

[DESCRIPTION]

[Title of Invention] PSYCHOLOGICAL STATE ESTIMATION SYSTEM,
PSYCHOLOGICAL STATE ESTIMATION METHOD, AND PROGRAM

[Technical Field]

5 [0001]

The present invention relates to a psychological state estimation system, a psychological state estimation method, and a program.

[Background Art]

10 [0002]

In recent years, there is a need to provide more appropriate services to users by using techniques to detect biological information, such as blood pressure and heart rate of the users, through biometric sensors, and estimate the psychological states of the users based on the detected biological information.

[0003]

For example, Patent Literature (PTL) 1 discloses a method and a device for displaying living body information which associate at least two types of living body information with a point on a two-dimensional coordinate system based on the pulse wave signals and electrocardiograph signals of a subject (hereinafter, also referred to as a target person), and display a region for indicating a correspondence relationship between the point on the two-dimensional coordinate system and the psychological state of the subject on a display screen.

[Citation List]

[Patent Literature]

[0004]

[PTL 1] Japanese Unexamined Patent Application Publication No.
30 2006-034803

[Summary of Invention]

[Technical Problem]

[0005]

However, it is difficult to say that the technique disclosed in PTL
35 1 is capable of accurately estimating the psychological state of the

subject.

[0006]

In view of the above, the present invention provides a psychological state estimation system, a psychological state estimation method, and a program which are capable of accurately
5 estimating the psychological state of a subject.

[Solution to Problem]

[0007]

A psychological state estimation system according to one
10 aspect of the present disclosure includes: a physiological data
obtainer that obtains one of heart rate data or pulse wave data of a
subject; a first state quantity calculator that calculates a first index
based on the one of the heart rate data or the pulse wave data
obtained by the physiological data obtainer, and calculates a first
15 state quantity based on the first index calculated, the first index
indicating a balance between a sympathetic nervous system and a
parasympathetic nervous system, the first state quantity indicating a
state of the balance between the sympathetic nervous system and the
parasympathetic nervous system of the subject; a second state
20 quantity calculator that calculates a second index based on the one
of the heart rate data or the pulse wave data obtained by the
physiological data obtainer, and calculates a second state quantity
based on the second index calculated, the second index indicating an
amount of an autonomic nervous system activity, the second state
25 quantity indicating a state of the amount of the autonomic nervous
system activity of the subject; and a psychological state estimator
that estimates a psychological state of the subject by considering (i)
the first state quantity calculated by the first state quantity calculator
as a value on a first axis and (ii) the second state quantity calculated
30 by the second state quantity calculator as a value on a second axis
that intersects with the first axis, the first axis being oblique to both
a pleasure-displeasure axis and an arousal-sleepiness axis in Russell's
circumplex model of affect.

[0008]

35 A psychological state estimation method according to one

aspect of the present disclosure includes: obtaining one of heart rate data or pulse wave data of a subject; calculating a first index based on the one of the heart rate data or the pulse wave data obtained in the obtaining, and calculating a first state quantity based on the first index calculated, the first index indicating a balance between a sympathetic nervous system and a parasympathetic nervous system, the first state quantity indicating a state of the balance between the sympathetic nervous system and the parasympathetic nervous system of the subject; calculating a second index based on the one of the heart rate data or the pulse wave data obtained in the obtaining, and calculating a second state quantity based on the second index calculated, the second index indicating an amount of an autonomic nervous system activity, the second state quantity indicating a state of the amount of the autonomic nervous system activity of the subject; and estimating a psychological state of the subject by considering (i) the first state quantity calculated in the calculating of the first state quantity as a value on a first axis and (ii) the second state quantity calculated in the calculating of the second state quantity as a value on a second axis that intersects with the first axis, the first axis being oblique to both a pleasure-displeasure axis and an arousal-sleepiness axis in Russell's circumplex model of affect.

[0009]

A program according to one aspect of the present invention is a program for causing a computer to execute the psychological state estimation method.

[Advantageous Effects of Invention]

[0010]

According to the present invention, it is possible to achieve a psychological state estimation system, a psychological state estimation method, and a program which are capable of accurately estimating the psychological state of a subject.

[Brief Description of Drawings]

[0011]

[FIG. 1]

FIG. 1 is a diagram for explaining an outline of a psychological

state estimation system according to Embodiment 1.

[FIG. 2]

FIG. 2 is a block diagram illustrating an example of a functional configuration of the psychological state estimation system according to Embodiment 1.

[FIG. 3]

FIG. 3 is a flowchart illustrating an example of an operation of the psychological state estimation system according to Embodiment 1.

[FIG. 4]

FIG. 4 illustrates examples of heart rate data.

[FIG. 5]

FIG. 5 is a diagram for explaining a first state quantity calculation process, a second state quantity calculation process, and a psychological state estimation process.

[FIG. 6]

FIG. 6 illustrates examples of display information.

[FIG. 7]

FIG. 7 is a block diagram illustrating an example of a functional configuration of a psychological state estimation system according to Embodiment 2.

[FIG. 8]

FIG. 8 is a flowchart illustrating an example of an operation of the psychological state estimation system according to Embodiment 2.

[Description of Embodiments]

[0012]

Hereinafter, embodiments will be specifically described with reference to the drawings. Each of the following embodiments below describes a general or specific example. The numerical values, shapes, materials, structural elements, the arrangement and connection of the structural elements, etc. shown in the following embodiments are mere examples, and therefore do not limit the present invention. Among the structural elements in the following embodiments, those not recited in any of the independent claims are

described as optional structural elements.

[0013]

The figures are represented schematically, and are not necessarily precise illustrations. In the figures, elements that are essentially the same share like reference signs, and duplicate description thereof is omitted or simplified.

[0014]

[Embodiment 1]

[Outline]

First, an outline of a psychological state estimation system according to Embodiment 1 will be described. FIG. 1 is a diagram for explaining an outline of the psychological state estimation system according to Embodiment 1.

[0015]

Psychological state estimation system 100 illustrated in FIG. 1 calculates the state quantity of the balance between the sympathetic nervous system and the parasympathetic nervous system and the state quantity of the amount of the autonomic nervous system activity based on the physiological data of subject 1. Psychological state estimation system 100 then converts these state quantities into values on the two axes in Russell's circumplex model of affect, and estimates the psychological state of subject 1 based on the converted values. This allows the psychological state of subject 1 to be accurately estimated.

[0016]

Moreover, psychological state estimation system 100 may display the estimated psychological state of subject 1. This allows subject 1 to visually recognize his or her own psychological state.

[0017]

In psychological state estimation system 100, for example, the heart rate data or pulse wave data (so-called physiological data) measured by sensor 10 is transmitted to server device 30 via information terminal 20, and the psychological state of subject 1 estimated by server device 30 based on the physiological data is displayed on information terminal 20. In the example in FIG. 1, the

various calculation processes for estimating the psychological state of subject 1 are performed by server device 30, but may be performed by information terminal 20.

[0018]

5 The physiological data of subject 1 is heart rate data or pulse wave data. Heart rate data is, for example, heart rate, and pulse wave data is, for example, pulse rate. The heart rate or pulse wave is measured by sensor 10.

[0019]

10 The autonomic nervous system includes a sympathetic nervous system and a parasympathetic nervous system. The functions of the organs of a person are maintained by the balanced functioning of these two types of nervous systems. The sympathetic nervous system works to increase the activity level of the body and athletic
15 ability. The parasympathetic nervous system, on the other hand, works to calm the body and mind, reduce energy consumption, and store energy. For example, when the sympathetic nervous system is activated, the heart rate increases, and when the parasympathetic nervous system is activated, the heart rate decreases. In such a
20 manner, the level of heart activity is determined by the balance between the two types of nervous systems.

