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(54) **METHOD AND DEVICE FOR DETERMINING FATIGUE STATE OF BRAIN**

(57) According to an embodiment of the present invention, there is provided a method for determining whether the brain is fatigued, the method comprising: collecting electroencephalogram signals of a testee; quantifying the electroencephalogram signals utilizing a sample entropy algorithm to obtain a final sample entropy value of the electroencephalogram signals; determining whether the brain of the testee is fatigued according to the final sample entropy value, wherein it is determined that the brain of the testee is in a fatigue state when the final sample entropy value is within a predetermined range. According to an embodiment of the present invention, there is also provided an apparatus for executing the method hereinabove. A sample entropy algorithm may be utilized to calculate a sample entropy value of electroencephalogram signals, and the degree of fatigue of the testee's brain can be objectively and accurately evaluated according to the sample entropy value.

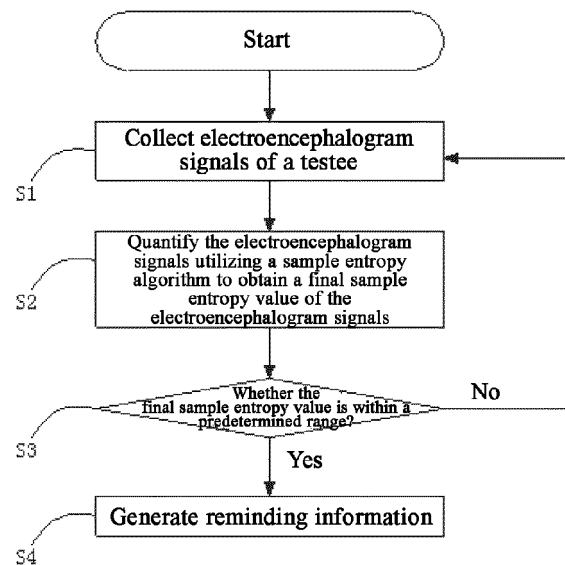


Fig. 1

Description

[0001] The present application claims priority of Chinese patent application No. 201510266869.5 filed on May 22, 2015, the content of which is referred to entirely as part of the present application.

TECHNICAL FIELD

[0002] Embodiments of the present invention relate to an apparatus and method for determining whether the brain is fatigued.

BACKGROUND

[0003] With the rapid development of industrialization technologies, brainwork has become a major work form in nowadays society. However, with fierce competition in modern society and a surge in working pressure, the prolonged, high-intensity and monotonous brainwork may cause brain fatigue. At this time, if the brain is still forced to work continually, the efficiency of learning and working will be reduced, harming human health and also easily leading to accidents.

[0004] Current methods for determination of brain fatigue are mainly subjective evaluation and objective evaluation. The subjective evaluation method determines the degree of fatigue according to a worker's physical and neurological feeling symptoms, which is conducted mainly through a questionnaire. The scoring criterion of the subjective evaluation method is vulnerable to subjective factors and not easily unified, and cannot objectively evaluate psychophysiological states during fatigue. The objective evaluation method observes human physical and biochemical indexes by means of auxiliary tools such as instruments, devices or the like, and comprehensively evaluates these indexes to estimate the degree of fatigue. However, the relationship between these physical and biochemical indexes and the degree of fatigue is uncertain with great individual differences, and it is difficult to be objective and quantified.

SUMMARY

[0005] According to embodiments of the present invention, there is provided a method and apparatus for determining whether the brain is fatigued, and the fatigue state of the brain may be measured objectively by utilizing the method and apparatus.

[0006] According to one aspect of the embodiments of the present invention, there is provided a method for determining whether the brain is fatigued, wherein the method comprises:

S1. collecting electroencephalogram signals of a testee;

S2. quantifying the electroencephalogram signals

utilizing a sample entropy algorithm to obtain a final sample entropy value of the electroencephalogram signals;

S3. determining whether the brain of the testee is fatigued according to the final sample entropy value, wherein it is determined that the brain of the testee is in a fatigue state when the final sample entropy value is within a predetermined range.

[0007] According to an exemplary embodiment of the present invention, the electroencephalogram signals of the testee may be collected in real time.

[0008] According to an exemplary embodiment of the present invention, the predetermined range is [0,0.8].

[0009] In the step S3, when the final sample entropy value is within the range (0.8,1], it is determined that the brain of the testee is in an active state, and then it proceeds to the step S1.

[0010] According to an exemplary embodiment of the present invention, the predetermined range comprises a first predetermined sub-range [0, 0.5] and a second predetermined sub-range (0.5, 0.8]. When the final sample entropy value is within the first predetermined sub-range, it is determined that the brain of the testee is in an excessive fatigue state, and when the final sample entropy value is within the second predetermined sub-range, it is determined that the brain of the testee is in a mild fatigue state.

[0011] According to an exemplary embodiment of the present invention, when it is determined in the step S3 that the brain of the testee is in a fatigue state, the method further comprises:

S4. generating reminding information.

[0012] According to the exemplary embodiment of the present invention, the reminding information comprises first reminding information and second reminding information, and the step S4 comprises: generating the first reminding information when the final sample entropy value is in the range [0, 0.5], and generating the second reminding information when the final sample entropy value is in the range (0.5, 0.8]. For example, the first reminding information and the second reminding information may be different from each other.

[0013] According to an exemplary embodiment of the present invention, the reminding information comprises audio reminding information and/or vibration reminding information.

[0014] According to an exemplary embodiment of the present invention, the reminding information comprises the vibration reminding information, which is applied to Fengchi acupoint of the testee in the step S4.

