreover actually contain direct instructions regarding the corrective actions to be performed, in order to

avoid the threatening condition. Thus, the person who may already be partially mentally incapacitated, will not only get an alarm at a time where he is no longer capable of remembering what the correct corrective actions are and how to perform these, but will get a voice message reminding him of he correct corrective actions. Thus, according to a preferred embodiment said voice message relates to said biological incident.

According to a preferred embodiment of the first aspect of the invention, said voice messages are stored in the apparatus. Storing the voice messages in the apparatus obviates the need of carrying any further devices, or the need of a synthetic voice generator.

According to a further preferred embodiment of the first aspect of the invention, the voice messages are formatted into a format suitable for storage and replay in the apparatus. This reduces the need for storage space, and may thus allow for an overall size reduction, or the storage of a larger variety of voice messages.

According to another embodiment of the first aspect of the invention, said voice messages have been edited in accordance with the hearing capabilities of said person. Editing the voice messages allow built-in adaptation of the messages to a specific hearing loss of the person. This, in turn, increases the intelligibility of the voice message.

According to yet another embodiment of the first aspect of the invention, the apparatus comprises means for adjusting the presented voice message to the current ambient acoustic noise level when presenting the message. This further enhances intelligibility of the message.

According to a further embodiment of the first aspect of the invention, the apparatus comprises means for allowing the person carrying the apparatus to store messages therein in accordance with the persons own choice. This allows the carrying the apparatus to choose straight forward easy to understand messages.

According to yet a further embodiment of the first aspect of the invention, the apparatus is adapted to present the voice message in the ear of the person. Presenting the message directly in the ear of the user is advantageous in that it reduces external disturbances such as ambient noise. Moreover, it is advantageous in that it allows the EEG monitoring

apparatus to further comprise the functionalities of a hearing aid or form part of a hearing aid.

According to another embodiment of the first aspect of the invention, the apparatus comprises means for the person carrying the apparatus to acknowledge the presented message. Hereby it becomes possible to ensure that the person carrying the apparatus has actually heard the message, and if necessary repeat the message until it has been acknowledged, possibly with increased volume.

According to yet another embodiment of the first aspect of the invention, the apparatus is further adapted to present voice messages relating to the handling of the apparatus. This aid the person carrying the apparatus in the handling and use thereof, e.g. when placing the apparatus in the ear.

Embodiments of the method according to the second aspect of the invention generally provide the same advantages as the embodiments according to the first aspect.

The invention will now be described in greater detail based on non-limiting exemplary embodiments and the drawing, on which:

Fig. 1 depicts a head of a person with an EEG monitoring apparatus according to the invention,

Fig. 2 depicts a block diagram of the EEG monitoring apparatus according to Fig. 1,

Fig. 3 illustrates the storage and retrieval of messages in the EEG monitoring apparatus of Fig. 2,

Fig. 4 depicts a state diagram of the user interface of the EEG monitoring apparatus according to Fig. 2.

Fig. 1 schematically shows a head 1 of a person carrying an EEG monitoring apparatus 2 according to the invention. The EEG monitoring apparatus 2 comprises an implant unit 3 for measuring EEG's. The implant unit 3 is located subcutaneously behind the ear 4 of a person. The implant unit 3 comprises an electronics part 5 and EEG pick-up means 6 such as probe with at least two electrodes (not shown) for picking up electrical EEG signals from the brain of the person. The electronics part 5 of the implant unit 3 comprises the necessary electronics for sampling

the EEG signals measured by the electrodes of the EEG pick-up means 6 and transmitting them wirelessly to an external unit 7 forming part of the EEG monitoring apparatus 2. Preferably, the energy supply to the implant unit 3 is received inductively from the external unit 7, so that the implant unit 3 has a long service life, not constrained by battery capacity, which is advantageous since a replacement of the battery would necessitate a surgical procedure for replacement of the whole implant unit 3.

