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(54) **Device for diagnosing attention deficit disorder**

Vorrichtung zur Diagnose von Aufmerksamkeitsstörungen

Dispositif de diagnostic du trouble du déficit de l'attention

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(73) Proprietor: **THE McLEAN HOSPITAL CORPORATION**
Belmont, MA 02478 (US)

(72) Inventors:
- **Blazey, Richard N.**
  Rochester,
  New York 14650-2201 (US)
- **Parks, Peter A.**
  Rochester,
  New York 14650-2201 (US)
- **Patton, David L.**
  Rochester,
  New York 14650-2201 (US)

(74) Representative: **Gervasi, Gemma**
Notarbartolo & Gervasi GmbH,
Bavariaring 21
80336 München (DE)

(56) References cited:
US-A- 5 771 261

- **DONOVAN A M; HALPERIN J M; NEWCORN J H; SHARMA V: "Thermal response to serotonergic challenge and aggression in attention deficit hyperactivity disorder children" JOURNAL OF CHILD AND ADOLESCENT PSYCHOPHARMACOLOGY, vol. 9, no. 2, 1999, pages 85-91, XP008019629**

EP 1 166 711 B1

Description

[0001] This invention relates in general to a technique for diagnosing Attention Deficit Disorder (ADD) and more particularly to a technique for measuring an individual's peripheral temperature to determine values indicative of ADD.

[0002] ADD (with and without hyperactivity) is the most common neurobehavioral disorder of childhood as well as among the most prevalent health conditions affecting school-aged children. Between 4% and 12% of school age children (several millions) are affected. $3 billion is spent annually on behalf of students with ADD. Moreover, in the general population, 9.2% of males and 2.9% of females are found to have behavior consistent with ADD. Upwards of 10 million adults may be affected.

[0003] ADD is a difficult disorder to diagnose. The core symptoms of ADD in children include inattention, hyperactivity, and impulsivity. ADD children may experience significant functional problems, such as school difficulties, academic underachievement, poor relationships with family and peers, and low self-esteem. Adults with ADD often have a history of losing jobs, impulsive actions, substance abuse, and broken marriages. ADD often goes undiagnosed if not caught at an early age and affects many adults who may not be aware of the condition. ADD has many look-alike causes (family situations, motivations) and co-morbid conditions (depression, anxiety, learning disabilities).

[0004] Diagnosis of ADD involves a process of elimination using written and verbal tests. However, there is no one objective, independent valid test for ADD. Various objective techniques have been proposed but have not yet attained acceptance. These include:

1. The eye problem called convergence insufficiency was found to be three times more common in children with ADD than in other children by University of California, San Diego researchers.
2. Infrared tracking to measure difficult-to-detect movements of children during attention tests combined with functional MRI imaging of the brain were used by psychiatrists at McLean Hospital in Belmont, Massachusetts to diagnose ADD in a small group of children (Nature Medicine, Vol. 6, No. 4, April 2000, Pages 470-473).
3. Techniques based on EEG biofeedback for the diagnoses and treatment of ADD are described by Lubar (Biofeedback and Self-Regulation, Vol. 16, No. 3, 1991, Pages 201-225).
4. U.S. Patent 5,913,310, issued June 22, 1999, inventor Brown, discloses a video game for the diagnosis and treatment of ADD.
5. U.S. Patent 5,377,100, issued December 27, 1994, inventors Pope et al., discloses a method of using a video game coupled with brain wave detection to treat patients with ADD.
6. Dr. Albert Rizzo of the Integrated Media Systems Center of the University of Southern California has used Virtual Reality techniques for the detection and treatment of ADD.

[0005] Although skin temperature spectral characteristics have been shown to indicate stress-related changes of peripheral vasomotor activity in normal subjects, there has been no disclosure of use of variations in skin-temperature response to assist in diagnosing ADD. (*See*: Biofeedback and Self-Regulation, Vol. 20, No. 4, 1995).

