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(54) **Method and apparatus for evaluating human stress using photoplethysmography**

Methode und Vorrichtung zur menschlichen Stressevaluierung durch Photoplethysmographie

Procédé et appareil d'évaluation du stress humaine par photoplethysmographie

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- **PATENT ABSTRACTS OF JAPAN vol. 1998, no. 08, 30 June 1998 (1998-06-30) & JP 10 071137 A (OMRON CORP), 17 March 1998 (1998-03-17)**
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Description

[0001] The present invention relates to evaluating human stress, and more particularly, to a method and apparatus for evaluating human stress using PhotoPlethysmoGraphy (PPG).

[0002] In the field of medical diagnosis, various attempts to diagnose cardiovascular diseases or detect the degree of development of a disease or the stiffness of a blood vessel using PPG. PPG indicates a signal corresponding to the quantity of light reflected from a selected part of a human body after being irradiated by light having a particular wavelength emitted from a light source of a light emitting device. Technology using PPG has been mainly developed for the purpose of determining a patient's physiological condition in association with an arterial system but usually used as an auxiliary means for diagnosing particular diseases.

[0003] For example, U.S. Patent No. 5,830,131 discloses a monitor configured to provide a calibration signal representative of a patient's physiological parameter in order to determine the patient's physiological condition. A hemoparameter is defined as any physiological parameter related to vessel blood such as pressure, flow, volume, velocity, blood vessel wall motion, blood vessel wall position and other related parameters. A processor is configured to determine a relationship between a property of a received PPG waveform and a property of the physiological parameter. With such an arrangement, arterial elasticity, arterial thickness, arterial stiffness, arterial wall compliance and other conditions can be determined.

[0004] U.S. Patent No. 6,340,346 discloses a method of inferring the condition of a fetus by measuring ECG, BP, PO_2, PCO_2, blood flow (corresponding to PPG), blood velocity, blood volume, thermal index, respiration, and other physiological signals from a pregnant woman and using a Box-Jenkins mathematical model based on changes in the physiological signals. U.S. Patent No. 6,117,075 discloses a method and device for determining the depth of anesthesia by collecting PPG and skin temperature (SKT) data from a patient's fingers, dividing the data into predetermined frequency bands, and performing spectrum analysis and concordance evaluation based on variations of the data.

[0005] In the meantime, a variety of methods using various types of physiological signals to which a human body reacts have been proposed to evaluate human pleasantness, human tranquility, or human stress. In these methods, human stress or pleasantness is measured and evaluated based on at least two physiological signals. In other words, in order to evaluate or continuously monitor the condition of a human body, various physiological signals such as ECG, EEG, EMG, PPG, GSR, and SKT are collected and analyzed.

[0006] For example, Japanese Patent Publication No. 2000-116614 discloses a method and apparatus for evaluating pleasantness. A glove is provided with a temperature sensor for measuring SKT, an electrode for measuring skin impedance, and a light emitting diode (LED) photo transistor for measuring a pulse wave. A pulse wave, SKT, and skin impedance respectively measured using a pulse wave detector circuit, a temperature detector circuit, and a skin impedance detector circuit are input to a measurement control processing unit (CPU). Based on the variations of the measured pulse wave, SKT and skin impedance, the pleasantness is evaluated. In addition, Japanese Patent Publication No. 1997-294724 discloses an apparatus for measuring SKT differences between a human subject's peripheral part such as a hand or foot and the human subject's truncal part using an infrared temperature sensor device to estimate a degree of stress and feeding the estimated value back to the human subject.

[0007] Such conventional technology can provide reliable analysis results by collecting various physiological signals. However, since there are many restrictions on human subjects along with the requirement of a large scale of system, measurement itself affects human subjects as a stress environment. Moreover, glove type or finger contact type measuring devices are used in order to obtain PPG from a human subject's fingers, so the human subject is restricted in performing operations such as working on a personal computer (PC) and other operations using a hand.

[0008] US 4867165 discloses a method for determining perfusion by evaluation of light emitted by at least one light source and influenced by arterial blood. The perfusion is displayed as variation in thickness from the sum of the parallel tissue enlargements or as a normalized volume. Use of perfusion as a measure of the stress condition of a patient is also disclosed.

[0009] According to the present invention, there is provided a PhotoPlethysmoGraphy, hereinafter referred to as PPG, apparatus comprising: a PPG measuring unit for radiating light having at least one wavelength reacting to a blood component to be measured at a measuring target and measuring a PPG signal from the measuring target during a predetermined period of time; an amplifying and filtering unit for amplifying the PPG signal provided from the PPG measuring unit to a predetermined level and performing filtering in order to remove noise components; and a signal processing unit for defining PPG parameters of the amplified and filtered PPG signal, characterized in that the signal processing unit is arranged to: define a pulse component amplitude, a peak-to-peak interval and a baseline spread range as the PPG parameters of the amplified and filtered PPG signal; and evaluate human stress using stress indexes acquired using all of the defined PPG parameters.

[0010] The human stress may be acquired from one of a long-term test and a short-term test, which are identified depending on a measuring time of the PPG signal provided from the amplifying and filtering unit.

[0011] The PPG measuring unit may have a "C" shape so that the measuring target can be inserted into the PPG measuring unit, and has one of transmissive and reflective structures.

[0012] The signal processing unit may be further arranged to: obtain an average of pulse component amplitudes during the predetermined period of time; compare the baseline spread range with the average of pulse component amplitudes during the predetermined period of time; and calculate a relative first stress index based on a relationship between the baseline spread range and the average of pulse component amplitudes.

[0013] The signal processing unit may be further arranged to: obtain an average of peak-to-peak intervals, and count a total number of peak-to-peak intervals, the number of peak-to-peak intervals less than the average peak-to-peak interval, and the number of peak-to-peak intervals greater than the average peak-to-peak interval, during the predetermined period of time; and calculate a relative second stress index based on a relationship between the number of peak-to-peak intervals less than the average peak-to-peak interval and the number of peak-to-peak intervals greater than the average peak-to-peak interval.

[0014] The signal processing unit may be further arranged to: count a total number of pulse components, the number of pulse components having an amplitude less than the average of pulse component amplitudes, and the number of pulse components having an amplitude greater than the average of pulse component amplitudes, during the predetermined period of time; and calculate a relative third stress index based on a relationship between the number of pulse components having an amplitude less than the average of pulse component amplitudes and the number of pulse components having an amplitude greater than the average of pulse component amplitudes.

[0015] The signal processing unit may be further arranged to average the stress indexes acquired from one of long-term and short-term tests based on the PPG parameters and determine an average stress index as a final stress index.

[0016] The apparatus may further comprise a display unit arranged to display at least one stress index and the evaluated human stress.

[0017] In the short-term test, the signal processing unit may be arranged to: obtain an average of peak-to-peak intervals during a predetermined period of time; count the number of peak-to-peak intervals less than the average peak-to-peak interval, and the number of peak-to-peak intervals greater than the average peak-to-peak interval, during the predetermined period of time; and calculate a relative stress index based on a relationship between the number of peak-to-peak intervals less than the average peak-to-peak interval and the number of peak-to-peak intervals greater than the average peak-to-peak interval.

[0018] In the long-term test the signal processing unit may be arranged to: obtain peak-to-peak intervals with respect to all of pulses during a predetermined period of time; define datasets composed of a predetermined number of peak-to-peak intervals with respect to all of the peak-to-peak intervals obtained during the predetermined period of time; perform a predetermined statistical method according to the number of datasets; and calculate a stress index based on a p-value detected as the result of performing the predetermined statistical method.

[0019] In the short-term test the signal processing unit may be arranged to: obtain an average of pulse component amplitudes during a predetermined period of time; count the number of pulse components having an amplitude less than the average of pulse component amplitudes, and the number of pulse components having an amplitude greater than the average of pulse component amplitudes, during the predetermined period of time; and calculate a relative stress index based on a relationship between the number of pulse components having an amplitude less than the average of pulse component amplitudes and the number of pulse components having an amplitude greater than the average of pulse component amplitudes. In the long-term test the signal processing unit may be arranged to: obtain pulse component amplitudes with respect to all of pulses during a predetermined period of time; define datasets composed of a predetermined number of pulse component amplitudes with respect to all of the pulse component amplitudes obtained during the predetermined period of time; perform a predetermined statistical method according to the number of datasets; and calculate a stress index based on a p-value detected as the result of performing the predetermined statistical method.

[0020] The predetermined statistical method may be a two-sample paired t-test when the number of datasets is two and is one-way ANalysis Of VAriance when the number of datasets is at least three.

[0021] The present invention thus provides an apparatus for evaluating a human subject's stress, i.e., a degree of tranquility, using the amplitude of a pulse component of PhotoPlethysmoGraphy (PPG), a change in a baseline, and a variation in the peak-to-peak interval of PPG generated in accordance with a heart rate.

[0022] The above and other features and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a graph illustrating a pulse component and a peak-to-peak interval in a PhotoPlethysmoGraphy (PPG) signal;
FIGS. 2A and 2B are graphs illustrating the spread range of a baseline in a PPG signal;
FIGS. 3A and 3B are graphs showing changes in PPG signals during stress and resting, respectively;
FIG. 4 is a graph showing the results of differentiating the PPG signal shown in FIG. 3A and the PPG signal shown in FIG. 3B;
FIG. 5 is a flowchart of a method of evaluating human stress using PPG according to an embodiment of the present invention;

FIG. 6 is a graph illustrating parameters defined in the method shown in FIG. 5;

FIGS. 7A and 7B are diagrams of examples of a PPG measuring device used to acquire PPG data in the method shown in FIG. 5;

FIGS. 8A and 8B are diagrams showing usage examples on the PPG measuring devices shown in FIGS. 7A and 7B;

FIG. 9 is a detailed flowchart of analysis in the method shown in FIG. 5;

FIG. 10 is a diagram showing an example of displaying stress based on the distribution of degrees of stress in the method shown in FIG. 5; and

FIG. 11 is a block diagram of an apparatus for evaluating human stress using PPG according to an embodiment of the present invention.

[0023] Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the attached drawings.