As can be seen the external unit 7 may resemble a Behind-The-Ear hearing aid (BTE hearing aid), comprising a housing part 8, which in normal use is placed behind an ear 4 of the person carrying the EEG monitoring apparatus 2. Like a BTE hearing aid, the housing part 8 is connected to an earplug 9 in the ear canal of the person via an intermediate connection 10. This could be a traditional sound tube leading to an earplug, or an electrical cord leading to a Receiver In The Ear type earplug (RITE earplug). This allows the external unit 7 to give off messages, such as alarms or warnings, into the ear 4 of the person carrying the EEG monitoring apparatus 2.

As indicated, the EEG monitoring apparatus 2 may optionally include a peripheral device 11, which as will be explained later may comprise additional and possibly more energy consuming electronic storage space for data.

Turning now to Fig. 2, the internal details of the external unit 7 of the EGG monitoring apparatus 2 are schematically shown. The external unit 7 comprises a health state monitor 12, comprising means for analysing an EEG signal received wirelessly from the implant unit 3, and for detecting anomalies in said EEG signal, in order to warn the person carrying the EEG monitoring apparatus 2 against health threatening conditions, such as e.g. hypoglycaemia or epileptic seizures. How this analysis is performed is not relevant for the present invention and will not be dealt with any further.

If a health threatening condition is detected the health state monitor 12 sends an appropriate signal to a device operating controller 13. The device operating controller 13 is also adapted for receiving other

input such as a signal indicating low battery level from a battery monitor 14 monitoring the battery 15, supplying the EEG monitoring apparatus 2, and a user input signal from a user button 16 comprising e.g. an electromechanical key switch 17.

The device operating controller 13 selects an appropriate message and settings for the message and sends a corresponding signal to an audio generator 18, which generates a message signal for an output converter 19, such as a DAC generating an output signal for an output transducer, such as a loudspeaker 20. As indicated above the loudspeaker could be placed in the housing 8 of the external device or it could be placed in the earplug 9, but it should be noted that the present invention is not limited to the use in BTE type devices, it could also be implemented in an In-The-Ear earplug (ITE earplug) or any other type of earplug known e.g. from hearing aids. The message signal or data relating thereto may pre stored in a non-volatile memory, such as an EEPROM 21.

Preferably, the EEG monitoring apparatus 2 also comprises means for monitoring ambient sound pressure level. In the illustrated embodiment, such means comprise a monitor microphone 22 delivering a signal to an input converter 23 such as an ADC. The input converter 23 delivers a signal to a sound pressure level monitor 24. The sound pressure level monitor 24 detects the ambient sound pressure level, and delivers a corresponding signal to the audio generator, 18, allowing the audio generator to adapt the volume settings for the signal to the output converter 19 in accordance with the ambient sound pressure level. Thus, it is ensured that the message signal delivered by the loudspeaker 20 has a volume level allowing it to be easily heard by the person carrying the EEG monitoring apparatus 2. At the same time it is ensured that the message is not presented with an excessive loudness in quiet surroundings, which could be both disturbing and uncomfortable for the person carrying the EEG monitoring apparatus 2. Evidently, the sound pressure level monitor need not be operative at all times. It is sufficient to sample the current sound pressure level for just a short time before presenting the message. Thus, power is saved.

Fig. 3 illustrates various messages stored in the non-volatile memory 21. Only five messages are illustrated, i.e. messages #1 to #4 and the last message #N, comprising typical warnings, such as "System OK", "Hypoglycaemia Warning", "Low Battery", "Press button to acknowledge" and "System Failure". These messages are retrieved from the non-volatile memory 21 by means of a control logic and address generator 25 in the device operating controller 13, addressing a desired message, or rather the data defining it, in the non-volatile memory and causing the corresponding message data to be sent to the audio generator 18, which produces the output signal to the output converter 19 on the basis thereof.

Depending on considerations such as the available storage, power consumption etc., the data defining the desired message and stored in the non-volatile memory may differ.

One way of storing the messages would be uncompressed digital audio, where the entire data stream necessary for the audio generator 18 to generate the signal to the output converter 19 is stored. In that case the audio generator 18 could generate a pulse code modulated signal for the output converter 19, which turns the pulse code modulated signal into an analog signal. However, because the dynamic range of speech is quite wide, the pulse code modulated signal could be a weighted signal such as an A-law or MU-law weighted signal, where the dynamic range is compressed before storage. The audio generator 18 would in that case also perform a corresponding expansion of the message signal.