[0006] US 5 771 261 discloses an apparatus for assessment of the effects mental stress involving the measurement of periodic changes in skin perfusion. Using a remotely mounted infrared camera, dynamic area telethermometry (DAT) measures the autonomic nervous activity by monitoring and quantitatively analyzing the modulation of cutaneous perfusion. The device can be used to meet the needs of a variety of psychiatric and psychological evaluation problems, including depression, drug addiction and dementia, as well as psychological learning disabilities.

[0007] Liebert in J. of child and adolescent psychopharmacology, vol. 9, 2, 1999, shows that there is no clear correlation between hyperactivity or aggression, which are symptoms of ADD, and body temperature.

[0008] There is thus a need for a simple, inexpensive, and reliable technique for assisting in the diagnosis of ADD.

[0009] According to the present invention, there is provided a solution to the problems and fulfillment of the needs discussed above.

[0010] According to the present invention, there is provided a device for determining whether an individual has Attention Deficit Disorder (ADD) according to claim 1

[0011] The invention has the following advantages.

1. A technique for diagnosing ADD is provided which is simple, inexpensive and reliable.

Fig. 1 is a diagrammatic view illustrating an embodiment of the present invention.
Fig. 2 is a block diagram of a system incorporating the present invention.
Fig. 3-5 are graphical views useful in explaining the present invention.
Fig. 6 is a diagrammatic view of another embodiment of the present invention.
Fig. 7 is a histogram of phase noise.

[0012] According to the invention, it has been found that a signature of ADD is hidden in fluctuation of the temperature of the skin as measured at the extremities such as at a fingertip. Biofeedback practitioners have long used measurement of hand temperature to help subjects manage their physiology by controlling blood flow to the extremities. The literature reports that reduced blood flow to the brain is frequently found in patients with ADD.

[0013] As shown in Fig. I, a subject 10 is sitting on a chair 12 watching a screen 14. The subject is at rest in an inactive state. The temperature of a fingertip 16 of subject 10 is measured by a sensor 18. The temperature readings are supplied to module 20.

[0014] As shown in Fig. 2, module 20 includes temperature sampling circuit 22, data storage 24, data processor 26 and output 28 such as a display.

[0015] In figure 1, the fingertip temperature is first recorded during an interval when the subject 10 has been asked to sit quietly for a period of about 10 minutes. The temperature data is sampled by 22 at a time interval Δt creating a list of N temperature samples which are stored in storage 24. The N samples are divided into groups of **m** samples each group corresponding to a given time window of width δt (~32-64 sec) equally spaced in time (~50 sec) across the entire data collection time interval Δt. The data from each window is then passed through a Fast Fourier Transform (FFT) algorithm in processor 26 producing 2^{m-1} data points spaced equally in frequency space. The values are complex numbers having form

$$FFT(f_n) = A(f_n)+B(f_n)\,\mathbf{i}$$

where **i** is the $\sqrt{-1}$. The Phase $\Phi(f_n)$ is then found from the equation

$$\Phi(f_n) = Tan^{-1}\left(\frac{B(f_n)}{A(f_n)}\right) \qquad (.00)$$

and the Magnitude $M(f_n)$ from

$$M(f_n) = \sqrt{B(f_n)^2 + A(f_n)^2} \qquad (0.0)$$

[0016] Figs. 3 and 4 showing an aspect not covered by the invention respectively graphically illustrate the phase transform for a normal subject and a person diagnosed with ADD and a normal subject. The magnitude spectrum undergoes dramatic changes essentially changing from a hyperbolic curve to a flat response and simultaneously the phase exhibits a burst of noise we call *phase noise.* Fig. 7 shows histograms of the phase noise data taken from subjects with diagnosed ADD and normal subjects. We measure the phase noise during a time window Δt. The data in Fig. 7 is a histogram of the standard deviation σ of the phase noise during 10 of these windows spaced equally across the 10 minute duration of the experimental period. Subjects with a diagnosis of ADD generally show significantly more phase noise than the normal subjects as evidenced by the fact that there are many more samples at high values of the σ we use as a phase noise metric than for the normal subjects.