[0024] Information about a degree of contraction of a peripheral blood vessel and an increase or decrease in a cardiac output is reflected on PhotoPlethysmoGraphy (PPG), and the degree of contraction of a peripheral blood vessel and the increase or decrease in a cardiac output are dominated by an autonomic nervous system controlling a myocardial motion. For example, when a sympathetic nerve is excited by an external stimulus, a cardiac function increases such as a heart rate (HR) and a stimulus conduction rate increase or excitibility increases, and contractility is accentuated. An HR indicates the number of times a heart pulses per one minute and is expressed as beats per minute (BPM). Normal adults have an HR of 60-90 BPM. An HR increases during exercise, mental excitement, or fever and decreases during sleep. In other words, when a sympathetic nerve is excited, a peat-to-peak interval of PPG decreases due to an increase in an HR, and the amplitude of a pulse component of PPG reduces due to the contraction of a peripheral blood vessel.

[0025] In the meantime, a baseline in PPG changes due to an irregular deep breath or other moving artifact made by a human subject not at rest. In a change in an HR during breathing, an HR increases during inhalation due to an acceleration in the motion of a sinoatrial node while decreasing during exhalation. With a change in the baseline in PPG, a peat-to-peak interval repeatedly increases and decreases, and its increasing and decreasing degrees and status vary depending on a degree of stimulus to a sympathetic nerve.

[0026] FIG. 1 is a graph illustrating a pulse component and a peak-to-peak interval (PPI) in a PPG signal collected from a human subject. In the graph, a height from the lowest to the highest points in each pulse is referred to as a pulse component amplitude 11, and a distance between adjacent highest points is referred to as a peat-to-peak interval 13.

[0027] FIGS. 2A and 2B are graphs illustrating the spread range of a baseline in a PPG signal. The spread range of a baseline is expressed by a difference between a largest peak value and a lowest peak value in the entire collected data. The spread range of a baseline reflects information on a change in the PPG baseline. A baseline spread range 21 appearing when an irregular breath or other moving artifact occurs, as shown in FIG. 2A, is greater than a baseline spread range 23 appearing when breathing or posture is stable, as shown in FIG. 2B. Here, it can be inferred that a change in a baseline is stabler when breathing or posture is stable.

[0028] FIGS. 3A and 3B are graphs showing changes in PPG signals during stress and resting, respectively. A pulse component amplitude 31 during stress is less than a pulse component amplitude 37 during resting, and a baseline spread range 33 during stress is greater than a baseline spread range 39 during resting.

[0029] FIG. 4 is a graph showing the results of primarily differentiating the PPG signal shown in FIG. 3A and the PPG signal shown in FIG. 3B in order to closely compare changes in a pulse component amplitude between stress and resting. Since primary differentiation removes direct current components from the PPG signals, only the pulse components can be easily compared. It can be seen from FIG. 4 that the pulse component amplitude during stress is reduced compared to the pulse component amplitude during resting.

[0030] Experiments were repeatedly performed on five human subjects in order to verify whether there was a statistically significant difference in an average of pulse component amplitudes in PPG, i.e., AC mean, between stress and resting, as shown in FIG. 4. Here, for a light source used to collect PPG signals, particular five wavelengths within a range of 500-1000 nm were selected and referred to as AC1, AC2, AC3, AC4, and AC5, respectively. After collecting PPG data with respect to the five wavelengths, pulse component amplitudes were extracted and configured into a data set. Then, a paired t-test was performed with respect to two groups in a stress condition and a resting condition, respectively. The results of the experiments are shown in Table 1.

Table 1

Human subject	Wavelength	Stress		Resting		p-value
		AC mean	AC sd	AC mean	AC sd	
#1-1	AC1	134.77	12.28	144.21	13.00	0.005
	AC2	90.87	10.79	96.59	7.57	0.026
	AC3	132.79	17.03	138.82	10.05	0.017
	AC4	127.44	13.02	133.26	7.32	0.034
	AC5	130.33	13.54	138.95	10.60	0.031
#1-2	AC1	125.79	15.23	150.34	12.95	0.000
	AC2	86.37	16.10	90.63	9.18	0.175
	AC3	120.11	15.68	140.79	11.52	0.000
	AC4	112.87	14.43	138.97	11.59	0.000
	AC5	119.08	17.18	134.24	11.41	0.000
#1-3	AC1	139.44	16.15	153.51	14.03	0.001
	AC2	88.37	11.37	93.98	11.05	0.046
	AC3	131.61	15.44	142.15	14.00	0.007
	AC4	130.27	13.80	138.39	13.17	0.025
	AC5	125.54	15.64	135.68	14.03	0.015
#2-1	AC1	178.29	13.10	198.26	15.97	0.000
	AC2	117.74	12.52	133.43	11.39	0.000
	AC3	178.06	12.22	200.23	16.23	0.000
	AC4	164.23	10.97	183.40	12.21	0.000
	AC5	170.83	12.09	193.03	13.68	0.000
#2-2	AC1	198.32	14.18	210.62	10.04	0.000
	AC2	135.21	11.01	140.71	7.61	0.019
	AC3	200.35	14.59	207.94	14.29	0.044
	AC4	186.15	13.99	191.62	11.97	0.101
	AC5	189.65	12.92	196.71	10.13	0.022
#2-3	AC1	198.50	12.95	216.38	12.56	0.000
	AC2	135.21	9.78	145.41	8.17	0.000
	AC3	199.41	11.91	215.12	13.34	0.000
	AC4	183.85	10.91	193.00	13.29	0.003
	AC5	187.68	10.63	198.74	12.23	0.000

(continued)

Human subject	Wavelength	Stress		Resting		p-value
		AC mean	AC sd	AC mean	AC sd	
#3-1	AC1	227.79	16.70	241.21	15.79	0.002
	AC2	138.45	12.27	154.89	13.15	0.000
	AC3	217.03	14.69	226.55	13.89	0.013
	AC4	214.05	16.28	232.00	15.69	0.000
	AC5	206.87	15.39	219.47	15.93	0.002
#3-2	AC1	212. 59	15.42	220.76	12.48	0.019
	AC2	137.43	13.93	145.35	11.93	0.004
	AC3	205.27	16.48	210.51	15.60	0.127
	AC4	208.41	13.57	214.19	11.94	0.028
	AC5	198.89	13.92	204.73	15.79	0.041
#4-1	AC1	478.58	19.78	529.92	23.33	0.000
	AC2	232.83	14.10	274.23	15.89	0.000
	AC3	392.63	19.03	451.33	21.58	0.000
	AC4	470.93	23.90	527.45	22.12	0.000
	AC5	466.33	20.28	526.83	24.48	0.000
#5-1	AC1	462.78	24.58	482.96	28.65	0.017
	AC2	246.89	15.20	262.93	15.77	0.005
	AC3	406.41	20.62	428.19	24.95	0.005
	AC4	440.15	18.61	459.81	21.70	0.005
	AC5	390.70	20.55	410.78	24.24	0.012
#5-2	AC1	484.04	17.10	513.68	14.69	0.000
	AC2	260.68	16.83	290.86	14.89	0.000
	AC3	428.50	17.03	451.71	18.41	0.000
	AC4	462.32	14.71	486.79	15.95	0.000
	AC5	414.18	16.22	434.07	13.09	0.000
#5-3	AC1	417.52	34.39	468.62	24.36	0.000
	AC2	222.72	20.10	263.38	18.11	0.000
	AC3	366.83	28.67	414.86	20.27	0.000
	AC4	395.03	32.38	443.62	21.24	0.000
	AC5	365.38	27.06	405.90	16.92	0.000

[0031] Referring to Table 1, when the two groups are compared, most of p-values are less than 0.05, that is, it is determined that there is a statistically significant difference in most cases. Even in otherwise cases, it can be seen that an AC mean during stress is less than that during resting.

[0032] Table 2 shows relationships among PPG parameters defined by the present invention and a human subject's stress and resting conditions.

Table 2

Conditions \ PPG parameters	Pulse component amplitude	PPI	Baseline spread range
Strain, Stress, Irregular breath, Moving artifact	↓	↓	↑
Tranquil, Resting, Regular breath, Stable posture	↑	↑	↓

[0033] FIG. 5 is a flowchart of a method of evaluating human stress using PPG according to an embodiment of the present invention. The method includes definition of parameters in step 51, collection of PPG data in step 53, filtering in step 55, analysis in step 57, and display in step 59.

[0034] Referring to FIG. 5, PPG parameters are defined, as shown in FIG. 6, in step 51. Referring to FIG. 6, a pulse component amplitude 61 is defined by a difference between a highest point and a lowest point of each pulse. In association with the pulse component amplitude 61, an AC mean and a total number of pulse components per a predetermined period of time are defined. In the total number of pulse components, the number of pulse components having an amplitude less than AC mean is defined as a "small AC count". A ratio of the small AC count to the total number of pulse components is defined as a "small AC count %". A value obtained by subtracting the small AC count % from 100 is defined as a "large AC count %".

[0035] Next, an i-th PPI 63 is defined by a time interval between an i-th peak P(i) and an adjacent (i+1)-th peak P(i+1) and is represented by PPI (i). A difference between a data index of the i-th peak P(i) and a data index of the (i+1)-th peak P(i+1) is obtained and then multiplied by a sampling rate to define a time interval. For example, when the data index of the i-th peak P(i) is i(n) and the data index of the (i+1)-th peak P(i+1) is i(n+k), PPI(i) can be expressed by Formula (1)

$$PPI(i) = [i(n+k)-i(n)]\times \text{sampling rate} \qquad ...(1)$$

[0036] In association with the PPI 63, an average PPI and a total number of PPIs per a predetermined period of time are defined. In the total number of PPIs, the number of PPIs less than the average PPI is defined as "fast PPI count". A ratio of the fast PPI count to the total number of PPIs is defined as a "fast PPI count %". A value obtained by subtracting the fast PPI count % from 100 is defined as a "slow PPI count %".

[0037] Next, a baseline spread range 65 is defined by a difference between a maximum peak Pmax and a minimum peak Pmin in the entire PPG data collected per a predetermined period of time.

[0038] Referring to back to FIG. 5, a predetermined period of time is set as a unit time, and PPG data is collected during the unit time in step 53. For this operation, a PPG measuring device shown in FIG. 7A or 7B is used.