[0015] According to an exemplary embodiment of the present invention, the step S2 comprises:

S21. filtering the electroencephalogram signals to

remove noise interference;

S22. quantifying the electroencephalogram signals without noises by utilizing a sample entropy algorithm, to obtain an initial sample entropy value;

S23. performing normalization processing on the initial sample entropy value to obtain the final sample entropy value.

[0016] According to another aspect of the embodiments of the present invention, there is provided an apparatus for determining whether the brain is fatigued, wherein the apparatus comprises:

an electroencephalogram signal collection module for collecting electroencephalogram signals of a testee;

a quantization processing module for quantifying the electroencephalogram signals utilizing a sample entropy algorithm to obtain a final sample entropy value of the electroencephalogram signals; and

a fatigue state determination module for determining whether the brain of the testee is fatigued according to the final sample entropy value, wherein it is determined that the brain of the testee is in a fatigue state when the final sample entropy value is within a predetermined range.

[0017] According to an exemplary embodiment of the present invention, an input terminal of the quantization processing module is connected with an output terminal of the electroencephalogram signal collection module.

[0018] According to an exemplary embodiment of the present invention, an input terminal of the fatigue state determination module is connected with an output terminal of the quantization processing module.

[0019] According to an exemplary embodiment of the present invention, the predetermined range is [0,0.8], and when the final sample entropy value is within the range (0.8,1], the fatigue state determination module determines that the brain of the testee is in an active state.

[0020] According to an exemplary embodiment of the present invention, the electroencephalogram signal collection module comprises a main collection electrode for being disposed at a position of the prefrontal cortex of the testee, and a first communication unit for outputting the electroencephalogram signals to the quantization processing module. The main collection electrode is for collecting the electroencephalogram signals of the testee and electrically connected to the first communication unit, the quantization processing module comprises a second communication unit for communicating with the first communication unit and a processing unit for performing quantization of the electroencephalogram signals. The first communication unit is formed as the output terminal

of the electroencephalogram signal collection module, and the second communication unit is formed as the input terminal of the quantization processing module.

[0021] According to an exemplary embodiment of the present invention, both the first communication unit and the second communication unit are wireless communication units.

[0022] According to an exemplary embodiment of the present invention, the electroencephalogram signal collection module further comprises a reference electrode for being disposed behind the ear(s) of the testee and for collecting electroencephalogram signals of the testee, the reference electrode also being electrically connected with the first communication unit.

[0023] According to an exemplary embodiment of the present invention, the quantization processing module further comprises a filtering unit and a post-processing unit, the filtering unit being connected with the second communication unit to receive the electroencephalogram signals and the filtering unit being used for filtering the received electroencephalogram signals to remove noise interference, the processing unit being used for quantifying the electroencephalogram signals without noises by utilizing a sample entropy algorithm to obtain an initial sample entropy value, the post-processing unit being used for performing normalization processing on the initial sample entropy value to obtain the final sample entropy value.

[0024] According to an exemplary embodiment of the present invention, the predetermined range comprises a first predetermined sub-range [0, 0.5] and a second predetermined sub-range (0.5, 0.8]. When the final sample entropy value is within the first predetermined sub-range, it is determined that the brain of the testee is in an excessive fatigue state, and when the final sample entropy value is within the second predetermined sub-range, it is determined that the brain of the testee is in a mild fatigue state.

[0025] According to an exemplary embodiment of the present invention, the apparatus further comprises a reminding information generation module, and the fatigue state determination module can generate a reminding control signal when the brain of the testee is determined to be in a fatigue state, and send the reminding control signal to the reminding information generation module which can generate reminding information according to the reminding control signal.

[0026] According to an exemplary embodiment of the present invention, the reminding control signal comprises a first reminding control signal and a second reminding control signal, and the fatigue state determination module can generate the first reminding control signal when the final sample entropy value is within the range [0, 0.5] and generate the second reminding control signal when the final sample entropy value is within the range (0.5, 0.8]. The reminding information comprises first reminding information and second reminding information, and the reminding information generation module can generate the

first reminding information upon receipt of the first reminding control signal and generate the second reminding information upon receipt of the second reminding control signal. For example, the first reminding information and the second reminding information may be different from each other.

[0027] According to an exemplary embodiment of the present invention, the fatigue state determination module comprises a third communication unit and a fatigue state determination unit for determining whether the brain of the testee is in a fatigue state according to the final sample entropy value and for generating a corresponding reminding control signal. The reminding information generation module comprises a fourth communication unit, a reminding signal generation unit, an audio storage unit and an audio play unit. The third communication unit is used for sending the reminding control signal to the fourth communication unit which sends the reminding control signal to the reminding signal generation unit upon receipt of the reminding control signal. The reminding signal generation unit can send a play signal to the audio storage unit upon receipt of the reminding control signal, so as to play the audio stored in the audio storage unit via the audio play unit.

[0028] According to an exemplary embodiment of the present invention, the reminding information generation module further comprises a vibration generation unit and a vibration conduction unit, and upon receipt of the reminding control signal, the fourth communication unit sends the reminding control signal to the reminding signal generation unit which can send out a vibration start signal to the vibration generation unit upon receipt of the reminding control signal, so as to generate, via the vibration generation unit, a vibration which is transmitted to the testee via the vibration conduction unit. For example, the vibration conduction unit may be fixedly connected to the vibration generation unit.

[0029] According to an exemplary embodiment of the present invention, the apparatus comprises a wear body on which the electroencephalogram signal collection module and the reminding information generation module are disposed. The electroencephalogram signal collection module comprises a main collection electrode and a reference electrode, the audio play unit comprises a bone conduction headset, and the vibration conduction unit comprises a vibration terminal. The wear body is formed as a curved rod-like component, so that the wear body can be worn on the head of the testee. The main collection electrode is disposed on one end of the wear body to be able to fit on the prefrontal cortex of the testee, the reference electrode is disposed on the other end of the wear body to be able to fit behind the testee's ear(s), and the audio play unit is disposed on the wear body and on the same end with the reference electrode. The audio play unit and the reference electrode are disposed in such a way that when the reference electrode fits behind the testee's ear(s), the audio play unit is able to fit in the testee's ear(s). The vibration conduction unit is disposed

in the middle of the wear body while protruding towards the center of the wear body.