[0017] The following is a feature of the present invention:

Raw Data

[0018] The raw data $T_{i,k}(t)$ is the temperature taken at a fingertip during the 10-minute baseline period, which preceded each session of the VIBE project. The sessions were taken over a period of weeks or months. Some subjects had as few as 2 sessions and some as many as 5 sessions. **k** is used to represent the session.

Windows

[0019] The data for each session were divided into a series of windows prior to performing the Fourier Transform operation. Call the window width **w**. In the data reported in Fig. 5, the window width was 64 seconds and there were 10 windows spaced at 50 second intervals (the windows overlap) across the 600 sec baseline spanning the range of 100

- 500 sec. The window number in a session is referred to with the letter **j**. For each window a FFT algorithm calculates the Fourier Transform F(f). The Magnitude and Phase of this transform are defined as given above. The range of magnitude variation during a window is given below where $\mathbf{f}_{max}$ and f_{min} are the frequencies where the Magnitude is the greatest and the least respectively (note the dc component at frequency zero is excluded).

Session Mean and Standard Deviation

[0020] The mean magnitude range for subject **i** during session **k** is found from equation 1.0. where **m** is the number of windows in the session.

$$< M_{i,k} >= \frac{\sum_{j=1}^{m} [M(f_{max})_j - M(f_{min})_j]}{m} \qquad (1.0)$$

[0021] And the corresponding standard deviation is:

$$< s_{i,k} >= \sqrt{\frac{\sum_{j=1}^{m} \{[M(f_{max})_j - M(f_{min})_j] - < M_{i,k} >\}^2}{m-1}} \qquad .....(1.1)$$

[0022] Combining these session means and standard deviations over all the sessions **n** that a subject attended gives the ensemble mean μ_i and ensemble standard deviation, σ_i

$$\mu_i = \frac{\sum_{k=1}^{n} < M_{i,k} >}{n} \qquad (1.2)$$

and correspondingly the ensemble standard deviation is

$$< \sigma_i >= \frac{\sum_{k=1}^{n} s_{i,k}}{n} \qquad (1.3)$$

Chart

[0023] Fig. 5 is a chart comparing all the subject data in a data base. For each subject the curve shows the ensemble mean μ_i given from equation 1.2 and the 1 standard deviation limits given equations 1.4 and 1.5.

$$Mh_i = \mu_i + \sigma_i \qquad (1.4)$$

$$Ml_i = \mu_i - \sigma_i \qquad (1.5)$$

Diagnosis

[0024] Diagnosis is made from the chart by setting a threshold level for one of the parameters. Below that limit, the

subject is diagnosed with ADD above the limit, the subject is called normal. In the chart the limit is set at a value of μ_i of 3.0. which yields one false negative (subject with >3.0 who says he has ADD) and two false positives (subjects who are less than 3.0 and do not report a diagnosis of ADD).

[0025] Fig. 6 illustrates a schematic view of a subject and apparatus of another embodiment of the present invention. Shown is a subject 110, viewing a screen 120, wearing a set of earphones 130 connected via a wire 140 to a sound generating device 150. The subject's 110 skin temperature is monitored via a finger temperature sensor 160 connected via a wire 170 to a control and recording device 180. The earphone 130 maybe used to block out ambient noise or to produce a white noise intended to reduce or eliminate the audio stimulus from the environment during the test.

[0026] The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the invention.

Claims

1. A device for determining whether an individual has Attention Deficit Disorder (ADD) comprising:

   a) means for sampling the peripheral skin temperature of a subject during a predetermined time interval to provide N sampled peripheral skin temperature data;
   b) means for analyzing during a number of windows the fluctuations in the sampled peripheral skin temperature data using a fast Fourier transform algorithm to produce phase and magnitude data for each window;
   c) means for calculating for each window from the magnitude date the greatest and least magnitude value, wherein the dc component is excluded and the difference between said greatest and least magnitude value defines a magnitude range;
   d) means for calculating from the magnitude ranges the mean magnitude range and the corresponding standard deviation; and
   e) means for calculating from the mean magnitude range and the corresponding standard deviation the value of a pre-selected parameter indicative of whether or not said subject has ADD.