[0039] FIG. 7A shows a transmissive PPG measuring device including a light emitting part 72 with a light emitting element 71 radiating light and a light receiving part 75 with a light receiving element 74 detecting light transmitted by a measuring target 73. The housings of the light emitting part 72 and the light receiving part 75 are connected at their one ends to form a "⊂" shape. FIG. 7B shows a reflective PPG measuring device including a light emitting/receiving part 78 with a light emitting element 76 radiating light and a light receiving element 77 detecting light reflected from a measuring target 73. A measuring target support 79 is connected to the one end of the light emitting/receiving part 78 to form a "⊂" shape. As shown in FIGS. 8A and 8B, a PPG measuring device 81 shown in FIG. 7A or 7B can be used at any part of human body, for example, an ear 83, a finger 85, or a toe.

[0040] In step 53, light having a particular wavelength is radiated at the measuring target 73 of a human body using the PPG measuring device 81, and light reflected or transmitted by the measuring target 73 is detected. Here, light used in the light emitting part 72 or 78 has a particular wavelength suiting with the purpose of measurement, such as a wavelength of 500-1000 nm, and may have a single wavelength or at least two wavelengths. A data sampling frequency is selected to be in an appropriate range considering a highest frequency in PPG so that an aliasing phenomenon or distortion of an original signal can be avoided. A data sampling time may be fundamentally set to be at least 30 seconds but may be optionally set to be appropriate to the purpose of measuring.

[0041] Referring back to FIG. 5, in step 55, low-pass filtering is performed in order to remove high-frequency noise from the PPG data collected in step 53. Here, a low-pass filter having a 10 Hz cut-off frequency may be used.

[0042] In step 57, the PPG data filtered in step 55 is analyzed using the PPG parameters defined in step 51 to calculate a human subject's stress index. Step 57 will be described in detail with reference to FIG. 9.

[0043] Referring to FIG. 9, a baseline spread range is compared with an AC mean to obtain a stress index SI. For example, stress indexes are classified into 8 classes according to conditional formulae shown in Table 3. If a data group to be compared satisfies a condition for a particular class among the 8 classes, subtraction or addition is performed on a stress index SI in accordance with the condition. The stress index obtained as the result of the above operation is referred to as SI_1 and is adjusted not exceed 100.

Table 3

Class	Condition	Stress index (initial value=30)
A	AC mean*3 ≤ baseline spread range	SI = SI-20
B	AC mean*3 < baseline spread range ≤ AC mean*4	SI = SI+5
C	AC mean*4 < baseline spread range ≤ AC mean*5	SI = SI+15
D	AC mean*5 < baseline spread range ≤ AC mean*6	SI = SI+20
E	AC mean*6 < baseline spread range ≤ AC mean*7	SI = SI+30
F	AC mean*7 < baseline spread range ≤ AC mean*8	SI = SI+40
G	AC mean*8 < baseline spread range ≤ AC mean*9	SI = SI+50
H	AC mean*9 < baseline spread range	SI = SI+60

[0044] In step 93, a fast PPI count % is calculated based on an average PPI, and it is determined whether the fast PPI count % is within a predetermined range to obtain a stress index SI. For example, stress indexes are classified into 3 classes according to conditional formulae shown in Table 4. If a data group to be compared satisfies a condition for a particular class among the 3 classes, subtraction or addition is performed on a stress index SI in accordance with the condition. The stress index obtained as the result of the above operation is referred to as SI_2 and is adjusted not exceed 100.

Table 4

Class	Condition	Stress index (initial value=50)
A	fast PPI count % ≤ 50	SI = SI-20
B	50 < fast PPI count % ≤ 60	SI = SI+15
C	60 < fast PPI count %	SI = SI+35

[0045] In the meantime, when it takes a little long period of time to collect PPG data, a statistical method can be used in order to increase the reliability of evaluation. For example, when it takes more than 1 minute to collect PPG data, it is determined whether a total number of PPIs in the collected PPG data is at least 50. If it is determined that the total number of PPIs is at least 50, a PPI time series data group from an initial PPI to 25th PPI is defined as a dataset_1, a PPI time series data group corresponding to the next 25 PPIs is defined as a dataset_2, and a dataset_n is defined in the same manner. If two data groups to be compared exist, a two-sample paired t-test is performed, and if at least three data groups to be compared exist, one-way ANalysis Of VAriance (ANOVA) is performed, in order to detect a p-value. If the detected p-value is greater than 0.05, a stable condition is determined. If the detected p-value is smaller than 0.05, an instable condition is determined. In addition, determination on a degree of stress based on a p-value can be more precisely performed on the basis of 0.05. For example, stress indexes are classified into 4 classes according to conditional formulae shown in Table 4. If a data group to be compared satisfies a condition for a particular class among the 4 classes, subtraction or addition is performed on a stress index SI in accordance with the condition. The stress index obtained as the result of the above operation is referred to as SI_3 and is adjusted not exceed 100.

Table 5

Class	Condition	Stress index (initial value=50)
A	p-value ≥ 0.05	SI = SI-20
B	0.01 ≤ p-value < 0.05	SI = SI+15
C	0.001 ≤ p-value < 0.01	SI = SI+25
D	p-value < 0.001	SI = SI+35

[0046] Next, in step 95, a small AC count % is calculated based on an AC mean, and it is determined whether the small AC count % exists within a predetermined range in order to obtain a stress index SI. For example, stress indexes are classified into 3 classes according to conditional formulae shown in Table 6. If a data group to be compared satisfies a condition for a particular class among the 3 classes, subtraction or addition is performed on a stress index SI in accordance with the condition. The stress index obtained as the result of the above operation is referred to as SI_4 and is adjusted not exceed 100.

Table 6

Class	Condition	Stress index (initial value=50)
A	small AC count % ≤ 50	SI = SI-20
B	50 < small AC count % ≤ 60	SI = SI+15
C	60 < small AC count %	SI = SI+35

[0047] In the meantime, when it takes a little long period of time to collect PPG data, a statistical method can be used in order to increase the reliability of evaluation. For example, when it takes more than 1 minute to collect PPG data, it is determined whether a total number of pulse components in the collected PPG data is at least 50. If it is determined that the total number of pulse components is at least 50, a pulse component amplitude time series data group from an initial pulse component to 25th pulse component is defined as a dataset_1, a pulse component amplitude time series data group corresponding to the next 25 pulse components is defined as a dataset_2, and a dataset_n is defined in the same manner. If two data groups to be compared exist, a two-sample paired t-test is performed, and if at least three data groups to be compared exist, one-way ANOVA is performed, in order to detect a p-value. If the detected p-value is greater than 0.05, a stable condition is determined. If the detected p-value is smaller than 0.05, an instable condition is determined. In addition, determination on a degree of stress based on a p-value can be more precisely performed on the basis of 0.05. For example, stress indexes are classified into 4 classes according to conditional formulae shown in Table 7. If a data group to be compared satisfies a condition for a particular class among the 4 classes, subtraction or addition is performed on a stress index SI in accordance with the condition. The stress index obtained as the result of the above operation is referred to as SI_5 and is adjusted not exceed 100.

Table 7

Class	Condition	Stress index (initial value=50)
A	p-value ≥ 0.05	SI = SI-20
B	0.01 ≤ p-value < 0.05	SI = SI+15
C	0.001 ≤ p-value < 0.01	SI = SI+25
D	p-value < 0.001	SI = SI+35

[0048] As described above, short-term stress indexes and long-term stress indexes can be obtained depending on time taken for collecting PPG data. A short-term stress index group 97 includes SI_1, SI_2, and SI_4, and a long-term stress index group 98 includes SI_1, SI_2, SI_3, SI_4, and SI_5. After setting maximum values for the respective stress indexes SI_1 through SI_5, a degree of stress can be evaluated based on the set values. For example, a maximum value of each of the stress indexes SI_1 through SI_5 can be set to 100 for convenience sake, and a degree of stress, which is referred to as a stress index %, can be calculated as shown in Formulae (2) and (3).

$$\text{Long-term stress index \%} = (\text{sum of long-term stress indexes}/300) \times 100 \quad ...(2)$$

$$\text{Short-term stress index \%} = (\text{sum of short-term stress indexes}/500) \times 100 \quad ...(3)$$

[0049] In other words, in step 57, the PPG data is divided into a long-term test and a short-term test depending on time taken for collecting the PPG data and separately analyzed. For example, data may be placed under the short-term test when a data collection time is less than one minute, and data may be placed under the long-term test when a data collection time exceeds one minute.

[0050] Referring back to FIG. 5, in step 59, items of the stress indexes detected in step 57 and a final stress index % are displayed. The stress index items can be changed when necessary. When it is determined whether the stress index % exists within a predetermined reference range, the stress index % can be displayed along with the predetermined reference range. For example, the stress index % can be evaluated based on its distribution, as shown in FIG. 10. In other words, when the stress index % is within a range of $\pm$10% centering around 43%, a normal condition is determined. When the stress index % exceeds the maximum limit of the normal range, a stress condition is determined. When the stress index % is less than the minimum limit of the normal range, a relaxed condition is determined.

[0051] FIG. 11 is a block diagram of an apparatus for evaluating human stress using PPG according to an embodiment of the present invention. The apparatus includes a PPG measuring unit 101, an amplifying and filtering unit 103, a signal processing unit 105, a storage unit 107, and a display unit 109.

[0052] Referring to FIG. 11, the PPG measuring unit 101 has a " $\subset$ " shape, as shown in FIG. 7A or 7B, so that a measuring target can be inserted into the PPG measuring unit 101. The PPG measuring unit 101 measures a PPG signal generated from a part of human body, such as a finger, toe, or earlobe, where peripheral blood vessels are concentrated. Here, its on/off interval is controlled by the signal processing unit 105. The amplifying and filtering unit 103 amplifies the PPG signal provided from the PPG measuring unit 101 to a predetermined level and performs filtering to remove noise components.

[0053] The signal processing unit 105 extracts a PPG signal reacting to a particular blood component from a signal provided from the amplifying and filtering unit 103, converts the extracted PPG signal to digital data, calculates pulse component amplitudes, a baseline spread range, and PPIs with respect to the PPG digital data during a predetermined period of time, and evaluates human stress using the calculated PPG parameters. A program for performing a method of evaluating human stress using PPG according to the present invention is recorded in the signal processing unit 105, and a computer-readable recording medium is installed therein.