[0030] When a person is clear-headed, brain neurons are highly excited, the brain receives huge information from the outside world, neuronal activities are highly random, and electroencephalogram signals are much complex. When the degree of fatigue of the brain increases, the degree of suppression of brain neurons increases, the brain receives less information from the outside world, the orderliness of neuronal activities increases, and similar periodic activities of electroencephalogram signals are enhanced, causing the degree of complexity of electroencephalogram signals decline. Therefore, the sample entropy algorithm can be used to calculate the sample entropy value of electroencephalogram signals, and the degree of fatigue of a testee's brain can be objectively and accurately evaluated according to the sample entropy value.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] To more clearly illustrate the technical solution of embodiments of the present invention, the accompanying drawings of the embodiments will be briefly described below. Apparently, the accompanying drawings in the following description merely relate to some embodiments of the present invention but are not meant to limit the present invention, in which,

Figure 1 is a flow chart of a method for determining whether the brain is fatigued, which is provided according to an embodiment of the present invention;

Figure 2 is a schematic module diagram of an apparatus for determining whether the brain is fatigued, which is provided according to an embodiment of the present invention;

Figure 3 is a schematic diagram of part of an apparatus for determining whether the brain is fatigued, which is provided according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0032] To make the purpose, technical solution and advantages of the embodiments of the present invention more clear, the technical solution of the embodiments of the present invention will be clearly and comprehensively described below with reference to the accompanying drawings of the embodiments of the present invention. Obviously, the described embodiments are merely part of, instead of all of, embodiments of the present invention. Based on the embodiments of the present invention described, all the other embodiments obtained by those of ordinary skill in the art without creative efforts fall within the scope of protection of the present invention.

[0033] As shown in Figure 1, according to an embod-

iment of the present invention, there is provided a method for determining whether the brain is fatigued, wherein the method comprises:

S1. collecting electroencephalogram signals of a testee;

S2. quantifying the electroencephalogram signals utilizing a sample entropy algorithm to obtain a final sample entropy value of the electroencephalogram signals;

S3. determining whether the brain of the testee is fatigued according to the final sample entropy value, wherein it is determined that the brain of the testee is in a fatigue state when the final sample entropy value is within a predetermined range.

[0034] According to an exemplary embodiment of the present invention, the electroencephalogram signals of the testee may be collected in real time.

[0035] The sample entropy algorithm is an algorithm for calculating irregularity or complexity of time series. The greater the randomness of the electroencephalogram signals and the higher the complexity, the larger the sample entropy value is; on the contrary, the more regular the electroencephalogram signals are, the smaller the sample entropy value is.

[0036] When a person is clear-headed, brain neurons are highly excited, the brain receives huge information from the outside world, neuronal activities are highly random, and electroencephalogram signals are much complex. When the degree of fatigue of the brain increases, the degree of suppression of brain neurons increases, the brain receives less information from the outside world, orderliness of neuronal activities increases, and similar periodic activities of electroencephalogram signals are enhanced, causing the degree of complexity of the electroencephalogram signals decline. Therefore, the sample entropy algorithm can be used to calculate the sample entropy value of electroencephalogram signals, and the degree of fatigue of the testee's brain can be objectively and accurately evaluated according to the sample entropy value.

[0037] As described hereinabove, the higher the sample entropy value is, the more clear the testee's brain is, while the lower the sample entropy value is, then the higher the degree of fatigue of the testee's brain is. Typically, a sample entropy value is a decimal between 0 and 1. The testee can set end values of the predetermined range by himself.

[0038] According to an exemplary embodiment of the present invention, the predetermined range is [0,0.8]. When the sample entropy value is within the range [0,0.8], it is determined that the brain of the testee is in a fatigue state. In the step S3, when the final sample entropy value is within the range (0.8,1], it is determined that the brain of the testee is in an active state and it

proceeds to the step S1.

[0039] Different degrees of fatigue affect behaviors of the testee differently, and the corresponding ways to relieve fatigue are different. Thus, the degrees of fatigue can be classified into mild and excessive fatigue. Accordingly, the predetermined range comprises a first predetermined sub-range [0, 0.5] and a second predetermined sub-range (0.5, 0.8]. When the final sample entropy value is within the first predetermined sub-range, it is determined that the brain of the testee is in an excessive fatigue state, and when the final sample entropy value is within the second predetermined sub-range, it is determined that the brain of the testee is in a mild fatigue state.

[0040] After a determination result is generated in the step S3, a display device may be utilized to display the determination result, and reminding information may also be generated according to the determination result generated in the step S3 to remind that the testee has already been in a fatigue state.

[0041] According to an exemplary embodiment of the present invention, when it is determined in the step S3 that the brain of the testee is in a fatigue state, the method further comprises:

S4. generating reminding information.

[0042] After receiving the reminding information, the testee should stop working and have a rest or conduct other relief activities.

[0043] As described hereinabove, according to the different degrees of fatigue, the brain fatigue of the testee is classified into a mild fatigue and an excessive fatigue. Accordingly, the reminding information comprises first reminding information and second reminding information, and the step S4 comprises: generating the first reminding information when the final sample entropy value is in the range [0, 0.5] (i.e., at excessive fatigue), and generating the second reminding information when the final sample entropy value is in the range (0.5, 0.8] (i.e., at mild fatigue). For example, the first reminding information and the second reminding information may be different from each other.