[0020]

[Configuration]

Next, a configuration of psychological state estimation system
25 100 according to Embodiment 1 will be described. FIG. 2 is a block diagram illustrating an example of a functional configuration of psychological state estimation system 100 according to Embodiment 1.

[0021]

30 Psychological state estimation system 100 includes sensor 10, information terminal 20, and server device 30.

[0022]

[Sensor]

35 Sensor 10 is, for example, worn by subject 1, measures the heart rate or pulse wave of subject 1, and transmits the measured

heart rate or pulse wave data to information terminal 20. Sensor 10 is, for example, a pulse sensor, but may also be a heart rate sensor. Sensor 10 is not limited to a contact type sensor (in other words, a wearable type sensor) as in the example in FIG. 1, but may also be a non-contact type sensor such as a radio wave sensor or an image sensor. Sensor 10 is communicably connected to information terminal 20. Communication between sensor 10 and information terminal 20 is, for example, wireless communication, but may also be wired communication. The communication standard is not particularly limited, but may be Bluetooth (registered trademark), for example.

[0023]

Specifically, the pulse wave sensor measures the pulse wave using transmission type photoplethysmography. Photoplethysmography is a pulse wave measurement method in which infrared or red light is emitted to the body surface (green light can also be used in the case of reflective type), and the amount of change in light passing through the body (or the amount of change in light reflected within the body) is considered as a change in blood flow volume. The pulse wave sensor is attached to, for example, the wrist, ankle, earlobe, fingertip, upper arm, and the like of subject 1, measures the pulse wave, and outputs the pulse wave data. The shape of the pulse wave sensor may be a band type (for example, wristwatch type), a clip type, a pasting type attached to the neck or the like, or a glasses type. Note that the pulse wave sensor may be an image sensor that measures the pulse wave based on changes in the chromaticity of the skin of the face, hand, and the like.

[0024]

Specifically, the heart rate sensor includes a pair of detection electrodes that come into contact with the surface of the body of subject 1, and measures the electrical signals generated by the pulse of the heart. The detection electrodes may be conductive adhesive gel electrodes, or dry electrodes made of conductive fiber, and the like. For example, a heart rate sensor is attached to the chest of subject 1, measures the electrical signals generated by the pulse of

the heart, and outputs heart rate data. The shape of the heart rate sensor may be, for example, a clothes type sensor in which clothes and detection electrodes are combined.

[0025]

5 [Information Terminal]

Information terminal 20 is a terminal that is operated by subject 1. Information terminal 20 is a portable information terminal such as a smartphone or a tablet terminal, but may also be a stationary information terminal such as a computer device.

10 [0026]

Information terminal 20 obtains, for example, the heart rate data or pulse wave data transmitted by sensor 10, and transmits the obtained data to server device 30. Information terminal 20 displays the psychological state of subject 1 estimated by server device 30.

15 [0027]

Information terminal 20 includes, for example, first communicator 21a, second communicator 21b, controller 22, storage 23, receiver 24, and display unit 25.

[0028]

20 First communicator 21a is a communication circuit (in other words, a communication module) for information terminal 20 to communicate with sensor 10 via a local communication network. First communicator 21a is, for example, a wireless communication circuit that performs wireless communication, but may also be a wired
25 communication circuit that performs wired communication. The communication standard for communications performed by first communicator 21a is not particularly limited. For example, first communicator 21a may communicate with sensor 10 via a relay device (for example, router) using Wi-Fi (registered trademark) or the
30 like, or directly communicate with sensor 10 using Bluetooth (registered trademark) or the like.

[0029]

Second communicator 21b is a communication circuit (in other words, a communication module) for information terminal 20 to
35 communicate with server device 30 via wide area communication

network 5 such as the Internet. Second communicator 21b is, for example, a wireless communication circuit that performs wireless communication, but may also be a wired communication circuit that performs wired communication. The communication standard for communications performed by second communicator 21b is not particularly limited.

[0030]

Controller 22 performs various information processing related to information terminal 20 based on the operation input received by receiver 24. Controller 22 is, for example, realized by a microcomputer, but may be realized by a processor.

[0031]

Storage 23 is a storage device in which dedicated application programs, and the like, which are to be executed by controller 22 are stored. Storage 23 is realized by, for example, a semiconductor memory.

[0032]

Receiver 24 is an input interface that receives an operation input made by the user (for example, subject 1) of information terminal 20. Receiver 24 is specifically realized by a touch panel display, and the like. For example, when receiver 24 includes a touch panel display, the touch panel display functions as display 25 and receiver 24. Receiver 24 is not limited to the touch panel display, but can also be, for example, a keyboard, a pointing device (for example, a stylus pen or a mouse), or a hardware button. Receiver 24 may also be a microphone when receiver 24 receives voice input.

[0033]

Display 25 is, for example, a display device that displays image information including text, and the like, based on control by controller 22. Examples of the display device include a display that includes, for example, a liquid crystal (LC) panel or an electro-luminescent (EL) panel as a display device.

[0034]

[Server Device]

Server device 30 calculates a state quantity indicating the state

of the autonomic nervous system of subject 1 based on the heart rate data or pulse wave data of subject 1 measured by sensor 10. Server device 30 then converts the calculated state quantity into values on the two axes of Russell's circumplex model of affect, and estimates the psychological state of subject 1 based on the converted values. Server device 30 also performs display processing to display the estimated psychological state of subject 1 on display 25 of information terminal 20.

[0035]

10 Server device 30 includes, for example, communicator 31, information processor 32, and storage 33.

[0036]

Communicator 31 is a communication circuit (in other words, a communication module) for server device 30 to communicate with information terminal 20 via wide area communication network 5 such as the Internet. The communications performed by communicator 31 are, for example, wireless communications, but may also be wired communications. The communication standard for communications performed by communicator 31 is not particularly limited.

20 [0037]

Information processor 32 performs the process of estimating the psychological state of subject 1, and performs information processing for displaying the estimated psychological state of subject 1 on display 25 of information terminal 20. Specifically, information processor 32 is realized by a microcomputer or a processor.

[0038]

Information processor 32 includes, as functional structural elements, physiological data obtainer 32a, first state quantity calculator 32b, second state quantity calculator 32c, psychological state estimator 32d, and display processor 32e. The functions of these structural elements are realized, for example, by a microcomputer or processor forming information processor 32 executing a computer program stored in storage 33. Details of the functions of physiological data obtainer 32a, first state quantity calculator 32b, second state quantity calculator 32c, psychological

state estimator 32d, and display processor 32e will be described below.
[0039]

Storage 33 is a storage device in which various information necessary for the above information processing and the above
5 computer program are stored. Storage 33 stores, for example, model 34 and database 35. Storage 33 is realized by a hard disk drive (HDD), for example, but may also be realized by a semiconductor memory.

[0040]

10 Model 34 is constructed based on data from a plurality of subjects stored in database 35. For example, model 34 is derived using data in which, for each of the subjects, the location (i.e., coordinates) of the point indicating the psychological state in Russell's circumplex model of affect determined based on the subjective
15 evaluation result of the subject regarding the psychological state is associated with the first index and the second index obtained from the actual measured values such as pulse wave. Model 34 includes, for example, a model (hereafter, also referred to as a first multiple regression model or a first formula) for calculating the first state
20 quantity from the first index, and a model (hereafter, also referred to as a second multiple regression model or a second formula) for calculating the second state quantity from the second index.