[0054] The storage unit 107 stores the processing result from the signal processing unit 105. The display unit 109 displays the processing result from the signal processing unit 105 to report it to a user.

[0055] In the meantime, an apparatus for evaluating human stress using PPG according to the present invention can employ a wireless communication mode so that the PPG measuring unit 101 transmits and receives data to and from a receiving side without being connected to a PC. Alternatively, although a wireless communication mode is not employed, since extraction of reliable parameters in the PPG measuring unit 101 simplifies an algorithm and reduces the amount of arithmetic operation, an apparatus of the present invention can be implemented in a stand alone type, in which the PPG measuring unit 101 and the signal processing unit 105 coexist.

[0056] The present invention can be realized as a code which is recorded on a computer-readable recording medium and can be read by a computer. For example, a method of evaluating human stress using PPG according to the present invention can be implemented by recording on a computer-readable recording medium a first program for defining PPG parameters including at least one of a pulse component amplitude, a PPI, and a baseline spread range; a second program for radiating light having at least one wavelength reacting to a blood component to be measured at a measuring target and measuring a PPG signal from the measuring target for a predetermined period of time; and a third program for evaluating human stress based on the PPG parameters defined by the first program, in a long-term test or a short-term test identified depending on a measuring time of the PPG signal. The computer-readable recording medium may be any type on which data which can be read by a computer system can be recorded, for example, a ROM, a RAM, a CD-ROM, a magnetic tape, a floppy disc, or an optical data storage device. The present invention can also be realized as carrier waves (for example, transmitted through the Internet). Alternatively, computer readable recording media are distributed among computer systems connected through a network so that the present invention can be realized as a code which is stored in the recording media and can be read and executed in the computers. Functional programs, codes, and code segments for implementing the present invention can be easily inferred by programmers skilled in the art of the present invention.

[0057] As described above, according to the present invention, a degree of a human subject's stress is determined using an average of pulse component amplitudes, i.e., AC mean, an average PPI, and a baseline spread range which are defined with respect to a PPG signal, so a human subject can be provided with as much convenience as possible, and the reliability of analysis can also be increased.

[0058] In addition, according to the present invention, a PPG measuring device can be simplified and miniaturized so that a PPG signal can be measured from any body part, such as an earlobe where peripheral blood vessels are concentrated, as well as a finger. As a result, even when a human subject works on a PC, a degree of stress can be continuously measured for a long period of time.

Claims

1. A PhotoPlethysmoGraphy, hereinafter referred to as PPG, apparatus comprising:

   a PPG measuring unit (101) for radiating light having at least one wavelength reacting to a blood component to be measured at a measuring target (73) and measuring a PPG signal from the measuring target (73) during a predetermined period of time;
   an amplifying and filtering unit (103) for amplifying the PPG signal provided from the PPG measuring unit (101) to a predetermined level and performing filtering in order to remove noise components; and
   a signal processing unit (105) for defining PPG parameters of the amplified and filtered PPG signal, said signal processing unit (105) being arranged to:

      define a pulse component amplitude (61), a peak-to-peak interval (63) and a baseline spread range (65) as the PPG parameters of the amplified and filtered PPG signal; and
      evaluate human stress using stress indexes acquired using all of the defined PPG parameters of the amplified and filtered PPG signal.

2. The apparatus of claim 1, wherein the human stress is acquired from one of a long-term test and a short-term test, which are identified depending on a measuring time of the PPG signal provided from the amplifying and filtering unit (103).

3. The apparatus of any one of claims 1 or 2, wherein the PPG measuring unit (101) has a "C" shape so that the measuring target (73) can be inserted into the PPG measuring unit (101), and has one of transmissive and reflective structures.

4. The apparatus of any one of claims 1 to 3, wherein the signal processing unit (105) is further arranged to:

   obtain an average of pulse component amplitudes (61) during the predetermined period of time;
   compare the baseline spread range (65) with the average of pulse component amplitudes during the predetermined period of time; and
   calculate a relative first stress index based on a relationship between the baseline spread range (65) and the average of pulse component amplitudes.

5. The apparatus of any one of claims 1 to 4, wherein the signal processing unit (105) is further arranged to:

   obtain an average peak-to-peak interval (63) during the predetermined period of time, and count a total number of peak-to-peak intervals (63), the number of peak-to-peak intervals less than the average peak-to-peak interval, and the number of peak-to-peak intervals greater than the average peak-to-peak interval, during the predetermined period of time; and
   calculate a relative second stress index based on a relationship between the number of peak-to-peak intervals less than the average peak-to-peak interval and the number of peak-to-peak intervals greater than the average peak-to-peak interval.

6. The apparatus of any one of claims 1 to 5, wherein the signal processing unit (105) is further arranged to:

   count a total number of pulse components, the number of pulse components having an amplitude less than the average of pulse component amplitudes (61), and the number of pulse components having an amplitude greater than the average of pulse component amplitudes (61), during the predetermined period of time; and calculate a relative third stress index based on a relationship between the number of pulse components having an amplitude less than the average of pulse component amplitudes and the number of pulse components having an amplitude greater than the average of pulse component amplitudes.

7. The apparatus of any one of claims 1 to 6, wherein the signal processing unit (105) is further arranged to average the stress indexes acquired from one of long-term and short-term tests based on the PPG parameters and determine an average stress index as a final stress index.

8. The apparatus of any one of claims 1 to 7, further comprising a display unit (109) arranged to display at least one stress index and the evaluated human stress.

9. The apparatus of claim 2, wherein in the short-term test the signal processing unit (105) is arranged to:

obtain an average of peak-to-peak intervals (63) during a predetermined period of time;
count the number of peak-to-peak intervals (63) less than the average peak-to-peak interval, and the number of peak-to-peak intervals (63) greater than the average peak-to-peak interval, during the predetermined period of time; and
calculate a relative stress index based on a relationship between the number of peak-to-peak intervals less than the average peak-to-peak interval, and the number of peak-to-peak intervals greater than the average peak-to-peak interval.

10. The apparatus of claim 2, wherein in the long-term test the signal processing unit (105) is arranged to:

obtain peak-to-peak intervals (63) with respect to all of pulses during a predetermined period of time;
define datasets composed of a predetermined number of peak-to-peak intervals (63) with respect to all of the peak-to-peak intervals obtained during the predetermined period of time;
perform a predetermined statistical method according to the number of datasets; and
calculate a stress index based on a p-value detected as the result of performing the predetermined statistical method.

11. The apparatus of claim 2, wherein in the short-term test the signal processing unit (105) is arranged to:

obtain an average of pulse component amplitudes (61) during a predetermined period of time;
count the number of pulse components having an amplitude less than the average of pulse component amplitudes (61), and the number of pulse components having an amplitude greater than the average of pulse component amplitudes (61), during the predetermined period of time; and
calculate a relative stress index based on a relationship between the number of pulse components having an amplitude less than the average of pulse component amplitudes and the number of pulse components having an amplitude greater than the average of pulse component amplitudes.

12. The apparatus of claim 2, wherein in the long-term test the signal processing unit (105) is arranged to:

obtain pulse component amplitudes (61) with respect to all of pulses during a predetermined period of time;
define datasets composed of a predetermined number of pulse component amplitudes (61) with respect to all of the pulse component amplitudes (61) obtained during the predetermined period of time;
perform a predetermined statistical method according to the number of datasets; and
calculate a stress index based on a p-value detected as the result of performing the predetermined statistical method.

13. The apparatus of claim 10 or 12, wherein the predetermined statistical method is a two-sample paired t-test when the number of datasets is two and is one-way ANalysis Of VAriance when the number of datasets is at least three.

Patentansprüche

1. Vorrichtung zur Photoplethysmographie, nachfolgend als PPG bezeichnet, umfassend:

eine PPG-Messeinheit (101) zum Einstrahlen von Licht mit mindestens einer Wellenlänge, das auf eine zu

messende Blutkomponente in einem Messobjekt (73) reagiert, und Messen eines PPG-Signals vom Messobjekt (73) während einer bestimmten Zeitspanne,
eine Verstärker- und Filtereinheit (103) zum Verstärken des von der PPG-Messeinheit (101) bereitgestellten PPG-Signals auf ein bestimmtes Niveau und Durchführen einer Filterung, um Rauschkomponenten zu eliminieren, und
eine Signalverarbeitungseinheit (105) zum Definieren von PPG-Parametern des verstärkten und gefilterten PPG-Signals, wobei die Signalverarbeitungseinheit (105) so ausgebildet ist, dass sie
eine Pulskomponentenamplitude (61), ein Peak-zu-Peak-Intervall (63) und einen Basislinienstreubereich (65) als die PPG-Parameter des verstärkten und gefilterten PPG-Signals definiert, und
Belastung beim Menschen unter Verwendung von Belastungsindices ermittelt, die unter Verwendung aller definierter PPG-Parameter des verstärkten und gefilterten PPG-Signals gewonnen sind.

2. Vorrichtung nach Anspruch 1, wobei die Belastung beim Menschen aus einem Langzeittest oder einem Kurzzeittest gewonnen sind, die in Abhängigkeit von einer Messdauer des PPG-Signals identifiziert sind, das von der Verstärker- und Filtereinheit (103) bereitgestellt wird.

3. Vorrichtung nach Anspruch 1 oder 2, wobei die PPG-Messeinheit (101) eine "C-Form" aufweist, so dass das Messobjekt (73) in die PPG-Messeinheit (101) eingesetzt werden kann, und eine Transmissions- oder Reflexionsstruktur aufweist.