[0044] According to the different first and second reminding information, the degree of brain fatigue of the testee may be determined more accurately, whereby different relief measures may be taken for different degrees of brain fatigue.

[0045] According to an exemplary embodiment of the present invention, the specific type of the reminding information may not be specifically defined. For example, the reminding information may comprise audio reminding information and/or vibration reminding information.

[0046] The audio reminding information may be soothing music, and when it is determined that the brain of the testee is in a fatigue state, soothing music may be played, so that the testee's brain gets relaxed and rest.

[0047] In case that the reminding information comprises the vibration reminding information, when feeling the

vibration reminding information, the testee may stop working and have a rest. Optionally, in the step S4, the vibration reminding information may be applied to the testee's Fengchi acupoint. Applying the vibration reminding information to the Fengchi acupoint is equivalent to massage on the Fengchi acupoint, which can relieve fatigue of the testee.

[0048] In order to make the determination result in the step S3 more accurate, according to an exemplary embodiment of the present invention, the step S2 may comprise:

S21. filtering the electroencephalogram signals to remove noise interference;

S22. quantifying the electroencephalogram signals without noises by utilizing a sample entropy algorithm, to obtain an initial sample entropy value;

S23. performing normalization processing on the initial sample entropy value to obtain the final sample entropy value.

[0049] According to another aspect of the embodiments of the present invention, there is provided an apparatus for determining whether the brain is fatigued, which apparatus may be used to execute the method for determining whether the brain is fatigued. Specifically, the apparatus comprises:

an electroencephalogram signal collection module 100 for collecting electroencephalogram signals of the testee;

a quantization processing module 200 for quantifying the electroencephalogram signals utilizing a sample entropy algorithm to obtain a final sample entropy value of the electroencephalogram signals;

a fatigue state determination module 300 for determining whether the brain of the testee is fatigued according to the final sample entropy value, wherein it is determined that the brain of the testee is in a fatigue state when the final sample entropy value is within a predetermined range.

[0050] According to an exemplary embodiment of the present invention, an input terminal of the quantization processing module 200 may be connected with an output terminal of the electroencephalogram signal collection module 100.

[0051] According to an exemplary embodiment of the present invention, an input terminal of the fatigue state determination module 300 is connected with an output terminal of the quantization processing module 200.

[0052] The electroencephalogram signal collection module 100 is used to execute the step S1, the quantization processing module 200 is used to execute the step

S2, and the fatigue state determination module 300 is used to execute the step S3. As described hereinabove, the quantization processing module 200 may be utilized to quantify the degree of fatigue of the brain, so that it may be more objectively and accurately determined whether the brain of the testee is in a fatigue state or not.

[0053] According to an exemplary embodiment of the present invention, the quantization processing module 200 and the fatigue state determination module 300 may be integrated on the same circuit board, the electroencephalogram signal collection module 100 may be independent of the quantization processing module 200 and the fatigue state determination module 300, and the electroencephalogram signal collection module 100 may be connected to and communicate with the quantization processing module 200 through a wire, data line, etc., and also may communicate with the quantization processing module 200 through wireless signals. According to an exemplary embodiment of the present invention, a storage module may be disposed in the fatigue state determination module 300, and a chip implementing the sample entropy algorithm may be disposed in the quantization processing module 200.

[0054] As described hereinabove, the predetermined range may be $[0, 0.8]$. When the final sample entropy value obtained in the quantization processing module 200 is within $[0, 0.8]$, the fatigue state determination module determines that the testee is in a brain fatigue state. Accordingly, when the final sample entropy value is within the range $(0.8, 1]$, the fatigue state determination module determines that the brain of the testee is in an active state. According to an exemplary embodiment of the present invention, the range $(0.8, 1]$ may be stored in the fatigue state determination module 300.

[0055] According to an exemplary embodiment of the present invention, the specific structure of the electroencephalogram signal collection module is not specially defined as long as it can collect electroencephalogram signals. According to an exemplary embodiment of the present invention, the electroencephalogram signal collection module 100 may comprise a main collection electrode 110 for being disposed at a position of the prefrontal cortex of the testee, and a first communication unit 120 for outputting the electroencephalogram signals to the quantization processing module 200. The main collection electrode 110 is used for collecting electroencephalogram signals of the testee, and is electrically connected to the first communication unit 120. The quantization processing module 200 comprises a second communication unit 210 for communicating with the first communication unit 120 and a processing unit 220 for performing quantization of the electroencephalogram signals. The first communication unit 120 is formed as the output terminal of the electroencephalogram signal collection module 100, and the second communication unit 210 is formed as the input terminal of the quantization processing module 200.

[0056] According to an exemplary embodiment of the

present invention, the processing unit 220 may directly conduct the sample entropy algorithm on the electroencephalogram signals and take the directly calculated sample entropy value as the final sample entropy value.

[0057] To make the sample entropy value obtained by the quantization processing module 200 more comply with the real electroencephalogram state, according to an exemplary embodiment of the present invention, the quantization processing module 200 further comprises a filtering unit 230 and a post-processing unit 240. The filtering unit 230 is used for filtering the received electroencephalogram signals to remove noise interference, the processing unit 220 is used for quantifying the electroencephalogram signals without noises by utilizing the sample entropy algorithm, so as to obtain an initial sample entropy value, and the post-processing unit 240 is used for performing normalization processing on the initial sample entropy value to obtain the final sample entropy value.

[0058] According to an exemplary embodiment of the present invention, the main collection electrode 110 may be a dry-state electrode, and utilizing the dry-state electrode to collect electroencephalogram signals may reduce the difficulty of collecting electroencephalogram signals.