[0041]

Database 35 contains, for each of a plurality of subjects, the
25 calculated value of the first index, the calculated value of the second index, the first state quantity, the second state quantity, and the subjective evaluation result of the subject regarding the psychological state, which are associated with one another.

[0042]

30 [Operation]

Next, an operation of psychological state estimation system
100 according to Embodiment 1 will be described. FIG. 3 is a flowchart illustrating an example of an operation of psychological state estimation system 100 according to Embodiment 1. FIG. 4
35 illustrates examples of heart rate data. FIG. 5 is a diagram for

explaining a first state quantity calculation process, a second state quantity calculation process, and a psychological state estimation process.

[0043]

5 Upon obtaining the heart rate data or pulse wave data measured by sensor 10 via communicator 31 (S11), physiological data obtainer 32a of server device 30 outputs the obtained heart rate data or pulse wave data to first state quantity calculator 32b and second state quantity calculator 32c (not illustrated).

10 [0044]

 Upon obtaining the heart rate data or pulse wave data output from physiological data obtainer 32a, first state quantity calculator 32b calculates a first index indicating the balance between the sympathetic nervous system and the parasympathetic nervous system
15 based on the obtained data (S12). For example, upon obtaining the heart rate data, first state quantity calculator 32b calculates the first index based on the interval between adjacent R waves (called RR interval (RRI) or heartbeat interval) illustrated in (a) of FIG. 4.

[0045]

20 The first index is a parameter indicating the state of balance between the sympathetic nervous system and the parasympathetic nervous system. Examples of the first index include root mean square of the difference between adjacent RR intervals such as RRI_i and RRI_{i+1} illustrated in (b) of FIG. 4 (root mean square of successive
25 difference (RMSSD)), percent of difference between adjacent normal RR intervals greater than or equal to 50ms (pNN50), high-frequency (HF) component and low-frequency (LF) component of the power spectrum of the heart rate variability calculated by frequency domain analysis, and the ratio of the low-frequency component to the high-
30 frequency component (LF/HF).

[0046]

 Next, first state quantity calculator 32b calculates a first state quantity indicating the state of balance between the sympathetic nervous system and the parasympathetic nervous system of subject
35 1 based on the first index calculated in step S12 (S13), and outputs

the calculated first state quantity to psychological state estimator 32d (not illustrated). Specifically, first state quantity calculator 32b calculates the first state quantity of subject 1 using the first multiple regression model included in model 34 as a first formula. The first state quantity is a value on the first axis (see (b) in FIG. 5). For example, first state quantity calculator 32b calculates the first state quantity by applying the first index to the first multiple regression model. The first multiple regression model is a formula constructed using one or more first indexes, and includes an intercept and a coefficient of each first index.

[0047]

Upon obtaining the heart rate data or pulse wave data output from physiological data obtainer 32a, second state quantity calculator 32c calculates a second index indicating the amount of autonomic nervous system activity based on the obtained data (S14). The second index is a parameter indicating the state of the amount of autonomic nervous system activity. Examples of the second index include the mean of multiple RR intervals (RRI:RR Interval) illustrated in (b) of FIG. 4, the standard deviation of all R-R interval (SDNN), the standard deviation of differences between adjacent RR interval (SDSD), the coefficient of variation of RR interval, and the full-domain component (TP:Total Power) of the power spectrum of the heart rate variability calculated by frequency domain analysis. When pulse wave data is obtained, the first index and the second index may be calculated based on the pulse wave data. The time interval between pulse wave peaks (so-called PP interval) corresponds, for example, to the interval between adjacent R waves (RR interval) in the electrocardiogram illustrated in (a) of FIG. 4. The mean of the PP interval is calculated from, for example, a PP interval of ten seconds. This corresponds to the mean of ten seconds of the interval between adjacent R waves (RR intervals) among consecutive R waves of the electrocardiogram illustrated in (b) of FIG. 4.

[0048]

Next, second state quantity calculator 32c calculates a second state quantity indicating the state of the amount of the autonomic

nervous system activity of subject 1 based on the second index calculated in step S14 (S15), and outputs the calculated second state quantity to psychological state estimator 32d (not illustrated). Specifically, second state quantity calculator 32c calculates the
5 second state quantity of subject 1 using the second multiple regression model included in model 34 as a second formula. The second state quantity is the value on the second axis (see (b) in FIG. 5). For example, second state quantity calculator 32c applies the second index to the second multiple regression model to calculate the
10 second state quantity. The second multiple regression model is a formula constructed using one or more second indexes, and includes an intercept and a coefficient of each second index.

[0049]

Next, psychological state estimator 32d considers the first state
15 quantity calculated by first state quantity calculator 32b in step S13 as a value on the first axis that is oblique to both the pleasure-displeasure axis and the arousal-sleepiness axis in Russell's circumplex model of affect, and considers the second state quantity calculated by second state quantity calculator 32c in step S15 as a
20 value on the second axis that intersects with the first axis (S16). By performing step S16, psychological state estimator 32d identifies the location of the point indicating the psychological state of subject 1 in Russell's circumplex model of affect. Specifically, for example, psychological state estimator 32d takes the first state quantity and
25 the second state quantity as parameters, multiplies each of these parameters by the coefficient of a trigonometric function of a predetermined angle, and performs addition or subtraction. By doing so, psychological state estimator 32d calculates a value on the pleasure-displeasure axis corresponding to the first state quantity (in
30 other words, the value on the first axis), and a value on the arousal-sleepiness axis corresponding to the second state quantity (in other words, the value on the second axis).

[0050]

(b) of FIG. 5 is a diagram for explaining a process of calculating
35 the first state quantity and the second state quantity and a process

of converting the first state quantity and the second state quantity to values on the two axes of Russell's circumplex model of affect. The first axis is oblique to both the pleasure-displeasure axis and the arousal-sleepiness axis of Russell's circumplex model of affect, and the second axis intersects with the first axis. The second axis may be orthogonal to, for example, the first axis. For example, the first axis is oblique to the pleasure-displeasure axis of Russell's circumplex model of affect at a predetermined angle, and the second axis is oblique to the arousal-sleepiness axis of Russell's circumplex model of affect at a predetermined angle. Specifically, the predetermined angle is within the range from at least 40 degrees to at most 50 degrees, but may be, for example, 45 degrees. The inventors of the present application examined the accuracy of estimating the psychological states when the predetermined angle was set to 15 degrees, 30 degrees, 45 degrees, 60 degrees, and 75 degrees. The inventors of the present application have confirmed that the accuracy of estimating the psychological state increases from 15 degrees to 45 degrees, and the accuracy increases from 75 degrees to 45 degrees. [0051]

Next, psychological state estimator 32d estimates the psychological state of subject 1 based on the location of the identified point (S17). Specifically, psychological state estimator 32d estimates the psychological state of subject 1 based on to which quadrant of the four quadrants in Russell's circumplex model of affect the identified point belong. [0052]

As illustrated in (a) of FIG. 5, in Russell's circumplex model of affect, the psychological state of subject 1 is divided into four quadrants. The first quadrant indicates that the psychological state of subject 1 is, for example, astonished, excited, happy, delighted, or glad. The second quadrant indicates that the psychological state of subject 1 is, for example, afraid, angry, frustrated, tense, distressed, alarmed, or annoyed. The third quadrant indicates that the psychological state of subject 1 is, for example, sad, gloomy, tired, bored, or droopy. The fourth quadrant indicates that the

psychological state of subject 1 is, for example, satisfied, serene, at ease, relaxed, or drowsy.