2. The device of claim 1, wherein means are provided for dividing the N sampled peripheral skin temperature data into m samples corresponding to windows equally spaced in time across said time interval, processing the data from each window with a fast Fourier transform (FFT) to produce 2^{m-1} data points of magnitude spaced equally in frequency space, to calculate the corresponding mean magnitude range and standard deviation.

3. The device of claim 1, further comprising means for comparing the value of said pre-selected parameter to a threshold level indicative of whether or not said subject has ADD.

4. The device of claim 1-3, wherein said means for sampling is a sensor for sensing the skin temperature of at least one extremity of said subject.

5. The device of claim 4, wherein said device includes a sensor for sensing the skin temperature of at least one finger of said subject.

6. The device of claim 1-3, including means to reduce or eliminate audio stimulus from the ambient environment during said time interval.

7. The device of claim 6, wherein said means to reduce or eliminate audio stimulus is an earphone.

Patentansprüche

1. Vorrichtung zum Bestimmen, ob eine Person Aufmerksamkeitsstörungen (ADD) hat, wobei die Vorrichtung umfasst:

   a) Mittel zum Abtasten der Körperoberflächenhaut-Temperatur einer Testperson während eines vorgegebenen Zeitintervalls, um N abgetastete Köperoberflächenhaut-Temperaturdaten zu liefern;
   b) Mittel zum Analysieren der Schwankungen der abgetasteten Köperoberflächenhaut-Temperaturdaten während einer Anzahl von Fenstern unter Verwendung eines schnellen Fourier-Transformations-Algorithmus, um für jedes Fenster Phasen- und Absolutwertdaten zu erzeugen;
   c) Mittel zum Berechnen des größten und des kleinsten Absolutwerts aus den Absolutwertdaten für jedes

Fenster, wobei die Gleichstromkomponente ausgeschlossen wird und die Differenz zwischen dem genannten größten und dem genannten kleinsten Absolutwert einen Absolutwertbereich definiert;
d) Mittel zum Berechnen des mittleren Absolutwertbereichs und der entsprechenden Standardabweichung aus den Absolutwertbereichen;
e) Mittel zum Berechnen des Werts eines im Voraus gewählten Parameters, der angibt, ob die Testperson ADD hat, aus dem mittleren Absolutwertbereich und aus der entsprechenden Standardabweichung.

2. Vorrichtung gemäß Anspruch 1, bei der Mittel vorgesehen sind zum Aufteilen der N abgetasteten Köperoberflächenhaut-Temperaturdaten in m Abtastwerte, die Fenstern entsprechen, die in der Zeit über das genannte Zeitintervall äquidistant sind, und zum Verarbeiten der Daten aus jedem Fenster mit einer schnellen Fourier-Transformation (FFT) zum Erzeugen von 2^{m-1} im Frequenzraum äquidistanten Datenpunkten des Absolutwerts, um den entsprechenden mittleren Absolutwertbereich und die entsprechende Standardabweichung zu berechnen.

3. Vorrichtung gemäß Anspruch 1, die ferner Mittel zum Vergleichen des Werts des genannten im Voraus gewählten Parameters mit einem Schwellenpegel, der angibt, ob die genannte Testperson ADD hat, umfasst.

4. Vorrichtung gemäß einem der Ansprüche 1 bis 3, bei der die genannten Mittel zum Abtasten ein Sensor zum Abtasten der Hauttemperatur wenigstens einer Extremität der genannten Testperson sind.

5. Vorrichtung gemäß Anspruch 4, bei der die genannte Vorrichtung einen Sensor enthält, um die Hauttemperatur wenigstens eines Fingers der genannten Testperson abzutasten.

6. Vorrichtung gemäß einem der Ansprüche 1 bis 3, die Mittel zum Verringern oder Beseitigen eines Audiostimulus aus der Umgebung während des genannten Zeitintervalls enthält.

7. Vorrichtung gemäß Anspruch 6, bei der die genannten Mittel zum Verringern oder Beseitigen eines Audiostimulus ein Kopfhörer sind.