[0059] The first communication unit 120 and the second communication unit 210 may communicate with each other through a data line. To simplify the structure and not to affect the activity of the testee during the collection of electroencephalogram signals, according to an exemplary embodiment of the present invention, both the first communication unit 120 and the second communication unit 210 are wireless communication units. After wearing the electroencephalogram signal collection module 100, the testee may move freely without affecting his/her normal work and life.

[0060] To collect more accurate and real electroencephalogram signals, according to an exemplary embodiment of the present invention, the electroencephalogram signal collection module 100 may further comprise a reference electrode 130 for being disposed behind the ear(s) of the testee and for collecting electroencephalogram signals of the testee, where the reference electrode is also electrically connected with the first communication unit 120.

[0061] As described hereinabove, the predetermined range comprises a first predetermined sub-range [0, 0.5] and a second predetermined sub-range (0.5, 0.8]. When the final sample entropy value is within the first predetermined sub-range, it is determined that the brain of the testee is in an excessive fatigue state, and when the final sample entropy value is within the second predetermined sub-range, it is determined that the brain of the testee is in a mild fatigue state.

[0062] To remind the testee, according to an exemplary embodiment of the present invention, the apparatus may further comprise a reminding information generation module 400. The fatigue state determination module 300

can generate a reminding control signal when determining that the brain of the testee is in a fatigue state and send the reminding control signal to the reminding information generation module 400 which can generate reminding information according to the reminding control signal.

[0063] To facilitate the testee in knowing his/her current brain fatigue state, according to an exemplary embodiment of the present invention, the reminding control signal comprises a first reminding control signal and a second reminding control signal. The fatigue state determination module 300 can generate the first reminding control signal when the final sample entropy value is within the range [0, 0.5] and generate the second reminding control signal when the final sample entropy value is within the range (0.5, 0.8]. The reminding information comprises first reminding information and second reminding information. The reminding information generation module 400 can generate the first reminding information upon receipt of the first reminding control signal and generate the second reminding information upon receipt of the second reminding control signal. For example, the first reminding information and the second reminding information may be different from each other.

[0064] According to an exemplary embodiment of the present invention, the fatigue state determination module 300 may comprise a third communication unit 320, and a fatigue state determination unit 310 for determining whether the brain of the testee is in a fatigue state according to the final sample entropy value and for generating a corresponding reminding control signal. The reminding information generation module 400 comprises a fourth communication unit 410, a reminding signal generation unit 420, an audio storage unit 430 and an audio play unit 440. The third communication unit 320 is used for sending the reminding control signal to the fourth communication unit 410 which transmits the reminding control signal to the reminding signal generation unit 420 upon receipt of the reminding control signal. The reminding signal generation unit 420 can send a play signal to the audio storage unit 430 upon receipt of the reminding control signal, so as to play audio stored in the audio storage unit 430 via the audio play unit 440.

[0065] The audio stored in the audio storage unit 430 may be soothing music, and the audio play unit 440 may be a stereo and may also be a headset. The third communication unit 320 and the fourth communication unit 420 may be connected with each other via a data line, and may also communicate with each other through wireless signals.

[0066] According to an exemplary embodiment of the present invention, the reminding information generation module 400 further comprises a vibration generation unit 450 and a vibration conduction unit 460. Upon receipt of the reminding control signal, the fourth communication unit 410 transmits the reminding control signal to the reminding signal generation unit 420 which can send out a vibration start signal to the vibration generation unit 450

upon receipt of the reminding control signal, so as to generate a vibration via the vibration generation unit 450, where the vibration is transmitted to the testee via the vibration conduction unit 460. The vibration generation unit 450 may be fixedly connected to the vibration conduction unit 460, so that the vibration signal is delivered from the vibration generation unit to the vibration signal conduction unit.

[0067] According to an exemplary embodiment of the present invention, the apparatus may comprise a wear body 500, on which the electroencephalogram signal collection module 100 and the reminding information generation module 400 are disposed. The electroencephalogram signal collection module 100 comprises a main collection electrode 110 and a reference electrode 130, the audio play unit 440 comprises a bone conduction headset, and the vibration conduction unit 460 comprises a vibration terminal. The wear body 500 may be formed as a curved rod-like component, so that the wear body 500 can be worn on the head of the testee. The main collection electrode 110 is disposed on one end of the wear body 500 to be able to fit on the prefrontal cortex of the testee, the reference electrode 130 is disposed on the other end of the wear body 500 to be able to fit behind the testee's ear(s), and the audio play unit 440 is disposed on the wear body 500 and on the same end with the reference electrode 130. The audio play unit 440 and the reference electrode 130 are disposed in such a way that when the reference electrode 130 fits behind the testee's ear(s), and the audio play unit 440 is able to fit in the testee's ear(s). The vibration conduction unit 460 is disposed in the middle of the wear body 500 while protruding towards the center of the wear body 500.

[0068] When the determination of the brain fatigue state of the testee is performed, the wear body 500 is worn on the brain of the testee, the reference electrode 130 fits behind an ear of the testee, the audio play unit 440 fits in the ear close to the reference electrode 130, the main collection electrode 110 fits on the prefrontal cortex of the testee, and the vibration conduction unit 460 is pressed on the Fengchi acupoint of the testee.

[0069] When the fatigue state determination module determines that the testee is in a brain fatigue state, the audio play unit starts to play soothing music, the vibration conduction unit 460 receives the vibration from the vibration generation unit 450 and the testee's Fengchi acupoint is massaged to achieve the purpose of relieving fatigue.

[0070] It will be understood that the above description is merely about exemplary embodiments of the present invention and is not meant to limit the scope of the present invention, and the scope of the present invention is defined by the appended claims. Those of ordinary skill in the art may make various variations and improvements, without departing from the spirit and essence of the present invention, and these variations and improvements also fall within the scope of the present invention.