An alternative could be compressed audio as is known from speech or audio codecs, where the compressed data signal is stored as data in the memory. Examples of such speech and audio codecs are; MPEG-1 (mp3), described in the standard ISO/IEC-11172 part 3, DPCM (Differential Pulse Code Modulation), ADPCM (Adaptive Differential Pulse Code Modulation), described in the standard ITU G.726, subband-ADPCM as described in the standard ITU G.722, or speech codecs as described in standards ITU G.729 or ITU G.728.

Also, instead of compressed audio based on a real speech sig-

nal, synthetic speech could be used. Synthetic speech can be generated from symbol-linguistic representations, such as phonemes or other symbol representation of basic building blocks of a speech signal. In that case these symbols are stored in the non-volatile memory 21, and the audio generator comprises a synthesizer, which synthesizes waveform signals based on the symbols. Such synthesizing will typically be based on a mapping from the symbol representation to waveform signals based on segments of a sampled speech signal.

In addition to the above methods, or possibly a combination thereof, the EEG monitoring apparatus may also comprise means for generating non-speech sounds, such as simple sounds like pure tones, or "pling", "boing", "bleep" or the like or sounds resembling musical instruments. Such sounds may be generated by an audio generator 18 comprising one or more tone generators and/or filters, e.g. impulse response filters or simple filters.

Fig. 4 shows a state diagram of the user interface of the EEG monitoring apparatus according to the invention. The diagram is simplified to illustrate only the most essential messages, but as will be understood from Fig. 3 there can be many more messages, adding of course to the complexity of the interface.

In Fig. 4 the following texts are used:

Message Mnemonic	**Message**
SysOK	"System OK"
LowBat	"Low battery"
HealthStateWarn	"Hypoglycaemia warning"
KeyToAck	"Press key to acknowledge

Timer	Timer Usage
T1	Timer for repeating unacknowledged messages
T2	Timer for repeating warnings from health state monitor
T3	Battery alarm timer

User Interface Input	Description
UserPressKey	User key press
LowBat	Low battery signal from battery monitor
HealthStateSig	Signal from health state monitor

The state diagram of Fig. 4 will now be described. However, for full explanation, reference to apparatus parts not shown in Fig. 4 is also made in the following description. Please refer to Figs. 1 and 2 for those reference numerals not found in Fig. 4.

Starting at the top of Fig. 4 the EEG monitoring apparatus 2 boots in box 100 when switched on. During booting, the EEG monitoring apparatus performs a number of self-tests, such as testing the functioning of the electrodes of the EEG pick-up means 6, and the communication link between the implant unit 3 and the external device 7. If the self-test is successful a true flag is set and, in box 101, the device operating controller 13 sends SysOK to the audio generator 18, which retrieves the message "System OK" in the non-volatile memory and presents it to the person carrying the EEG monitoring apparatus 2 via the output converter 19 and the speaker 20. The person carrying the EEG monitoring apparatus 2 thus receives confirmation that the EEG monitoring apparatus 2 is operating and functional. After the "System OK" message has been sent, the EEG monitoring apparatus 2 enters its normal state in box 102. In box 102, the person wearing the EEG monitoring apparatus can at any time activate the user push button 16 by pressing the key switch 17, which will lead to a new self-test and message in box 101.

If at any time the battery monitor 14 detects low battery, it sends the low battery signal, LowBat, to the device operating controller 13, or preferably sets it high as a flag for the device operating controller 13 to detect. Provided a timer T3 is not running, the device operating controller 13 sends LowBat to the audio generator 18, which retrieves the message "Low battery" in the non-volatile memory and, in box 103, presents it to the person carrying the EEG monitoring apparatus 2 via the output converter 19 and the speaker 20. At the same time the timer T3 is started. If the timer T3 is still running, i.e. has not timed out, LowBat is not sent to the to the audio generator. By proper selection of the time value of T3, the person carrying the EEG monitoring apparatus is thus prevented from hearing the "low battery" messages so frequently that it annoys him. Thus, at intervals corresponding to T3 the person carrying the EEG monitoring apparatus is repeatedly reminded to change the battery. When he eventually does so, the EEG monitoring apparatus 2 boots again in box 100.