[0053]

For example, as illustrated in (b) of FIG. 5, the point indicating the psychological state of subject 1 is located in the first quadrant of Russell's circumplex model of affect. In this case, since the degree of pleasure is high and the degree of arousal is low, psychological state estimator 32d estimates that subject 1 is in the psychological state of pleasure such as happy or glad.

[0054]

Next, display processor 32e performs a process for displaying the psychological state of subject 1 estimated by psychological state estimator 32d in step S17 on display 25 of information terminal 20 (not illustrated). Specifically, display processor 32e transmits a display command for displaying the estimated psychological state of subject 1 on information terminal 20 to information terminal 20 via communicator 31 (not illustrated).

[0055]

Next, information terminal 20 receives the display command transmitted from display processor 32e, and displays display information indicating the psychological state of subject 1 on display 25 based on the received display command (S18). FIG. 6 illustrates examples of display information. In FIG. 6, (a) illustrates an example of display information, and (b) illustrates another example of the display information. In the display information illustrated in (a) of FIG. 6, the point indicating the psychological state of subject 1 is displayed in Russell's circumplex model of affect. For example, the point indicating the psychological state of subject 1 may be displayed in a color such as red, or may be displayed in a blinking manner. Moreover, in the display information illustrated in (b) of FIG. 6, a region indicating the psychological state of subject 1 may be displayed on the coordinate plane represented by the pleasure-displeasure axis and the arousal-sleepiness axis of Russell's circumplex model of affect. For example, when subject 1 taps the region with his or her finger, text information indicating the attributes of the region, such as "glad,

pleased, happy”, may be displayed.

[0056]

In the examples of FIG. 6, the estimation result of the current psychological state of subject 1 is displayed. However, for example, time series data showing changes in the psychological state of subject 1 in a predetermined period of time may be displayed. This allows subject 1 to visually recognize his or her own psychological state and its changes. This will highly likely to lead to, for example, behavioral changes in subject 1.

10 [0057]

[Advantageous Effects, etc.]

As described above, psychological state estimation system 100 includes: physiological data obtainer 32a that obtains one of heart rate data or pulse wave data of subject 1; first state quantity calculator 32b that calculates a first index based on the one of the heart rate data or the pulse wave data obtained by physiological data obtainer 32a, and calculates a first state quantity based on the first index calculated, the first index indicating a balance between a sympathetic nervous system and a parasympathetic nervous system, the first state quantity indicating a state of the balance between the sympathetic nervous system and the parasympathetic nervous system of subject 1; second state quantity calculator 32c that calculates a second index based on the one of the heart rate data or the pulse wave data obtained by physiological data obtainer 32a, and calculates a second state quantity based on the second index calculated, the second index indicating an amount of an autonomic nervous system activity, the second state quantity indicating a state of the amount of the autonomic nervous system activity of subject 1; and psychological state estimator 32d that estimates a psychological state of subject 1 by considering (i) the first state quantity calculated by first state quantity calculator 32b as a value on a first axis and (ii) the second state quantity calculated by second state quantity calculator 32c as a value on a second axis that intersects with the first axis, the first axis being oblique to both a pleasure-displeasure axis and an arousal-sleepiness axis in Russell’s circumplex model of affect. For example,

psychological state estimator 32d may consider the second state quantity calculated by second state quantity calculator 32c to be a value on a second axis orthogonal to the first axis.

[0058]

5 Psychological state estimation system 100 described above converts the value on the first axis, which is the first state quantity indicating the state of balance between the sympathetic nervous system and the parasympathetic nervous system of subject 1, and the value on the second axis, which is the second state quantity
10 indicating the state of the amount of the autonomic nervous system activity of subject 1, into the value on the two axes of Russell's circumplex model of affect. By doing so, psychological state estimation system 100 is capable of identifying the location of the point indicating the psychological state of subject 1 in Russell's
15 circumplex model of affect. This allows psychological state estimation system 100 to estimate the psychological state of subject 1 based on the location of the identified point, thus enabling accurate estimation of the psychological state of subject 1.

[0059]

20 Moreover, for example, the first axis is oblique to the pleasure-displeasure axis at a predetermined angle, the second axis is oblique to the arousal-sleepiness axis at the predetermined angle, and the predetermined angle is within a range from at least 40 degrees to at most 50 degrees.

25 [0060]

 Psychological state estimation system 100 described above multiplies the values on the first axis and the second axis with the coefficient of the trigonometric function of a predetermined angle as parameters and performs addition or subtraction. By doing so,
30 psychological state estimation system 100 is capable of identifying the location of the point indicating the psychological state of subject 1 in Russell's circumplex model of affect. In particular, psychological state estimation system 100 is capable of accurately identifying the location of the point indicating the psychological state of subject 1
35 when the predetermined angle is within the range from at least 40

degrees to at most 50 degrees.

[0061]

Moreover, for example, psychological state estimation system 100 further includes display processor 32e that displays, on display 25 of information terminal 20, the psychological state of subject 1 estimated by psychological state estimator 32d.

[0062]

Psychological state estimation system 100 described above displays the estimation result of the psychological state on display 25, so that subject 1 is able to visually recognize his or her own psychological state.

[0063]

Moreover, a psychological state estimation method performed by a computer such as psychological state estimation system 100 includes: obtaining (S11 in FIG. 3) one of heart rate data or pulse wave data of subject 1 ; calculating (S12) a first index based on the one of the heart rate data or the pulse wave data obtained in the obtaining (S11), and calculating (S13) a first state quantity based on the first index calculated, the first index indicating a balance between a sympathetic nervous system and a parasympathetic nervous system, the first state quantity indicating a state of the balance between the sympathetic nervous system and the parasympathetic nervous system of subject 1; calculating (S14) a second index based on the one of the heart rate data or the pulse wave data obtained in the obtaining (S11), and calculating (S15) a second state quantity based on the second index calculated, the second index indicating an amount of an autonomic nervous system activity, the second state quantity indicating a state of the amount of the autonomic nervous system activity of subject 1; and estimating (S17) a psychological state of subject 1 by considering (S16) (i) the first state quantity calculated in the calculating of the first state quantity (S13) as a value on a first axis and (ii) the second state quantity calculated in the calculating of the second state quantity (S15) as a value on a second axis that intersects with the first axis, the first axis being oblique to both a pleasure-displeasure axis and an arousal-sleepiness axis in Russell's

circumplex model of affect. For example, in S16, the second state quantity calculated in the calculating of the second state quantity (S15) may be considered as a value on the second axis that is orthogonal to the first axis.

5 [0064]

The psychological state estimation method described above converts the value on the first axis, which is the first state quantity indicating the state of the balance between the sympathetic nervous system and the parasympathetic nervous system of subject 1, and
10 the value on the second axis, which is the second state quantity indicating the state of the amount of the autonomic nervous system activity of subject 1, into values on the two axes of Russell's circumplex model of affect. By doing so, the psychological state estimation method is capable of identifying the location of the point
15 indicating the psychological state of subject 1 in Russell's circumplex model of affect. This allows the psychological state estimation method to estimate the psychological state of subject 1 based on the location of the identified point, thus enabling accurate estimation of the psychological state of subject 1.