Claims

1. A method for determining whether the brain is fatigued, comprising:

S1. collecting electroencephalogram signals of a testee;

S2. quantifying the electroencephalogram signals utilizing a sample entropy algorithm to obtain a final sample entropy value of the electroencephalogram signals; and

S3. determining whether the brain of the testee is fatigued according to the final sample entropy value, wherein it is determined that the brain of the testee is in a fatigue state when the final sample entropy value is within a predetermined range.

2. The method according to claim 1, wherein the predetermined range is [0,0.8]; and in the step S3, when the final sample entropy value is within the range (0.8,1], it is determined that the brain of the testee is in an active state, and then it proceeds to the step S1.

3. The method according to claim 1 or 2, wherein the predetermined range comprises a first predetermined sub-range [0, 0.5] and a second predetermined sub-range (0.5, 0.8], and wherein it is determined that the brain of the testee is in an excessive fatigue state when the final sample entropy value is within the first predetermined sub-range, and it is determined that the brain of the testee is in a mild fatigue state when the final sample entropy value is within the second predetermined sub-range.

4. The method according to any one of claims 1 to 3, wherein when it is determined in the step S3 that the brain of the testee is in a fatigue state, the method further comprises:

S4. generating reminding information.

5. The method according to claim 4, wherein the reminding information comprises first reminding information and second reminding information, and the step S4 comprises: generating the first reminding information when the final sample entropy value is in the range [0, 0.5], and generating the second reminding information when the final sample entropy value is in the range (0.5, 0.8].

6. The method according to claim 4, wherein the reminding information comprises audio reminding information and/or vibration reminding information.

7. The method according to claim 6, wherein the reminding information comprises the vibration remind-

ing information which is applied to Fengchi acupoint of the testee in the step S4.

8. The method according to any one of claims 1 to 7, wherein the step S2 comprises:

S21. filtering the electroencephalogram signals to remove noise interference;
S22. quantifying the electroencephalogram signals without noises by utilizing a sample entropy algorithm, to obtain an initial sample entropy value; and
S23. performing normalization processing on the initial sample entropy value to obtain the final sample entropy value.

9. An apparatus for determining whether the brain is fatigued, comprising:

an electroencephalogram signal collection module for collecting electroencephalogram signals of a testee;
a quantization processing module for quantifying the electroencephalogram signals utilizing a sample entropy algorithm to obtain a final sample entropy value of the electroencephalogram signals; and
a fatigue state determination module for determining whether the brain of the testee is fatigued according to the final sample entropy value, wherein it is determined that the brain of the testee is in a fatigue state when the final sample entropy value is within a predetermined range.

10. The apparatus according to claim 9, wherein the predetermined range is $[0, 0.8]$, and when the final sample entropy value is within the range $(0.8, 1]$, the fatigue state determination module determines that the brain of the testee is in an active state.

11. The apparatus according to claim 9 or 10, wherein the electroencephalogram signal collection module comprises a main collection electrode for being disposed at a position of the prefrontal cortex of the testee and for collecting the electroencephalogram signals of the testee, and a first communication unit for outputting the electroencephalogram signals to the quantization processing module, the main collection electrode being electrically connected to the first communication unit, and wherein the quantization processing module comprises a second communication unit for communicating with the first communication unit and a processing unit for performing quantization of the electroencephalogram signals, the first communication unit being formed as an output terminal of the electroencephalogram signal collection module, the second communication unit being formed as an input terminal of the quantization

processing module.

12. The apparatus according to claim 11, wherein both the first communication unit and the second communication unit are wireless communication units.

13. The apparatus according to claim 11 or 12, wherein the electroencephalogram signal collection module further comprises a reference electrode for being disposed behind the ear(s) of the testee and for collecting the electroencephalogram signals of the testee, the reference electrode also being electrically connected with the first communication unit.

14. The apparatus according to any one of claims 11 to 13, wherein the quantization processing module further comprises a filtering unit and a post-processing unit, the filtering unit being connected with the second communication unit to receive the electroencephalogram signals and the filtering unit being used for filtering the received electroencephalogram signals to remove noise interference, the processing unit being used for quantifying the electroencephalogram signals without noises by utilizing a sample entropy algorithm to obtain an initial sample entropy value, the post-processing unit being used for performing normalization processing on the initial sample entropy value to obtain the final sample entropy value.

15. The apparatus according to any one of claims 9 to 14, wherein the predetermined range comprises a first predetermined sub-range $[0, 0.5]$ and a second predetermined sub-range $(0.5, 0.8]$, and wherein it is determined that the brain of the testee is in an excessive fatigue state when the final sample entropy value is within the first predetermined sub-range, and it is determined that the brain of the testee is in a mild fatigue state when the final sample entropy value is within the second predetermined sub-range.

16. The apparatus according to any one of claims 9 to 15, wherein the apparatus further comprises a reminding information generation module, and the fatigue state determination module is able to generate a reminding control signal when determining the brain of the testee is in a fatigue state and send the reminding control signal to the reminding information generation module which is able to generate reminding information according to the reminding control signal.

17. The apparatus according to claim 16, wherein the reminding control signal comprises a first reminding control signal and a second reminding control signal, and the fatigue state determination module is able to generate the first reminding control signal when the final sample entropy value is within the range $[0,$

0.5] and to generate the second reminding control signal when the final sample entropy value is within the range (0.5, 0.8], and wherein the reminding information comprises first reminding information and second reminding information, and the reminding information generation module is able to generate the first reminding information upon receipt of the first reminding control signal and generate the second reminding information upon receipt of the second reminding control signal.