If at any time the health state monitor 12 detects imminent hypoglycaemia, it sends the hypoglycaemia warning signal, HealthStateSig, to the device operating controller 13, or preferably sets it high as a flag for the operating controller 13 to detect. Provided a timer T2 is not running, the device operating controller 13 sends HealthStateWarn to the audio generator 18, which retrieves the message "Hypoglycaemia warning" in the non-volatile memory and, in box 104, presents it to the person carrying the EEG monitoring apparatus 2 via the output converter 19 and the speaker 20. At the same time a timer T1 is started. If the person carrying the EEG monitoring apparatus 2 activates the user push button 16 by pressing the key switch 17, the device operating controller receives the input UserKeyPress, which acknowledges that the user has heard the message presented to him. At the same time the timer T2 is started in box 105. If, in box 102 the timer T2 is still running, i.e. has not timed out, the user interface does not proceed from box 102 to 104 and the person carrying the EEG monitoring apparatus is thus prevented from hearing the "Hypoglycaemia warning" messages so frequently that

it annoys him, if he knows he does not yet need to take action or he is not in a position to take such action.

If the person carrying the EEG monitoring apparatus 2 does not acknowledge the message "Hypoglycaemia warning" the timer T1 will eventually time out and the interface will proceed from box 104 to 106. In box 106, the device operating controller 13 sends HealthStatWarn and KeyToAck to the audio generator 18, which sequentially retrieves the messages "Hypoglycaemia warning" and "Press key to acknowledge" and present them to the person carrying the EEG monitoring apparatus 2 via the output converter 19 and the speaker 20. At the same time the timer T1 is restarted. These two messages will then be repeated at intervals corresponding to the value of T1, which is preferably relatively short compared to T2, until either the person carrying the EEG monitoring apparatus 2 eventually activates the user push button 16 by pressing the key switch 17, or the signal or flag HealthStateWarn goes low, e.g. because the person carrying the EEG monitoring device has taken appropriate actions. In the former case, the interface proceeds to box 105, where the timer T2 is started, and back to box 102 where it remains until T2 times out as described above. In the latter case where HealthStateSig goes low, there is no danger any more and the interface returns to box 102 where it remains until changes occur. That is to say until the flags HealthStateSig or LowBat go high again, or until the user activates the push button 16 by pressing the key switch 17 in order to perform a self-test.

With such a user interface the EEG monitoring apparatus 2 gives off the alarm or warning to the person wearing the EEG monitoring apparatus 2, and does this repeatedly until the person has heard and responded to the warning. Since the alarm or warning is related to a life threatening condition it may be important to repeat the message frequently. A typical value for T1 could thus be less than a minute, e.g. 15 seconds. A typical value for T2, where the person carrying the EEG monitoring apparatus 2 has acknowledged the messages and is expected to take proper action, should be longer, e.g. several minutes. A typical value for T2 could be 10 to 15 minutes. T3 for the battery alarm could

depending of the criteria selected for the battery alarm be longer e.g. 1 to 2 hours or more.

In order to ensure that the person carrying the EEG monitoring apparatus 2 is not just missing the message by not hearing it, the volume could be increased with each repetition until it is acknowledged.

Though the interface above has been described only in relation to a simple structure with a few warning messages, the skilled person will realise that means for providing access to further messages could be realised, e.g. by activating the push button 16 by repeatedly pressing the key switch 17 twice or multiple times. The signal sent from the push button 16 to the device operating controller 13 depending on the number of times the key switch 17 is pressed. This could gain access to menu points and messages, where more data is provided to the person carrying the EEG monitoring apparatus 2. This is particularly interesting if the EEG data is logged over time. In such cases the user may learn more about when he typically has many warnings or the like. Also, it may provide access to the settings of the EEG monitoring apparatus 2, e.g. allowing the user to change alarm threshold, warning intervals, volume settings etc. Furthermore, the user may even use the menu to upload information externally to the peripheral device 11, with larger storage capacity, so as to store information about his daily behaviour in terms of blood sugar, so as to keep a diary about events and the like, or event to learn how to modify his behaviour.