Revendications

1. Un dispositif pour la détermination d'un trouble de déficit d'attention (ADD) chez un individu comprenant:

a) des moyens pour échantillonner la température de peau périphérique d'un sujet pendant un intervalle de temps prédéterminé pour fournir N données échantillonnées de la température de peau périphérique;
b) des moyens pour analyser, pendant un nombre de fenêtres, les fluctuations des données échantillonnées de la température de peau périphérique en utilisant un algorithme de transformation de Fourrier rapide pour produire des données de phase et de magnitude pour chaque fenêtre ;
c) des moyens pour calculer pour chaque fenêtre à partir des données de magnitude la plus grande et la plus petite valeur de magnitude, où le composant de courant continu est exclu et la différence entre ladite plus grande et plus petite valeur définit une zone de magnitude;
d) des moyens pour calculer à partir des zones de magnitude la zone moyenne de magnitude et la déviation standard correspondante; et
e) des moyens pour calculer à partir de la zone de magnitude moyenne et la déviation standard correspondante la valeur de paramètre présélectionnée indiquant si ledit sujet a un ADA ou non.

2. Le dispositif selon la revendication 1, où on a fourni : des moyens

- pour la division des N données échantillonnées de température de peau périphérique en m échantillons correspondant aux fenêtres temporellement espacées à travers ledit intervalle de temps,
- pour le traitement de données de chaque fenêtre avec une transformation rapide de Fourier (FFT) pour produire 2^{m-1} points de données de magnitude espacés régulièrement dans l'espace de fréquence pour calculer la zone de magnitude moyenne et la déviation moyenne.

3. Le dispositif selon la revendication 1, comprenant en outre des moyens pour comparer la valeur dudit paramètre présélectionné avec un niveau de seuil indiquant si ledit sujet a un ADA ou non.

4. Le dispositif selon la revendication 1 à 3, où ledit moyen d'échantillonnage est un capteur pour balayer la température

de peau d'au moins une extrémité dudit sujet.

5. Le dispositif selon la revendication 4, où ledit dispositif comprend un capteur pour balayer la température de peau d'au moins un doigt dudit sujet.

6. Le dispositif selon la revendication 1 à 3, comprenant des moyens pour réduire ou éliminer un stimulus audio à partir de l'environnement ambiant pendant ledit intervalle de temps.