18. The apparatus according to claim 16 or 17, wherein the fatigue state determination module comprises a fatigue state determination unit for determining whether the brain of the testee is in a fatigue state according to the final sample entropy value and for generating a corresponding reminding control signal, and a third communication unit for sending the reminding control signal to a fourth communication unit, and wherein the reminding information generation module comprises the fourth communication unit, a reminding signal generation unit, an audio storage unit and an audio play unit, and upon receipt of the reminding control signal, the fourth communication unit sends the reminding control signal to the reminding signal generation unit which is able to send a play signal to the audio storage unit upon receipt of the reminding control signal, so as to play audio stored in the audio storage unit via the audio play unit.

19. The apparatus according to claim 18, wherein the reminding information generation module further comprises a vibration generation unit and a vibration conduction unit, and upon receipt of the reminding control signal, the fourth communication unit sends the reminding control signal to the reminding signal generation unit which is able to send out a vibration start signal to the vibration generation unit upon receipt of the reminding control signal, so as to generate, via the vibration generation unit, a vibration which is transmitted to the testee via the vibration conduction unit.

20. The apparatus according to claim 19, wherein the apparatus comprises a wear body, on which the electroencephalogram signal collection module and the reminding information generation module are disposed, and wherein the electroencephalogram signal collection module comprises a main collection electrode and a reference electrode, the audio play unit comprises a bone conduction headset, the vibration conduction unit comprises a vibration terminal, and the wear body is formed as a curved rod-like component so that the wear body can be worn on the head of the testee, the main collection electrode being disposed on one end of the wear body to be able to fit on the prefrontal cortex of the testee,

the reference electrode being disposed on the other end of the wear body to be able to fit behind the testee's ear(s), the audio play unit being disposed on the wear body and on the same end with the reference electrode, the audio play unit and the reference electrode being disposed in such a way that when the reference electrode fits behind the testee's ear(s), the audio play unit is able to fit in the testee's ear(s), and the vibration conduction unit being disposed in the middle of the wear body while protruding towards the center of the wear body.