The invention has been described above with reference to various specific embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims. In particular the skilled person will realise that instead of using a subcutaneous implant, it will also be possible to implement the messages in a fully external EEG monitoring apparatus, e.g. in an earplug or BTE device using external electrodes in contact with the skin, as well as in an external EEG monitoring apparatus having a wired connection to the implant.

The skilled person will also realise that sufficient electronic storage space may be provided in the EEG monitoring apparatus to store generic speech messages which may be altered or interchanged with other messages by means of a peripheral device 11 such as a mobile telephone.

Messages may also be provided for guiding the person carrying the EEG monitoring device through the mounting process, when puts it on and starts carrying it.

P A T E N T C L A I M S

1. A portable EEG monitoring apparatus, said apparatus comprising:

EEG pick-up means adapted for measuring at least one EEG signal from the person carrying the apparatus,

a signal processing means for analysing said at least one EEG signal and adapted to identify or predict predetermined biological incidents in said person based on said analysis,

a decision means adapted to decide when information is to be presented to said person,

a message selection means for selecting a voice message providing said person with information, and

an acoustic transducer adapted for presenting the selected voice message to the person.

2. An EEG monitoring device according to claim 1, wherein said selected voice message relates to said biological incident.

3. An apparatus according to any one of claims 1 or 2, wherein said voice messages are stored in the apparatus.

4. An apparatus according to any one of the preceding claims, wherein said voice messages are formatted into a format suitable for storage and replay in the apparatus.

5. An apparatus according to any one of the preceding claims, wherein said voice messages have been edited in accordance with the hearing capabilities of said person.

6. An apparatus according to any one of the preceding claims, comprising means for adjusting the presented voice message to the current ambient acoustic noise level when presenting the message.

7. An apparatus according to any one of the preceding claims, comprising means for allowing the person carrying the apparatus to store messages therein in accordance with the persons own choice.

8. An apparatus according to any one of the preceding claims wherein said apparatus is adapted to present the voice message in the ear of the person.

9. An apparatus according to any one of the preceding claims,

wherein the apparatus comprises means for the person carrying the apparatus to acknowledge the presented message.

10. An apparatus according to any one of the preceding claims, further adapted to present voice messages relating to the handling of the apparatus.

11. A method for presenting voice messages in a portable EEG monitoring apparatus, said method comprising:

measuring at least one EEG signal from the person carrying the apparatus using an EEG pick-up means,

analysing said at least one EEG signal using a signal processing means adapted to identify or predict predetermined biological incidents in said person based on said analysis,

deciding, using a decision means, when information is to be presented to said person,

selecting, using a message selection means, a voice message providing said person with information, and

presenting the selected voice message to the person using an acoustic transducer.

12. A method according to claim 11, wherein said selected voice message relates to said biological incident.

13. A method according to claim 11 or 12, wherein said voice messages are stored in the apparatus.

14. A method according to any one of claims 11 to 13, wherein said voice messages are formatted into a format suitable for storage and replay in the apparatus.

15. A method according to any one of claims 11 to 14, wherein are edited in accordance with the hearing capabilities of said person.

16. A method according to any one of claims 11 to 15, wherein the presented voice message is adjusted to the current ambient acoustic noise level when presenting the message.

17. A method according to any one claims 11 to 16, wherein messages are stored in accordance with the persons own choice.

18. A method according to any one of claims 11 to 17, wherein the voice message is presented in the ear of the person.

19. A method according to any one of claims 11 to 18, wherein the person carrying the apparatus is required to acknowledge the presented message.

20. A method according to any one of claims 11 to 19, wherein voice messages relating to the handling of the apparatus are also presented.