7. Le dispositif selon la revendication 6, où ledit moyen pour réduire ou éliminer un stimulus audio est un écouteur.

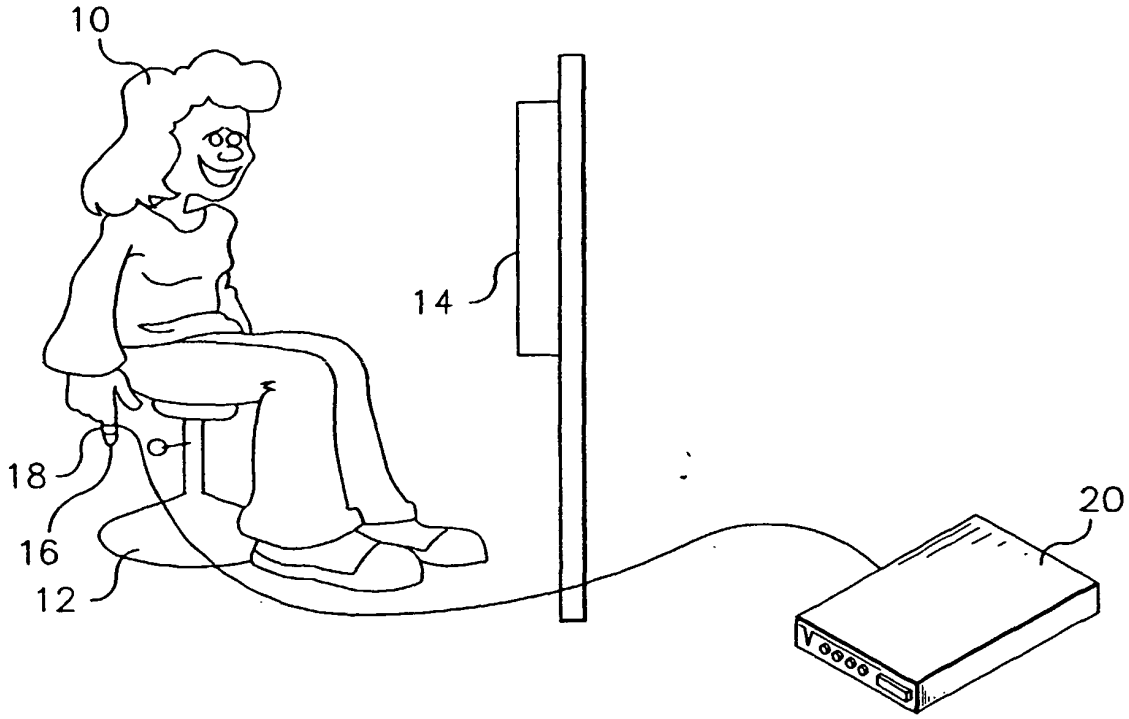
10
14
18
16
12
20

FIG. 1

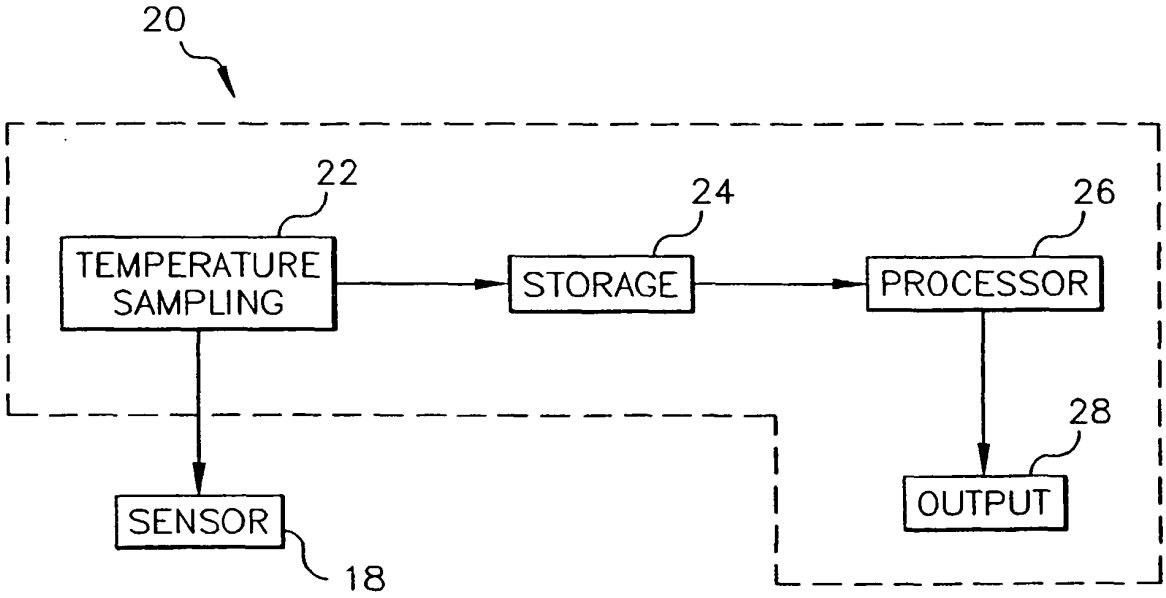
20
22
TEMPERATURE SAMPLING
24
STORAGE
26
PROCESSOR
28
OUTPUT
SENSOR
18

FIG. 2