4. Vorrichtung nach einem der Ansprüche 1 bis 3, wobei die Signalverarbeitungseinheit (105) ferner so ausgebildet ist, dass sie:

einen Mittelwert von Pulskomponentenamplituden (61) während der bestimmten Zeitspanne ermittelt,
den Basislinienstreubereich (65) mit dem Mittelwert der Pulskomponentenamplituden während der bestimmten Zeitspanne vergleicht und
einen ersten relativen Belastungsindex berechnet, der auf einer Beziehung zwischen dem Basislinienstreubereich (65) und dem Mittelwert der Pulskomponentenamplituden basiert.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, wobei die Signalverarbeitungseinheit (105) ferner so ausgebildet ist, dass sie:

einen Mittelwert des Peak-zu-Peak-Intervalls (63) während der bestimmten Zeitspanne ermittelt und eine Gesamtanzahl an Peak-zu-Peak-Intervallen (63), die Anzahl an Peak-zu-Peak-Intervallen, die kleiner sind als das mittlere Peak-zu-Peak-Intervall, und die Anzahl an Peak-zu-Peak-Intervallen, die größer sind als das mittlere Peak-zu-Peak-Intervall, während der bestimmten Zeitspanne zählt, und
einen relativen zweiten Belastungsindex basierend auf einer Beziehung zwischen der Anzahl an Peak-zu-Peak-Intervallen, die kleiner sind als das mittlere Peak-zu-Peak-Intervall, und der Anzahl an Peak-zu-Peak-Intervallen, die größer sind als das mittlere Peak-zu-Peak-Intervall, berechnet.

6. Vorrichtung nach einem der Ansprüche 1 bis 5, wobei die Signalverarbeitungseinheit (105) ferner so ausgebildet ist, dass sie:

eine Gesamtanzahl an Pulskomponenten, die Anzahl an Pulskomponenten, die eine kleinere Amplitude aufweisen als der Mittelwert der Pulskomponentenamplituden (61), und die Anzahl an Pulskomponenten, die eine größere Amplitude aufweisen als der Mittelwert der Pulskomponentenamplituden (61), während der bestimmten Zeitspanne zählt, und
einen relativen dritten Belastungsindex basierend auf einer Beziehung zwischen der Anzahl an Pulskomponenten, die eine kleinere Amplitude aufweisen als der Mittelwert der Pulskomponentenamplituden, und der Anzahl an Pulskomponenten, die eine größere Amplitude aufweisen als der Mittelwert der Pulskomponentenamplituden, berechnet.

7. Vorrichtung nach einem der Ansprüche 1 bis 6, wobei die Signalverarbeitungseinheit (105) ferner so ausgebildet ist, dass sie die aus einem Langzeit- oder Kurzzeittest erfassten Belastungsindices basierend auf den PPG-Parametern mittelt und einen mittleren Belastungsindex als endgültigen Belastungsindex bestimmt.

8. Vorrichtung nach einem der Ansprüche 1 bis 7, ferner umfassend eine Anzeigeeinheit (109), die so ausgebildet ist, dass sie mindestens einen Belastungsindex und die ermittelte Belastung des Menschen anzeigt.

9. Vorrichtung nach Anspruch 2, wobei die Signalverarbeitungseinheit (105) im Kurzzeittest so ausgebildet ist, dass sie:

einen Mittelwert von Peak-zu-Peak-Intervallen (63) während einer bestimmten Zeitspanne ermittelt,
die Anzahl an Peak-zu-Peak-Intervallen (63), die kleiner sind als das mittlere Peak-zu-Peak-Intervall, und die Anzahl an Peak-zu-Peak-Intervallen (63), die größer sind als das mittlere Peak-zu-Peak-Intervall, während der bestimmten Zeitspanne zählt, und
einen relativen Belastungsindex basierend auf einer Beziehung zwischen der Anzahl an Peak-zu-Peak-Intervallen, die kleiner sind als das mittlere Peak-zu-Peak-Intervall, und der Anzahl an Peak-zu-Peak-Intervallen, die größer sind als das mittlere Peak-zu-Peak-Intervall, berechnet.

10. Vorrichtung nach Anspruch 2, wobei die Signalverarbeitungseinheit (105) im Langzeittest so ausgebildet ist, dass sie:

Peak-zu-Peak-Intervalle (63) bezüglich aller Pulse während einer bestimmten Zeitspanne ermittelt,
Datensätze definiert, die aus einer bestimmten Anzahl an Peak-zu-Peak-Intervallen (63) bezüglich aller während der bestimmten Zeitspanne ermittelten Peak-zu-Peak-Intervalle bestehen,
gemäß der Anzahl an Datensätzen ein bestimmtes statistisches Verfahren durchführt und
einen Belastungsindex basierend auf einem p-Wert berechnet, der als Ergebnis der Durchführung des bestimmten statistischen Verfahrens erfasst ist.

11. Vorrichtung nach Anspruch 2, wobei die Signalverarbeitungseinheit (105) im Kurzzeittest so ausgebildet ist, dass sie:

einen Mittelwert von Pulskomponentenamplituden (61) während einer bestimmten Zeitspanne ermittelt,
die Anzahl an Pulskomponenten, die eine kleinere Amplitude aufweisen als der Mittelwert der Pulskomponentenamplituden (61), und die Anzahl an Pulskomponenten, die eine größere Amplitude aufweisen als der Mittelwert der Pulskomponentenamplituden (61), während der bestimmten Zeitspanne zählt, und
einen relativen Belastungsindex basierend auf einer Beziehung zwischen der Anzahl an Pulskomponenten, die eine kleinere Amplitude aufweisen als der Mittelwert der Pulskomponentenamplituden, und der Anzahl an Pulskomponenten, die eine größere Amplitude aufweisen als der Mittelwert der Pulskomponentenamplituden, berechnet.

12. Vorrichtung nach Anspruch 2, wobei die Signalverarbeitungseinheit (105) im Langzeittest so ausgebildet ist, dass sie:

Pulskomponentenamplituden (61) bezüglich aller Pulse während einer bestimmten Zeitspanne ermittelt,
Datensätze definiert, die aus einer bestimmten Anzahl an Pulskomponentenamplituden (61) bezüglich aller während der bestimmten Zeitspanne ermittelten Pulskomponentenamplituden (61) bestehen,
gemäß der Anzahl an Datensätzen ein bestimmtes statistisches Verfahren durchführt und
einen Belastungsindex basierend auf einem p-Wert berechnet, der als Ergebnis der Durchführung des bestimmten statistischen Verfahrens erfasst ist.

13. Vorrichtung nach Anspruch 10 oder 12, wobei das bestimmte statistische Verfahren ein t-Test für zwei gepaarte Stichproben ist, wenn die Anzahl an Datensätzen zwei beträgt, und eine einfaktorielle Varianzanalyse (one-way ANOVA), wenn die Anzahl an Datensätzen mindestens drei beträgt.

Revendications

1. Appareil de photopléthysmographie, ci-après désigné comme PPG, comprenant :

une unité de mesure de PPG (101) pour de la lumière rayonnante ayant au moins une longueur d'onde réagissant à un composant sanguin à mesurer sur une cible de mesure (73) et mesurant un signal de PPG venant de la cible de mesure (73) pendant une durée prédéterminée ;
une unité d'amplification et de filtration (103) pour amplifier le signal de PPG fourni par l'unité de mesure de PPG (101) à un niveau prédéterminé et effectuant la filtration pour éliminer les composantes du bruit ; et
une unité de traitement du signal (105) pour définir les paramètres de PPG du signal de PPG amplifié et filtré,

ladite unité de traitement du signal (105) étant agencée pour :

définir une amplitude de composante d'impulsion (61), un intervalle de pic à pic (63) et une gamme d'étalement

de la ligne de base (65), en tant que paramètres de PPG du signal de PPG amplifié et filtré, et
évaluer le stress humain au moyen des indices de stress obtenus en utilisant tous les paramètres de PPG définis du signal de PPG amplifié et filtré.

2. Appareil selon la revendication 1, dans lequel le stress humain est obtenu par un test à long terme ou un test à court terme, qui sont identifiés en fonction d'un temps de mesure du signal de PPG fourni par l'unité d'amplification et de filtration (103).

3. Appareil selon l'une quelconque des revendications 1 ou 2, dans lequel l'unité de mesure de PPG (101) a une forme en "C", si bien que la cible de mesure (73) peut être introduite dans l'unité de mesure de PPG (101) et a une structure à transmission ou à réflexion.

4. Appareil selon l'une quelconque des revendications 1 à 3, dans lequel l'unité de traitement du signal (105) est également agencée pour :

obtenir une moyenne des amplitudes des composantes d'impulsion (61) pendant la durée prédéterminée ;
comparer la gamme d'étalement de la ligne de base (65) avec la moyenne des amplitudes des composantes d'impulsion pendant la durée prédéterminée, et
calculer un premier indice de stress relatif basé sur une relation entre la gamme d'étalement de la ligne de base (65) et la moyenne des amplitudes des composantes d'impulsion.

5. Appareil selon l'une quelconque des revendications 1 à 4, dans lequel l'unité de traitement du signal (105) est également agencée pour :

obtenir un intervalle de pic à pic moyen (63) pendant la durée prédéterminée et compter un nombre total d'intervalles de pic à pic (63), le nombre d'intervalles de pic à pic inférieurs à l'intervalle moyen de pic à pic et le nombre d'intervalles de pic à pic supérieurs à l'intervalle moyen de pic à pic, pendant la durée prédéterminée, et
calculer un deuxième indice de stress relatif basé sur une relation entre le nombre d'intervalles de pic à pic inférieurs à l'intervalle moyen de pic à pic et le nombre d'intervalles de pic à pic supérieurs à l'intervalle moyen de pic à pic.

6. Appareil selon l'une quelconque des revendications 1 à 5, dans lequel l'unité de traitement du signal (105) est également agencée pour :

compter un nombre total de composantes d'impulsion, le nombre de composantes d'impulsion ayant une amplitude inférieure à la moyenne des amplitudes des composantes d'impulsion (61) et le nombre de composantes d'impulsion ayant une amplitude supérieure à la moyenne des amplitudes des composantes d'impulsion (61), pendant la durée prédéterminée, et
calculer un troisième indice de stress relatif basé sur une relation entre le nombre de composantes d'impulsion ayant une amplitude inférieure à la moyenne des amplitudes des composantes d'impulsion et le nombre de composantes d'impulsion ayant une amplitude supérieure à la moyenne des amplitudes des composantes d'impulsion.

7. Appareil selon l'une quelconque des revendications 1 à 6, dans lequel l'unité de traitement du signal (105) est également agencée pour établir la moyenne des indices de stress obtenus par un test à long terme ou un test à court terme basés sur les paramètres de PPG et déterminer un indice moyen de stress en tant qu'indice final de stress.