20 [0065]

(Embodiment 2)

Next, a psychological state estimation system according to Embodiment 2 will be described. In Embodiment 1, the first state quantity is calculated based on the first index and the second state quantity is calculated based on the second index. In Embodiment 2,
25 the first state quantity is calculated using a different first formula depending on the result of determining whether the parasympathetic nervous system is more dominant than the sympathetic nervous system based on the first index, and the second state quantity is
30 calculated using a different second formula depending on the result of determining whether the amount of the autonomic nervous system activity is greater than or equal to a threshold value based on the second index. Embodiment 2 is different from Embodiment 1 in these features. Hereinafter, the features that are different from
35 Embodiment 1 will be mainly described, and duplicated descriptions

will be omitted or simplified.

[0066]

[Configuration]

First, a configuration of a psychological state estimation system
5 according to Embodiment 2 will be described. FIG. 7 is a block
diagram illustrating an example of a functional configuration of
psychological state estimation system 100a according to Embodiment
2.

[0067]

10 As illustrated in FIG. 7, psychological state estimation system
100a according to Embodiment 2 differs from psychological state
estimation system 100 according to Embodiment 1 in the
configuration of information processor 32 and storage 33 of server
device 30a.

15 [0068]

Information processor 32 includes, as functional structural
elements, physiological data obtainer 32a, first state quantity
calculator 32f, second state quantity calculator 32g, first determiner
32h, second determiner 32i, psychological state estimator 32d, and
20 display processor 32e. The functions of these structural elements
are realized, for example, by a microcomputer or processor forming
information processor 32 executing a computer program stored in
storage 33. Details of the functions of physiological data obtainer
32a, first state quantity calculator 32f, second state quantity
25 calculator 32g, first determiner 32h, second determiner 32i,
psychological state estimator 32d, and display processor 32e will be
described below. The functions of these structural elements are
realized, for example, by a microcomputer or processor forming
information processor 32 executing a computer program stored in
30 storage 33.

[0069]

Storage 33 is a storage device in which various information
necessary for the above information processing and the above
computer program are stored. Storage 33 stores, for example,
35 model 34, model 34a, and database 35. Storage 33 is realized by a

hard disk drive (HDD), for example, but may also be realized by a semiconductor memory.

[0070]

Model 34 includes two different first multiple regression models
5 and two different second multiple regression models. For example,
model 34 is derived using data in which, in each of the four cases of
whether the parasympathetic nervous system is more dominant than
the sympathetic nervous system and whether the amount of the
autonomic nervous system activity is greater than or equal to a
10 threshold value, the coordinates based on the subjective evaluations
of the subjects regarding the psychological states are associated with
first and second indexes obtained from the actual measurement
values.

[0071]

15 The two different first multiple regression models are used to
calculate the first state quantity as two different first formulas. In
the following, the two different first formulas are also referred to as
a positive first formula (here, positive first multiple regression model)
and a negative first formula (here, a negative first multiple regression
20 model). The positive first formula is used to calculate the first state
quantity, when, for example, the parasympathetic nervous system is
determined to be more dominant than the sympathetic nervous
system based on the first index (in other words, when the first value
calculated by applying the first logistic regression model to the first
25 index is greater than or equal to the first threshold value). The
positive first formula is derived using data in which, for each of the
subjects, the location (so-called coordinates) of the point in Russell's
circumplex model of affect determined based on the subjective
evaluation of the subject regarding the psychological state when the
30 parasympathetic nervous system is more dominant than the
sympathetic nervous system is associated with a plurality of first
indexes obtained from the actual measurement values such as pulse
wave. The negative first formula is used to calculate the first state
quantity, when, for example, the parasympathetic nervous system is
35 determined not to be more dominant than the sympathetic nervous

system based on the first index (in other words, when the first value calculated by applying the first logistic regression model to the first index is not greater than or equal to the first threshold value). The negative first formula is derived using data in which, for each of the subjects, the location (so-called coordinates) of the point in Russell's circumplex model of affect determined based on the subjective evaluation of the subject regarding the psychological state when the sympathetic nervous system is more dominant than the parasympathetic nervous system is associated with a plurality of first indexes obtained from the actual measurement values such as pulse wave. In this way, by calculating the first state quantity using the positive first formula and the negative first formula, the accuracy of estimating the psychological state increases.

[0072]

The two different second multiple regression models are used to calculate the second state quantity as two different second formulas. In the following, the two different second formulas are also referred to as a positive second formula (here, positive second multiple regression model) and a negative second formula (here, negative second multiple regression model). The positive second formula is used to calculate the second state quantity, for example, when it is determined that the amount of autonomic nervous system activity is greater than or equal to a threshold value based on the second index (in other words, when the second value calculated by applying the second logistic regression model to the second index is greater than or equal to the second threshold value). The positive second formula is derived using data in which, for each of the subjects, the location (so-called coordinates) of the point in Russell's circumplex model of affect determined based on the subjective evaluation of the subject regarding the psychological state when the autonomic nervous system activity is greater than or equal to a threshold value is associated with a plurality of second indexes obtained from the actual measurement values such as pulse wave. The negative second formula is used to calculate the second state quantity, for example, when it is determined that the amount of

autonomic nervous system activity is not greater than or equal to the threshold value based on the second index (in other words, when the second value calculated by applying the second logistic regression model to the second index is not greater than or equal to the second threshold value). The negative second formula is derived using data in which, for each of the subjects, the location (so-called coordinates) of the point in Russell's circumplex model of affect determined based on the subjective evaluation of the subject regarding the psychological state when the autonomic nervous system activity is less than a threshold value is associated with a plurality of second indexes obtained from the actual measurement values such as pulse wave. In this way, by calculating the first state quantity using the positive first formula and the negative first formula, the accuracy of estimating the psychological state increases.

[0073]

Model 34a is constructed based on data from a plurality of subjects stored in database 35. For example, model 34a is derived using data in which, for each of the subjects, the location (i.e., coordinates) of the point indicating the psychological state in Russell's circumplex model of affect determined based on the subjective evaluation result of the subject regarding the psychological state is associated with the first index and the second index obtained from the actual measurement values such as pulse wave. Model 34a includes, for example, a first logistic regression model for determining whether the parasympathetic nervous system is more dominant than the sympathetic nervous system based on the first index, and a second logistic regression model for determining whether the amount of autonomic nervous system activity is greater than or equal to a threshold value based on the second index.

[0074]

Database 35 stores, for each of the subjects, the calculated value of the first index, the calculated value of the second index, the first state quantity, the second state quantity, and the subjective evaluation result of the subject regarding the psychological state, which are associated with one other.

[0075]

[Operation]

Next, an operation of psychological state estimation system 100a according to Embodiment 2 will be described. FIG. 8 is a flowchart illustrating an example of an operation of psychological state estimation system 100a according to Embodiment 2. S11, S12 and S14 in FIG. 8 correspond to S11, S12 and S14 in FIG. 3.

[0076]

When physiological data obtainer 32a of server device 30a obtains the heart rate data or pulse wave data measured by sensor 10 via communicator 31 (S11), physiological data obtainer 32a outputs the obtained heart rate data or pulse wave data to first state quantity calculator 32f and second state quantity calculator 32g (not illustrated).

[0077]

Upon obtaining the heart rate data or pulse wave data output from physiological data obtainer 32a, first state quantity calculator 32f calculates a first index indicating the balance between the sympathetic nervous system and the parasympathetic nervous system based on the obtained data (S12).

[0078]

First determiner 32h determines whether the parasympathetic nervous system of subject 1 is more dominant than the sympathetic nervous system based on the first index calculated in step S12 (S131). Specifically, first determiner 32h determines whether the first value calculated by applying the first logistic regression model to the first index calculated in step S12 is greater than or equal to the first threshold value.