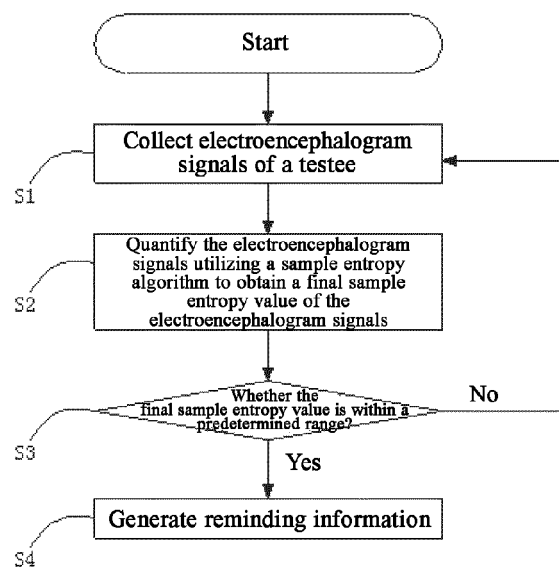


Fig. 1

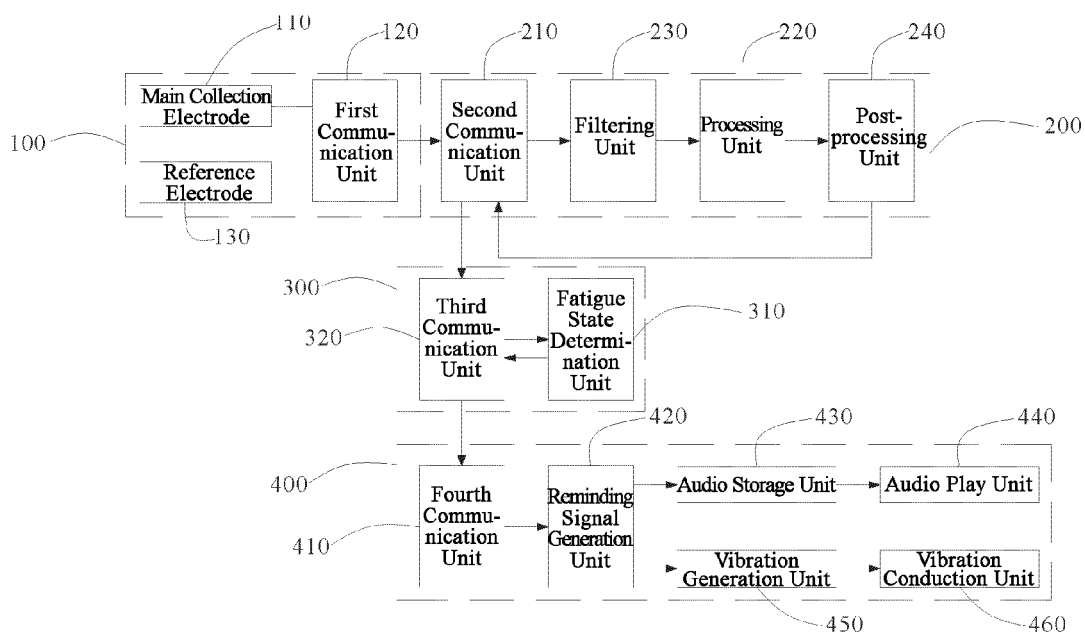


Fig. 2

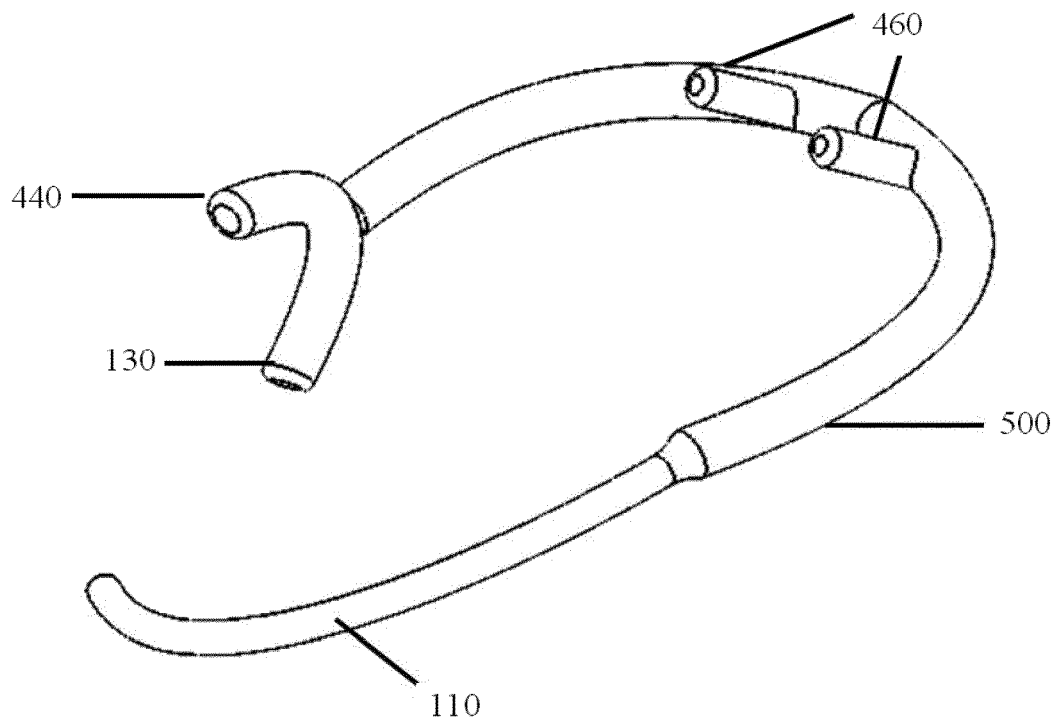


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/091644

A. CLASSIFICATION OF SUBJECT MATTER

A61B 5/00 (2006.01) i; A61B 5/0476 (2006.01) i
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI, CNABS, CNTXT, CNKI, GOOGLESCHOLAR: load, brain, vigor, mental, entropy, fatigue, brain wave, brain electricity, EEG, sample entropy, complexity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 104814735 A (BOE TECHNOLOGY GROUP CO., LTD.), 05 August 2015 (05.08.2015), claims 1-20	1-20
X	XU, Shili. "Study on the Distinguishing Method of Driving Fatigue Based on Physiological Signals", ELECTRONIC TECHNOLOGY & INFORMATION SCIENCE, CHINA MASTER'S THESES FULL-TEXT DATABASE, no. 1, 31 January 2013 (31.01.2013), ISSN: 1674-0246, main body, pages 3-43	1-3, 8-15
Y	XU, Shili. "Study on the Distinguishing Method of Driving Fatigue Based on Physiological Signals", ELECTRONIC TECHNOLOGY & INFORMATION SCIENCE, CHINA MASTER'S THESES FULL-TEXT DATABASE, no. 1, 31 January 2013 (31.01.2013), ISSN: 1674-0246, main body, pages 3-43	4-7, 16-20
Y	CN 104305964 A (SOUTHEAST UNIVERSITY), 28 January 2015 (28.01.2015), description, paragraph [0037]	4-7, 16-20
A	CN 103610447 A (TIANJIN UNIVERSITY), 05 March 2014 (05.03.2014), the whole document	1-2

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search

26 January 2016 (26.01.2016)

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/091644

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 102715889 A (TIANJIN UNIVERSITY), 10 October 2012 (10.10.2012), the whole document	1-20
A	A US 2007066906 A1 (BETH ISRAEL DEACONESS MEDICAL CENTER), 22 March 2007 (22.03.2007), the whole document	1-20
A	US 2015018704 A1 (UNIV NAT CHIAO TUNG), 15 January 2015 (15.01.2015), the whole document	1-20

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2015/091644

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 104814735 A	05 August 2015	None	
CN 104305964 A	28 January 2015	None	
CN 103610447 A	05 March 2014	CN 103610447 B	09 December 2015
CN 102715889 A	10 October 2012	CN 102715889 B	29 January 2014
US 2007066906 A1	22 March 2007	US 7882167 B2	01 February 2011
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Form PCT/ISA/210 (patent family annex) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	确定脑疲劳状态的方法和装置		
公开(公告)号	EP3298954A4	公开(公告)日	2019-01-16
申请号	EP2015848147	申请日	2015-10-10
[标]申请(专利权)人(译)	京东方科技集团股份有限公司		
申请(专利权)人(译)	京东方科技集团股份有限公司.		
当前申请(专利权)人(译)	京东方科技集团有限公司		
[标]发明人	LI HUI		
发明人	LI, HUI		
IPC分类号	A61B5/00 A61B5/0476		
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优先权	201510266869.5 2015-05-22 CN		
其他公开文献	EP3298954A1		
外部链接	Espacenet		

摘要(译)

根据本发明的实施例，提供了一种用于确定大脑是否疲劳的方法，该方法包括：收集被测者的脑电图信号；利用样本熵算法量化脑电信号，得到脑电信号的最终样本熵值；根据最终样本熵值确定被测者的大脑是否疲劳，其中当最终样本熵值在预定范围内时，确定被测者的大脑处于疲劳状态。根据本发明的实施例，还提供了一种用于执行上述方法的装置。可以利用样本熵算法来计算脑电信号的样本熵值，并且可以根据样本熵值客观且准确地评估被测者的大脑的疲劳程度。