8. Appareil selon l'une quelconque des revendications 1 à 7, comprenant également une unité d'affichage (109) agencée de façon à afficher au moins un indice de stress et le stress humain évalué.

9. Appareil selon la revendication 2, dans lequel, dans le test à court terme, l'unité de traitement du signal (105) est agencée pour :

obtenir une moyenne des intervalles de pic à pic (63) pendant une durée prédéterminée ;
compter le nombre d'intervalles de pic à pic (63) inférieurs à l'intervalle moyen de pic à pic et le nombre d'intervalles de pic à pic (63) supérieurs à l'intervalle moyen de pic à pic, pendant la durée prédéterminée, et
calculer un indice de stress relatif basé sur une relation entre le nombre d'intervalles de pic à pic inférieurs à l'intervalle moyen de pic à pic et le nombre d'intervalles de pic à pic supérieurs à l'intervalle moyen de pic à pic.

10. Appareil selon la revendication 2, dans lequel, dans le test à long terme, l'unité de traitement du signal (105) est agencée pour :

obtenir des intervalles de pic à pic (63) par rapport à toutes les impulsions pendant une durée prédéterminée ;
définir des ensembles de données composés d'un nombre prédéterminé d'intervalles de pic à pic (63) par rapport à tous les intervalles de pic à pic obtenus pendant la durée prédéterminée ;
exécuter un procédé statistique prédéterminé selon le nombre d'ensembles de données, et
calculer un indice de stress basé sur une valeur p détectée en tant que résultat de l'exécution du procédé statistique prédéterminé.

11. Appareil selon la revendication 2, dans lequel, dans le test à court terme, l'unité de traitement du signal (105) est agencée pour :

obtenir une moyenne des amplitudes des composantes d'impulsion (61) pendant une durée prédéterminée ;
compter le nombre de composantes d'impulsion ayant une amplitude inférieure à la moyenne des amplitudes des composantes d'impulsion (61) et le nombre de composantes d'impulsion ayant une amplitude supérieure à la moyenne des amplitudes des composantes d'impulsion (61) pendant la durée prédéterminée, et
calculer un indice de stress relatif basé sur une relation entre le nombre de composantes d'impulsion ayant une amplitude inférieure à la moyenne des amplitudes des composantes d'impulsion et le nombre de composantes d'impulsion ayant une amplitude supérieure à la moyenne des amplitudes des composantes d'impulsion.

12. Appareil selon la revendication 2, dans lequel, dans le test à long terme, l'unité de traitement du signal (105) est agencée pour :

obtenir des amplitudes des composantes d'impulsion (61) par rapport à toutes les impulsions pendant une durée prédéterminée ;
définir des ensembles de données composés d'un nombre prédéterminé d'amplitudes de composantes d'impulsion (61) par rapport à toutes les amplitudes des composantes d'impulsion (61) obtenues pendant la durée prédéterminée ;
exécuter un procédé statistique prédéterminé selon le nombre d'ensembles de données, et
calculer un indice de stress basé sur une valeur p détectée en tant que résultat de l'exécution du procédé statistique prédéterminé.

13. Appareil selon la revendication 10 ou 12, dans lequel le procédé statistique prédéterminé est un test t par paire à deux échantillons lorsque le nombre d'ensembles de données est deux et est une ANalyse De VAriance unidirectionnelle lorsque le nombre d'ensembles de données est au moins trois.

FIG. 1

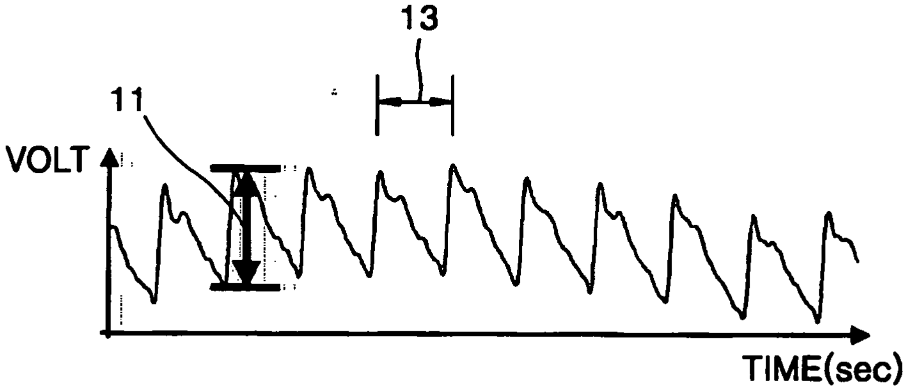
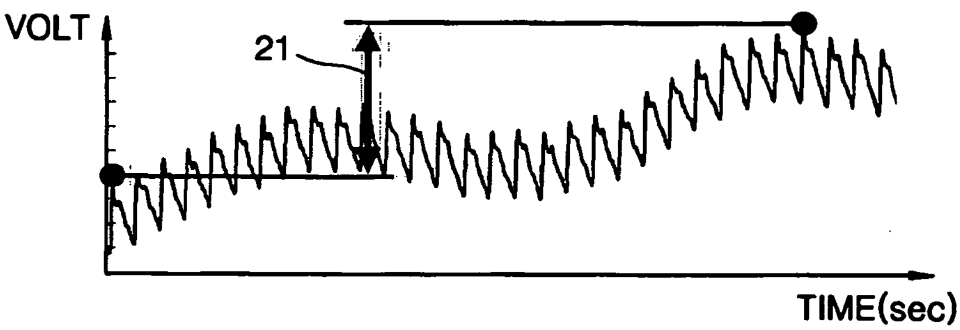