[0079]

Next, first state quantity calculator 32f calculates the first state quantity using a different first formula (in other words, a different first multiple regression model) depending on the determination result of first determiner 32h in step S131. Specifically, when first determiner 32h determines that the parasympathetic nervous system of subject 1 is more dominant than the sympathetic nervous system

(in other words, when the first value is determined to be greater than or equal to the first threshold value) (Yes in S131), first state quantity calculator 32f calculates the first state quantity using the positive first formula of the two different first formulas (S132). On the other hand,
5 when first determiner 32h determines that the parasympathetic nervous system of subject 1 is not dominant than the sympathetic nervous system (in other words, the first value is determined not to be greater than or equal to the first threshold value) (No in S131), first state quantity calculator 32f calculates the first state quantity
10 using the negative first formula of the two different first formulas (S133). First state quantity calculator 32f outputs the first state quantity calculated in step S132 or step S133 to psychological state estimator 32d (not illustrated).

[0080]

15 Upon obtaining the heart rate data or pulse wave data output from physiological data obtainer 32a, second state quantity calculator 32g calculates a second index indicating the amount of autonomic nervous system activity based on the obtained data (S14).

[0081]

20 Second determiner 32i determines whether the amount of autonomic nervous system activity of subject 1 is greater than or equal to the threshold value based on the second index calculated in step S14 (S151). Specifically, second determiner 32i determines whether the second value calculated by applying the second logistic
25 regression model to the second index calculated in step S14 is greater than or equal to a second threshold value.

[0082]

Next, second state quantity calculator 32g calculates the second state quantity using a different second formula (in other words,
30 a different second multiple regression model) depending on the determination result of second determiner 32i in step S151. Specifically, when second determiner 32i determines that the amount of the autonomic nervous system activity of subject 1 is greater than or equal to the threshold value (in other words, when the second value
35 is determined to be greater than or equal to the second threshold

value) (Yes in S151), second state quantity calculator 32g calculates the second state quantity using the positive second formula of the two different second formulas (S152). On the other hand, when second determiner 32i determines that the amount of the autonomic nervous system activity of subject 1 is not greater than or equal to the threshold value (in other words, the second value is determined not to be greater than or equal to the second threshold value) (No in S151), second state quantity calculator 32g calculates the second state quantity using the negative second formula of two different second formulas (S153). Second state quantity calculator 32g outputs the second state quantity calculated in step S152 or step S153 to psychological state estimator 32d (not illustrated).

[0083]

Upon obtaining the first state quantity and the second state quantity output from first state quantity calculator 32f and second state quantity calculator 32g, psychological state estimator 32d processes step S16 in FIG. 3. Psychological state estimation system 100a then performs steps S17 and S18 in FIG. 3, and then ends the process.

[0084]

[Advantageous Effects, etc.]

As described above, psychological state estimation system 100a includes: physiological data obtainer 32a that obtains one of heart rate data or pulse wave data of subject 1; first state quantity calculator 32f that calculates a first index based on the one of the heart rate data or the pulse wave data obtained by physiological data obtainer 32a, and calculates a first state quantity based on the first index calculated, the first index indicating a balance between a sympathetic nervous system and a parasympathetic nervous system, the first state quantity indicating a state of the balance between the sympathetic nervous system and the parasympathetic nervous system of subject 1; second state quantity calculator 32g that calculates a second index based on the one of the heart rate data or the pulse wave data obtained by physiological data obtainer 32a, and calculates a second state quantity based on the second index calculated, the

second index indicating an amount of an autonomic nervous system activity, the second state quantity indicating a state of the amount of the autonomic nervous system activity of subject 1; and psychological state estimator 32d that estimates a psychological state of subject 1
5 by considering (i) the first state quantity calculated by first state quantity calculator 32f as a value on a first axis and (ii) the second state quantity calculated by second state quantity calculator 32g as a value on a second axis that intersects with the first axis, the first axis being oblique to both a pleasure-displeasure axis and an arousal-sleepiness axis in Russell's circumplex model of affect. For example, psychological state estimator 32d may consider the second state quantity calculated by second state quantity calculator 32c as a value on the second axis orthogonal to the first axis.

[0085]

15 Psychological state estimation system 100a described above converts the value on the first axis, which is the first state quantity indicating the state of balance between the sympathetic nervous system and the parasympathetic nervous system of subject 1, and the value on the second axis, which is the second state quantity
20 indicating the state of the amount of the autonomic nervous system activity of subject 1, into values on the two axes of Russell's circumplex model of affect. By doing so, psychological state estimation system 100a is capable of identifying the location of the point indicating the psychological state of subject 1 in Russell's circumplex model of affect. This allows psychological state
25 estimation system 100a to estimate the psychological state of subject 1 based on the location of the identified point, thus enabling accurate estimation of the psychological state of subject 1.

[0086]

30 For example, the first axis is oblique to the pleasure-displeasure axis at a predetermined angle, the second axis is oblique to the arousal-sleepiness axis at the predetermined angle, and the predetermined angle is within a range from at least 40 degrees to at most 50 degrees.

35 [0087]

Psychological state estimation system 100a described above multiplies the values on the first axis and the second axis by the coefficient of the trigonometric function of a predetermined angle as parameters and performs addition or subtraction. By doing so, psychological state estimation system 100a is capable of identifying the location of the point indicating the psychological state of subject 1 in Russell's circumplex model of affect. In particular, psychological state estimation system 100a is capable of accurately identifying the location of the point indicating the psychological state of subject 1, when the predetermined angle is within the range from at least 40 degrees to at most 50 degrees.

[0088]

Moreover, psychological state estimation system 100a further includes: first determiner 32h that determines, based on the first index, whether the parasympathetic nervous system is more dominant than the sympathetic nervous system; and second determiner 32i that determines, based on the second index, whether the amount of the autonomic nervous system activity is greater than or equal to a threshold value. First state quantity calculator 32f calculates the first state quantity using a different first formula depending on a result of determination obtained by first determiner 32h, and second state quantity calculator 32g calculates the second state quantity using a different second formula depending on a result of determination obtained by second determiner 32i.

[0089]

Psychological state estimation system 100a described above is capable of switching between the first formulas to be applied to calculate the first state quantity depending on whether the parasympathetic nervous system of subject 1 is more dominant than the sympathetic nervous system, and switching between the second formulas to be applied to calculate the second state quantity depending on whether the amount of the autonomic nervous system activity is greater than or equal to a threshold value. Accordingly, since psychological state estimation system 100a is capable of more accurately calculating the first state quantity and the second state

quantity, psychological state estimation system 100a is capable of estimating the psychological state of subject 1 more accurately.

[0090]

Moreover, for example, in psychological state estimation system 100a, first determiner 32h determines whether a first value is greater than or equal to a first threshold value, the first value being calculated by applying a first logistic regression model to the first index, second determiner 32i determines whether a second value is greater than or equal to a second threshold value, the second value being calculated by applying a second logistic regression model to the second index, the second logistic regression model being different from the first logistic regression model, first state quantity calculator 32f calculates the first state quantity using a different first multiple regression model as the different first formula depending on a result of determining whether the first value is greater than or equal to the first threshold value, and second state quantity calculator 32g calculates the second state quantity using a different second multiple regression model as the different second formula depending on a result of determining whether the second value is greater than or equal to the second threshold value.