FIG. 2A



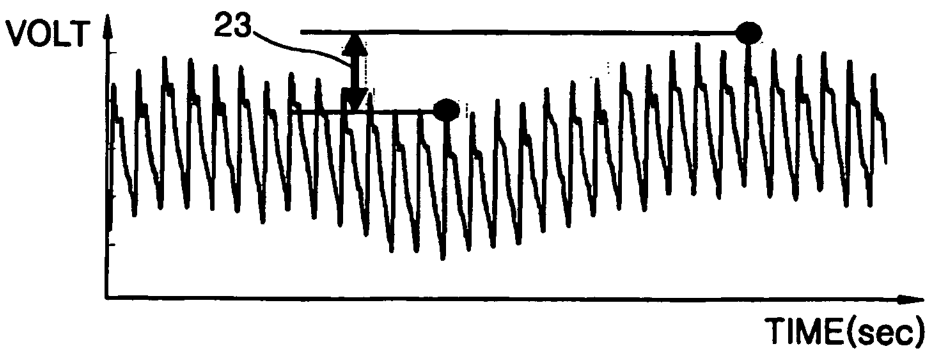


FIG. 3A

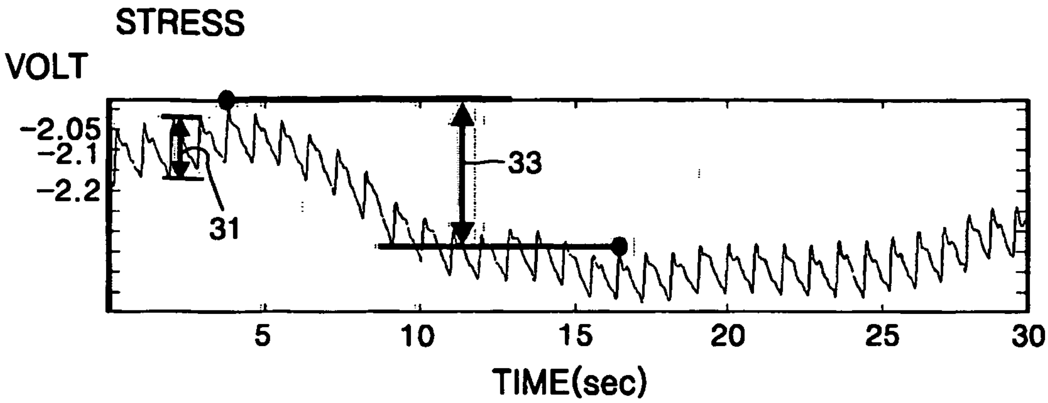


FIG. 3B

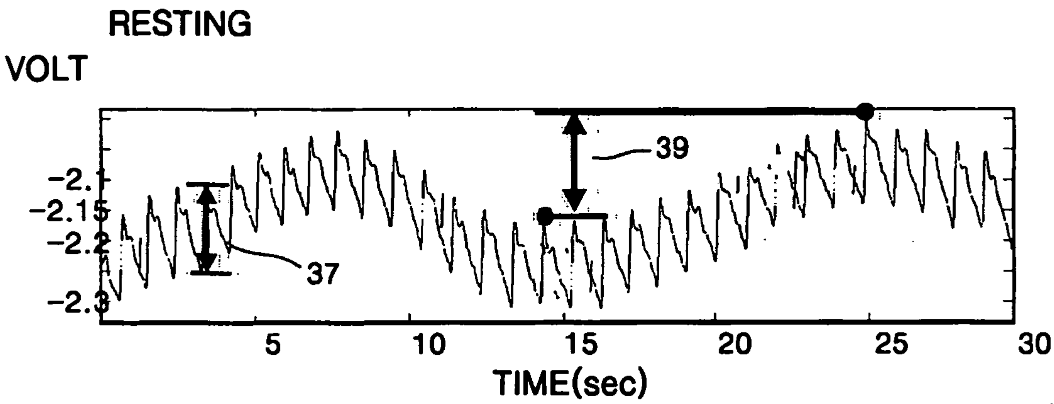


FIG. 4

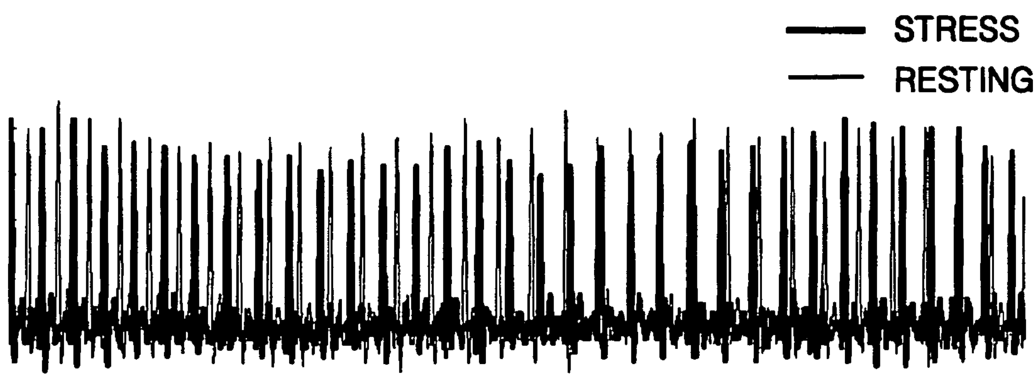


FIG. 5

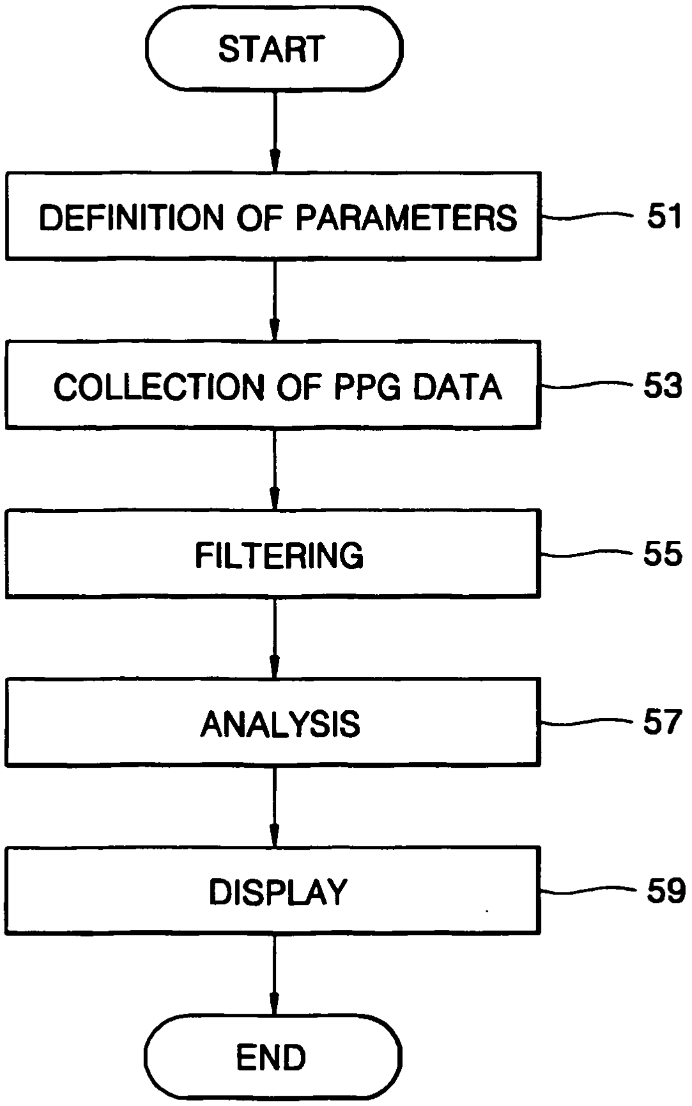

START
DEFINITION OF PARAMETERS
51
COLLECTION OF PPG DATA
53
FILTERING
55
ANALYSIS
57
DISPLAY
59
END

FIG. 6

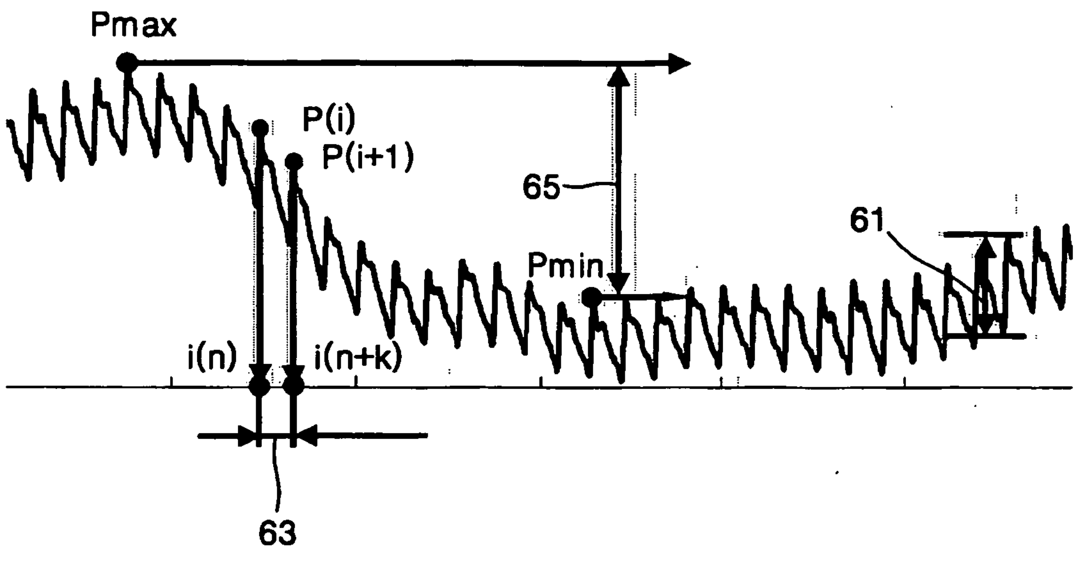


FIG. 7A

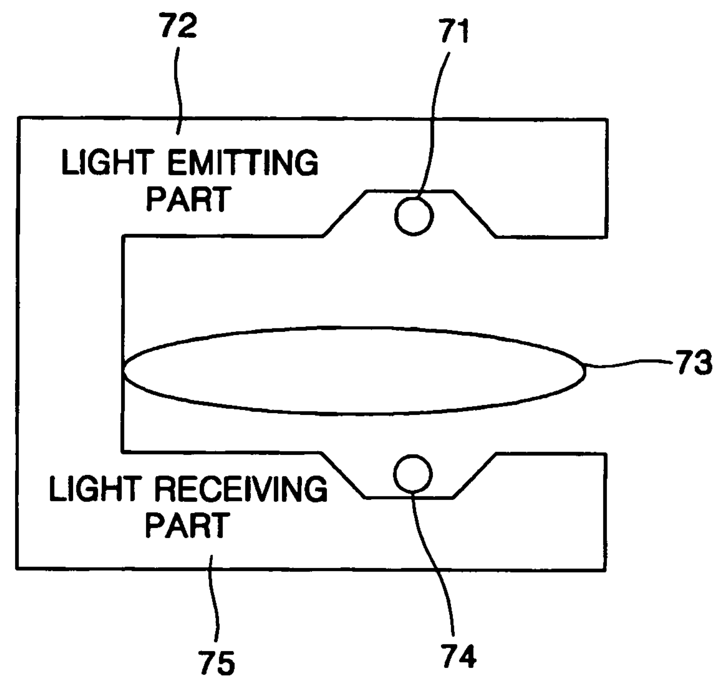

72
71
LIGHT EMITTING PART
73
LIGHT RECEIVING PART
75
74

FIG. 7B

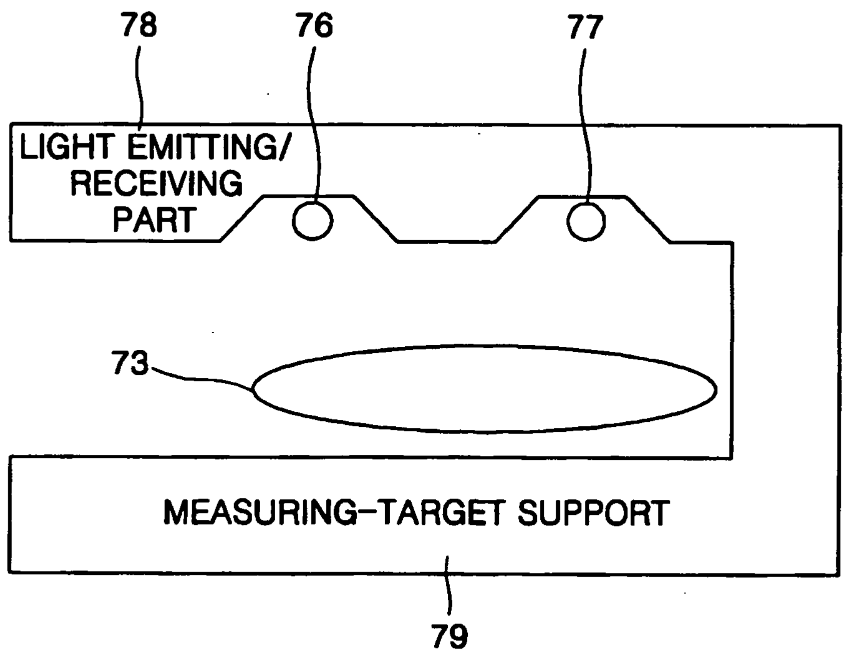

78
76
77
LIGHT EMITTING/ RECEIVING PART
73
MEASURING-TARGET SUPPORT
79

FIG. 8A

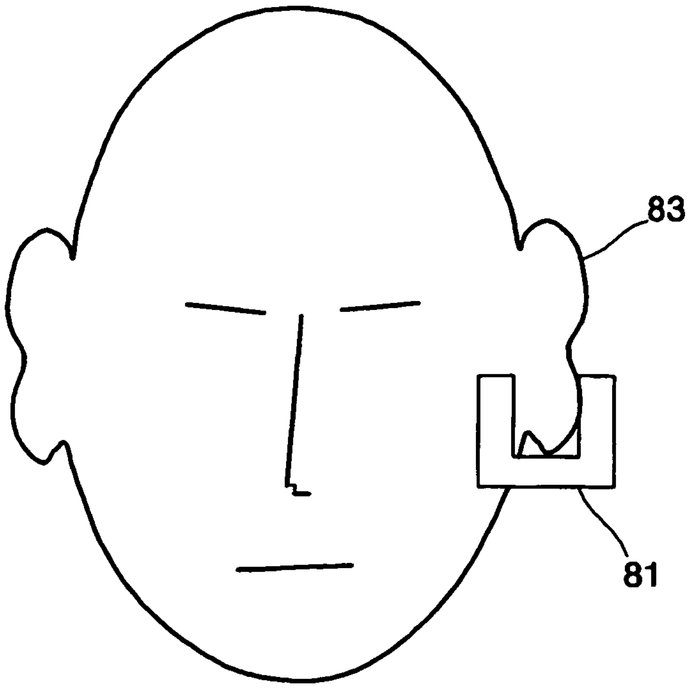


FIG. 8B

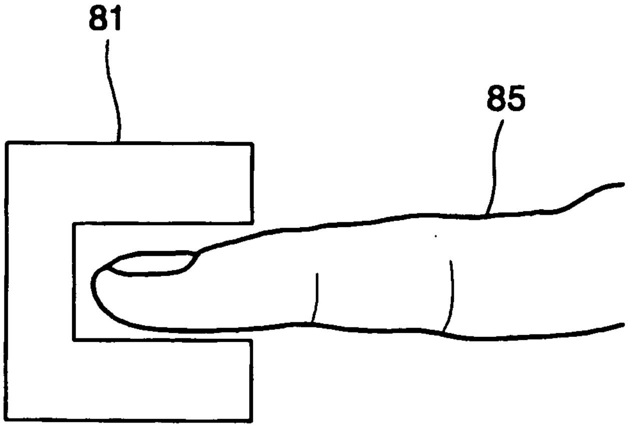


FIG. 9

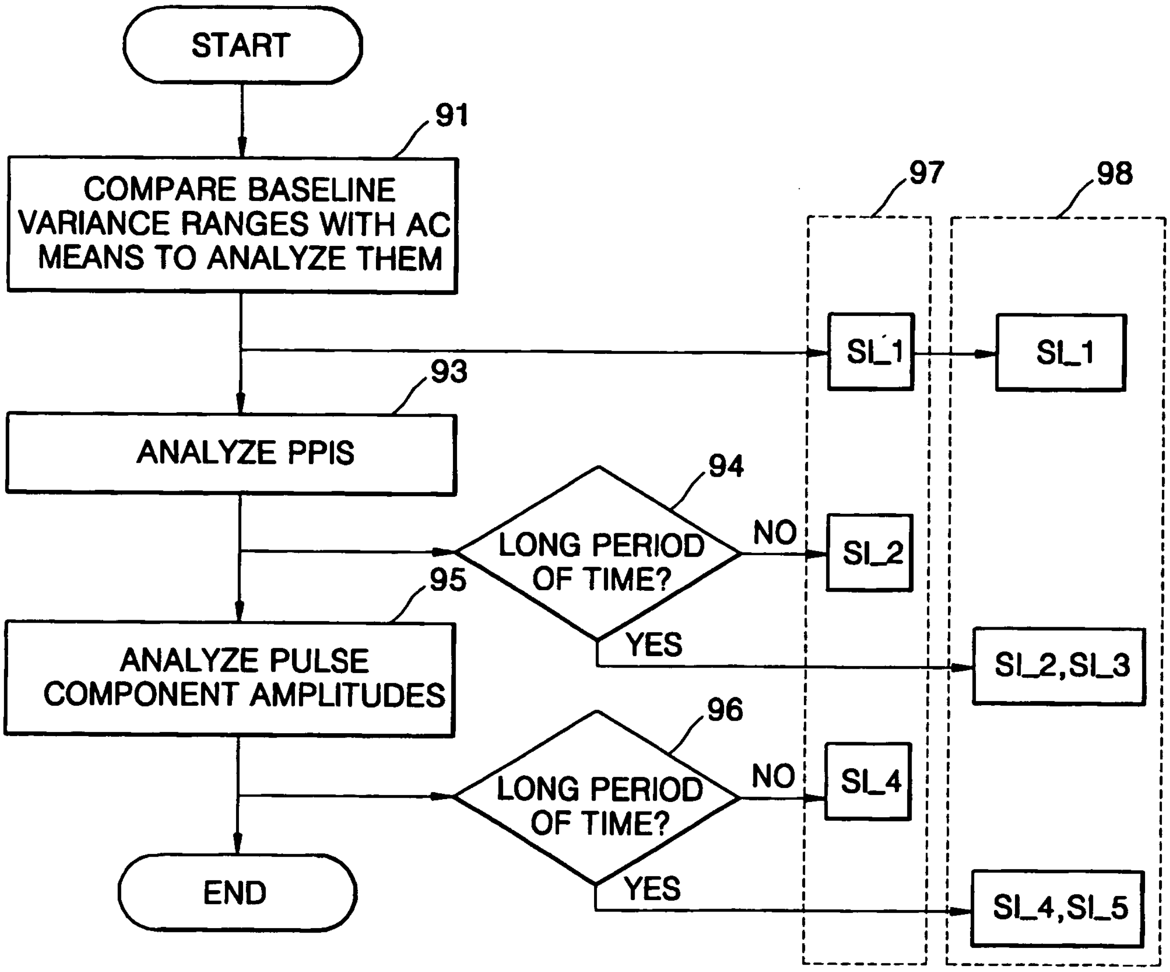

START
91
COMPARE BASELINE VARIANCE RANGES WITH AC MEANS TO ANALYZE THEM
97
98
SL'1
SL_1
93
ANALYZE PPIS
94
LONG PERIOD OF TIME?
NO
SL_2
95
YES
SL_2,SL_3
ANALYZE PULSE COMPONENT AMPLITUDES
96
LONG PERIOD OF TIME?
NO
SL_4
END
YES
SL_4,SL_5

FIG. 10