[0091]

Psychological state estimation system 100a described above determines whether the parasympathetic nervous system of subject 1 is more dominant than the sympathetic nervous system by applying the first logistic regression model to the first index. Psychological state estimation system 100a is capable of calculating the first state quantity more accurately by using a different first multiple regression model depending on the determination result. Moreover, psychological state estimation system 100a determines whether the amount of the autonomic nervous system activity of subject 1 is greater than or equal to a threshold value by applying the second logistic regression model to the second index. Psychological state estimation system 100a is capable of calculating the second state quantity more accurately by using a different second multiple regression model depending on the determination result.

Accordingly, psychological state estimation system 100a is capable of calculating the first state quantity and the second state quantity more accurately, thus enabling more accurate estimation of the psychological state of subject 1.

5 [0092]

Moreover, for example, psychological state estimation system 100a further includes display processor 32e that displays, on display 25 of information terminal 20, the psychological state of subject 1 estimated by psychological state estimator 32d.

10 [0093]

Psychological state estimation system 100a described above displays the estimation result of the psychological state on display 25, so that subject 1 is able to visually recognize his or her own psychological state.

15 [0094]

(Other Embodiments)

Although the embodiments have been described above, the present invention is not limited to the embodiments.

[0095]

20 For example, in the above embodiments, server device 30 obtains the heart rate or pulse wave data of subject 1 measured by sensor 10 (hereinafter, referred to as "physiological data"). However, server device 30 may obtain the physiological data of a plurality of subjects 1 to estimate the psychological state of each of subjects 1.

25 [0096]

Moreover, for example, server device 30 may obtain the physiological data stored in an external server, estimate the psychological state based on the obtained physiological data, and provide feedback on the estimated psychological state to the external server.

30

[0097]

Moreover, for example, server device 30 may obtain physiological data of a plurality of subjects stored in an external server, and store the obtained data in database 35. Server device 30 may update model 34 using the stored physiological data.

35

[0098]

For example, the psychological state estimation system may display, in addition to the estimation result of the psychological state of the subject, suggestions for guiding the psychological state of the subject in a better way. For example, when the psychological state of the subject is tired, text or audio information, such as "close your eyes and take a deep breath" or "have something sweet" may be presented to the subject.

[0099]

Moreover, for example, when the psychological state estimation system receives an input of the psychological state desired by a subject, the psychological state estimation system may provide nature sounds or music or suggest action to the subject, in order to lead the subject from the current psychological state to the psychological state desired by the subject (such as a state of relaxation).

[0100]

Moreover, for example, in the psychological state estimation system, the subject may select the display mode of the estimation result of the psychological state, and may also select the timing at which the estimation result is displayed.

[0101]

Moreover, in the above embodiments, an example has been described in which information processing is performed by the server device in the psychological state estimation system, but information processing may also be performed by an information terminal. The server device may be a local server or a cloud server.

[0102]

For example, in the above embodiments, the processes executed by a specific processor may be executed by another processor. Moreover, the order of the processes may be changed, and the processes may be executed in parallel.

[0103]

Moreover, in the above embodiments, each structural element may be realized by executing a software program suitable for each

structural element. Each of the structural elements may be realized by means of a program executing unit, such as a CPU or a processor, reading and executing the software program recorded on a recording medium such as a hard disk or a semiconductor memory.

5 [0104]

Each structural element may be realized by hardware. For example, each structural element may be realized by a circuit (or integrated circuit). These circuits may form one circuit as a whole, or may be separate circuits. These circuits may be general-purpose
10 circuits or dedicated circuits.

[0105]

The general and specific aspects of the present invention may be realized using a system, a device, a method, an integrated circuit, a computer program, or a computer-readable recording medium such
15 as a CD-ROM. Moreover, the general and specific aspects of the present invention may be realized in any combination of systems, devices, methods, integrated circuits, computer programs and recording media.

[0106]

For example, the present invention may be realized as a
20 psychological state estimation method, a program for causing a computer to execute the psychological state estimation method, or as a non-transitory computer-readable recording medium in which such a program is recorded.

25 [0107]

The present invention may be realized as the psychological state estimation system in the above embodiments, and as a program executed by a computer for causing the computer to operate as the psychological state estimation system. Moreover, the present
30 invention may be realized as a non-transitory computer-readable recording medium in which such a program is recorded.

[0108]

Moreover, in the above embodiments, the psychological state estimation system is realized by a plurality of devices, but may be
35 realized as a single device. When the psychological state estimation

system is realized by a plurality of devices, the structural elements included in the psychological state estimation system described in the embodiments may be distributed to the plurality of devices in any manner.

5 [0109]

In addition, a form obtained by making various modifications conceivable by those skilled in the art to each embodiment, and a form realized by arbitrarily combining the structural elements and functions in each embodiment without departing from the gist of the present invention are also included in the present invention.

[0110]

(Additional Information)

The inventions obtained from the disclosure of the description of the present application will be exemplified and the advantageous effects and the like obtained from the inventions will be described.

[0111]

[Invention 1]

A psychological state estimation system including:

a physiological data obtainer that obtains one of heart rate data or pulse wave data of a subject;

a first state quantity calculator that calculates a first index based on the one of the heart rate data or the pulse wave data obtained by the physiological data obtainer, and calculates a first state quantity based on the first index calculated, the first index indicating a balance between a sympathetic nervous system and a parasympathetic nervous system, the first state quantity indicating a state of the balance between the sympathetic nervous system and the parasympathetic nervous system of the subject;

a second state quantity calculator that calculates a second index based on the one of the heart rate data or the pulse wave data obtained by the physiological data obtainer, and calculates a second state quantity based on the second index calculated, the second index indicating an amount of an autonomic nervous system activity, the second state quantity indicating a state of the amount of the autonomic nervous system activity of the subject; and

a psychological state estimator that estimates a psychological state of the subject by considering (i) the first state quantity calculated by the first state quantity calculator as a value on a first axis and (ii) the second state quantity calculated by the second state quantity calculator as a value on a second axis that intersects with the first axis, the first axis being oblique to both a pleasure-displeasure axis and an arousal-sleepiness axis in Russell's circumplex model of affect.

[0112]

10 [Advantageous Effects of Invention 1]

The psychological state estimation system described above converts the value on the first axis, which is the first state quantity indicating the state of a balance between the sympathetic nervous system and the parasympathetic nervous system of the subject, and the value on the second axis, which is the second state quantity indicating the state of the amount of the autonomic nervous activity of the subject, into the values on the two axes of Russell's circumplex model of affect. By doing so, the psychological state estimation system is capable of identifying the psychological state of subject 1 in Russell's circumplex model of affect. This allows the psychological state estimation system to estimate the psychological state of the subject based on the location of the identified point, thus enabling accurate estimation of the psychological state of the subject.

[0113]

25 [Invention 2]

The psychological state estimation system according to Invention 1,

wherein the first axis is oblique to the pleasure-displeasure axis at a predetermined angle,

30 the second axis is oblique to the arousal-sleepiness axis at the predetermined angle, and

the predetermined angle is within a range from at least 40 degrees to at most 50 degrees.

[0114]

35 [Advantageous Effects of Invention 2]

The psychological state estimation system described above multiplies the values on the first axis and the second axis as parameters by the coefficient of the trigonometric function of a predetermined angle and performs addition or subtraction. By doing
5 so, the psychological state estimation system is capable of identifying the location of the point indicating the psychological state of subject 1 in Russell's circumplex model of affect. In particular, the psychological state estimation system is capable of accurately identifying the location of the point indicating the psychological state
10 of the subject, when the predetermined angle is within the range from at least 40 degrees to at most 50 degrees.

[0115]

[Invention 3]

The psychological state estimation system according to
15 Invention 1 or Invention 2, further including:

a first determiner that determines, based on the first index, whether the parasympathetic nervous system is more dominant than the sympathetic nervous system; and

a second determiner that determines, based on the second
20 index, whether the amount of the autonomic nervous system activity is greater than or equal to a threshold value,

wherein the first state quantity calculator calculates the first state quantity using a different first formula depending on a result of determination obtained by the first determiner, and

25 the second state quantity calculator calculates the second state quantity using a different second formula depending on a result of determination obtained by the second determiner.

[0116]

[Advantageous Effects of Invention 3]

30 The psychological state estimation system described above is capable of switching between the first formulas to be applied to calculate the first state quantity according to whether the parasympathetic nervous system of the subject is more dominant than the sympathetic nervous system and between the second formulas to
35 be applied to calculate the second state quantity according to whether

the amount of the autonomic nervous system activity is greater than or equal to a threshold value. Accordingly, the psychological state estimation system is capable of calculating the first state quantity and the second state quantity more accurately, enabling more accurate estimation of the psychological state of the subject.

[0117]

[Invention 4]

The psychological state estimation system according to Invention 3,

10 wherein the first determiner determines whether a first value is greater than or equal to a first threshold value, the first value being calculated by applying a first logistic regression model to the first index,

15 the second determiner determines whether a second value is greater than or equal to a second threshold value, the second value being calculated by applying a second logistic regression model to the second index, the second logistic regression model being different from the first logistic regression model,

20 the first state quantity calculator calculates the first state quantity using a different first multiple regression model as the different first formula depending on a result of determining whether the first value is greater than or equal to the first threshold value, and

25 the second state quantity calculator calculates the second state quantity using a different second multiple regression model as the different second formula depending on a result of determining whether the second value is greater than or equal to the second threshold value.

[0118]

30 [Advantageous Effects of Invention 4]

The psychological state estimation system described above determines whether the parasympathetic nervous system of the subject is more dominant than the sympathetic nervous system by applying the first logistic regression model to the first index, and uses
35 a different first multiple regression model depending on the

determination result, so that the first state quantity can be calculated more accurately. Moreover, the psychological state estimation system determines whether the amount of the autonomic nervous system activity of the subject is greater than or equal to a threshold value by applying the second logistic regression model to the second index, and uses a different second multiple regression model depending on the determination result, so that the second state quantity can be calculated more accurately. Accordingly, the psychological state estimation system is capable of calculating the first state quantity and the second state quantity more accurately, and thus, enabling more accurate estimation of the psychological state of the subject.

[0119]

[Invention 5]

The psychological state estimation system according to any one of Invention 1 to Invention 4, further including:

a display processor that displays, on a display of an information terminal, the psychological state of the subject estimated by the psychological state estimator.

[0120]

[Advantageous Effects of Invention 5]

The psychological state estimation system described above displays the estimation result of the psychological state on the display, so that the subject is able to visually recognize his or her own psychological state.

[Reference Signs List]

[0121]

1	subject
10	sensor
20	information terminal
25	display
32a	physiological data obtainer
32b, 32f	first state quantity calculator
32c, 32g	second state quantity calculator
32d	psychological state estimator

32e display processor
32h first determiner
32i second determiner
100, 100a psychological state estimation system

[CLAIMS]

[Claim 1]

A psychological state estimation system comprising:

5 a physiological data obtainer that obtains one of heart rate data or pulse wave data of a subject;

a first state quantity calculator that calculates a first index based on the one of the heart rate data or the pulse wave data obtained by the physiological data obtainer, and calculates a first state quantity based on the first index calculated, the first index
10 indicating a balance between a sympathetic nervous system and a parasympathetic nervous system, the first state quantity indicating a state of the balance between the sympathetic nervous system and the parasympathetic nervous system of the subject;

a second state quantity calculator that calculates a second
15 index based on the one of the heart rate data or the pulse wave data obtained by the physiological data obtainer, and calculates a second state quantity based on the second index calculated, the second index indicating an amount of an autonomic nervous system activity, the second state quantity indicating a state of the amount of the
20 autonomic nervous system activity of the subject; and

a psychological state estimator that estimates a psychological state of the subject by considering (i) the first state quantity calculated by the first state quantity calculator as a value on a first axis and (ii) the second state quantity calculated by the second state
25 quantity calculator as a value on a second axis that intersects with the first axis, the first axis being oblique to both a pleasure-displeasure axis and an arousal-sleepiness axis in Russell's circumplex model of affect.

30 [Claim 2]

The psychological state estimation system according to claim 1, wherein the first axis is oblique to the pleasure-displeasure axis at a predetermined angle,

the second axis is oblique to the arousal-sleepiness axis at the
35 predetermined angle, and

the predetermined angle is within a range from at least 40 degrees to at most 50 degrees.

[Claim 3]

5 The psychological state estimation system according to claim 1 or claim 2, further comprising:

 a first determiner that determines, based on the first index, whether the parasympathetic nervous system is more dominant than the sympathetic nervous system; and

10 a second determiner that determines, based on the second index, whether the amount of the autonomic nervous system activity is greater than or equal to a threshold value,

 wherein the first state quantity calculator calculates the first state quantity using a different first formula depending on a result of determination obtained by the first determiner, and

15 the second state quantity calculator calculates the second state quantity using a different second formula depending on a result of determination obtained by the second determiner.

20 [Claim 4]

 The psychological state estimation system according to claim 3, wherein the first determiner determines whether a first value is greater than or equal to a first threshold value, the first value being calculated by applying a first logistic regression model to the first index,

25 the second determiner determines whether a second value is greater than or equal to a second threshold value, the second value being calculated by applying a second logistic regression model to the second index, the second logistic regression model being different from the first logistic regression model,

30 the first state quantity calculator calculates the first state quantity using a different first multiple regression model as the different first formula depending on a result of determining whether the first value is greater than or equal to the first threshold value, and

35

the second state quantity calculator calculates the second state quantity using a different second multiple regression model as the different second formula depending on a result of determining whether the second value is greater than or equal to the second
5 threshold value.

[Claim 5]

The psychological state estimation system according to claim 1, further comprising:

10 a display processor that displays, on a display of an information terminal, the psychological state of the subject estimated by the psychological state estimator.

[Claim 6]

15 A psychological state estimation method comprising:
obtaining one of heart rate data or pulse wave data of a subject;

calculating a first index based on the one of the heart rate data or the pulse wave data obtained in the obtaining, and calculating a
20 first state quantity based on the first index calculated, the first index indicating a balance between a sympathetic nervous system and a parasympathetic nervous system, the first state quantity indicating a state of the balance between the sympathetic nervous system and the parasympathetic nervous system of the subject;

25 calculating a second index based on the one of the heart rate data or the pulse wave data obtained in the obtaining, and calculating a second state quantity based on the second index calculated, the second index indicating an amount of an autonomic nervous system activity, the second state quantity indicating a state of the amount of
30 the autonomic nervous system activity of the subject; and

estimating a psychological state of the subject by considering (i) the first state quantity calculated in the calculating of the first state quantity as a value on a first axis and (ii) the second state quantity calculated in the calculating of the second state quantity as
35 a value on a second axis that intersects with the first axis, the first

axis being oblique to both a pleasure-displeasure axis and an arousal-sleepiness axis in Russell's circumplex model of affect.

[Claim 7]

- 5 A program for causing a computer to execute the psychological state estimation method according to Claim 6.