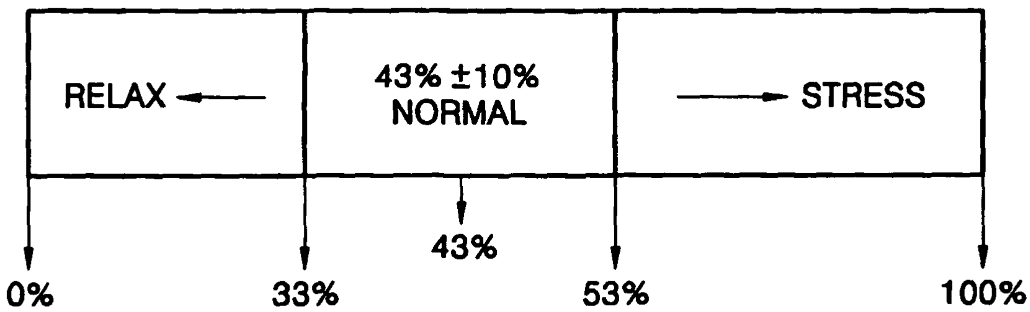
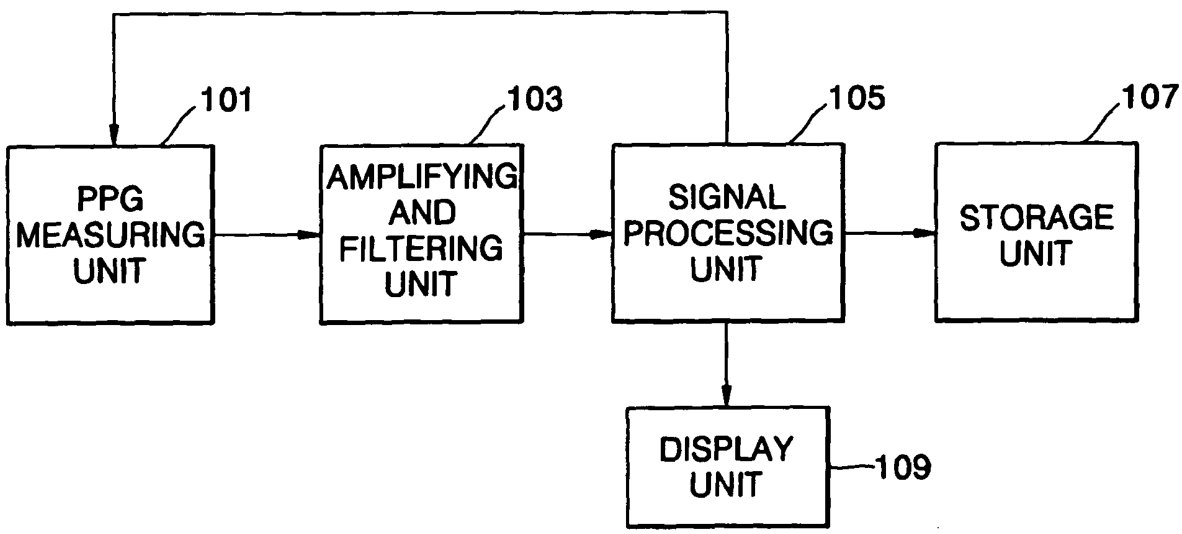

RELAX
43% ±10%
NORMAL
STRESS
43%
0%
33%
53%
100%

FIG. 11


101
103
105
107
PPG MEASURING UNIT
AMPLIFYING AND FILTERING UNIT
SIGNAL PROCESSING UNIT
STORAGE UNIT
DISPLAY UNIT
109

REFERENCES CITED IN THE DESCRIPTION

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- US 6340346 B **[0004]**
- US 6117075 A **[0004]**
- JP 2000116614 A **[0006]**
- JP 9294724 A **[0006]**
- US 4867165 A **[0008]**

专利名称(译)	使用光电容积描记法评估人体压力的方法和设备		
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优先权	1020030004256 2003-01-22 KR		
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外部链接	Espacenet		

摘要(译)

提供了一种使用PhotoPlethysmoGraphy（PPG）评估人类压力的方法和设备。使用PhotoPlethysmoGraphy（PPG）评估人类压力的方法，包括：定义至少一个PPG参数;辐射光，其具有至少一个波长，该波长在测量目标处对待测量的血液成分起反应，并在预定的时间段内测量来自测量目标的PPG信号;并使用从PPG参数获得的应力指数评估人体压力。

Table 2

PPG parameters / Conditions	Pulse component amplitude	PPI	Baseline spread range
Strain, Stress, Irregular breath, Moving artifact	↓	↓	↑
Tranquil, Resting, Regular breath, Stable posture	↑	↑	↓