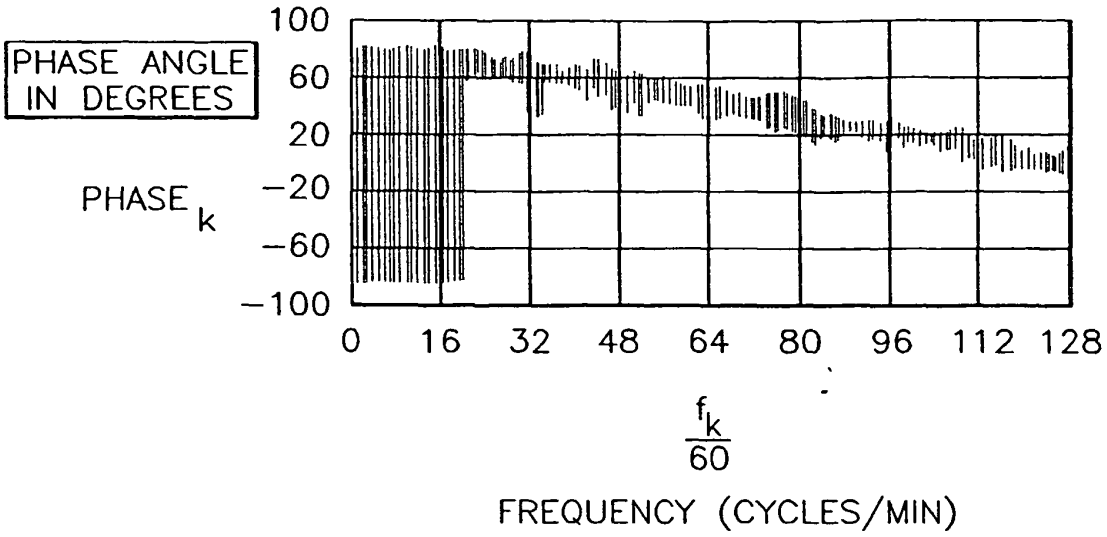
PHASE ANGLE IN DEGREES
PHASE k
100
60
20
−20
−60
−100
0
16
32
48
64
80
96
112
128
f k / 60
FREQUENCY (CYCLES/MIN)

FIG. 3

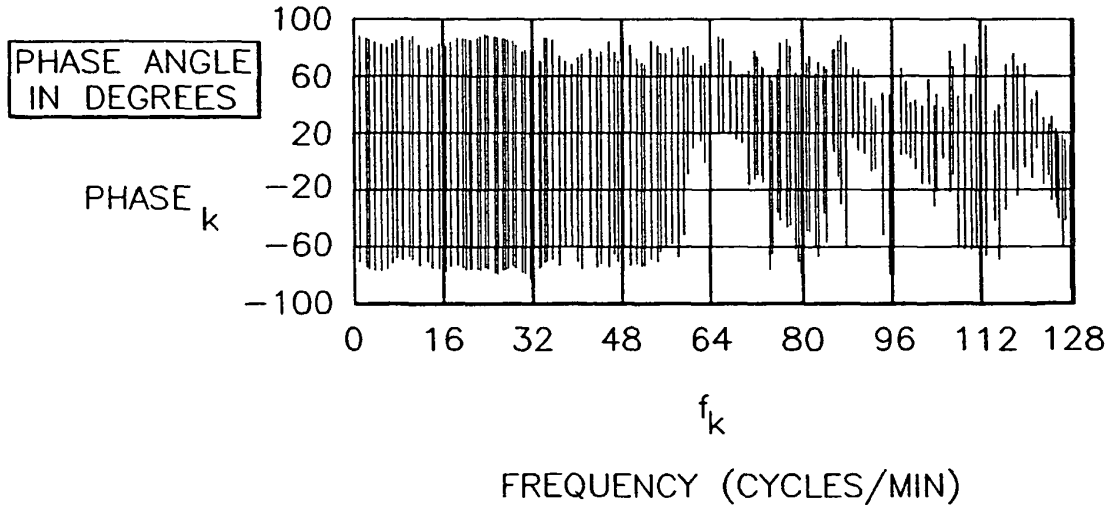
PHASE ANGLE IN DEGREES
PHASE k
100
60
20
−20
−60
−100
0
16
32
48
64
80
96
112
128
f k
FREQUENCY (CYCLES/MIN)

FIG. 4

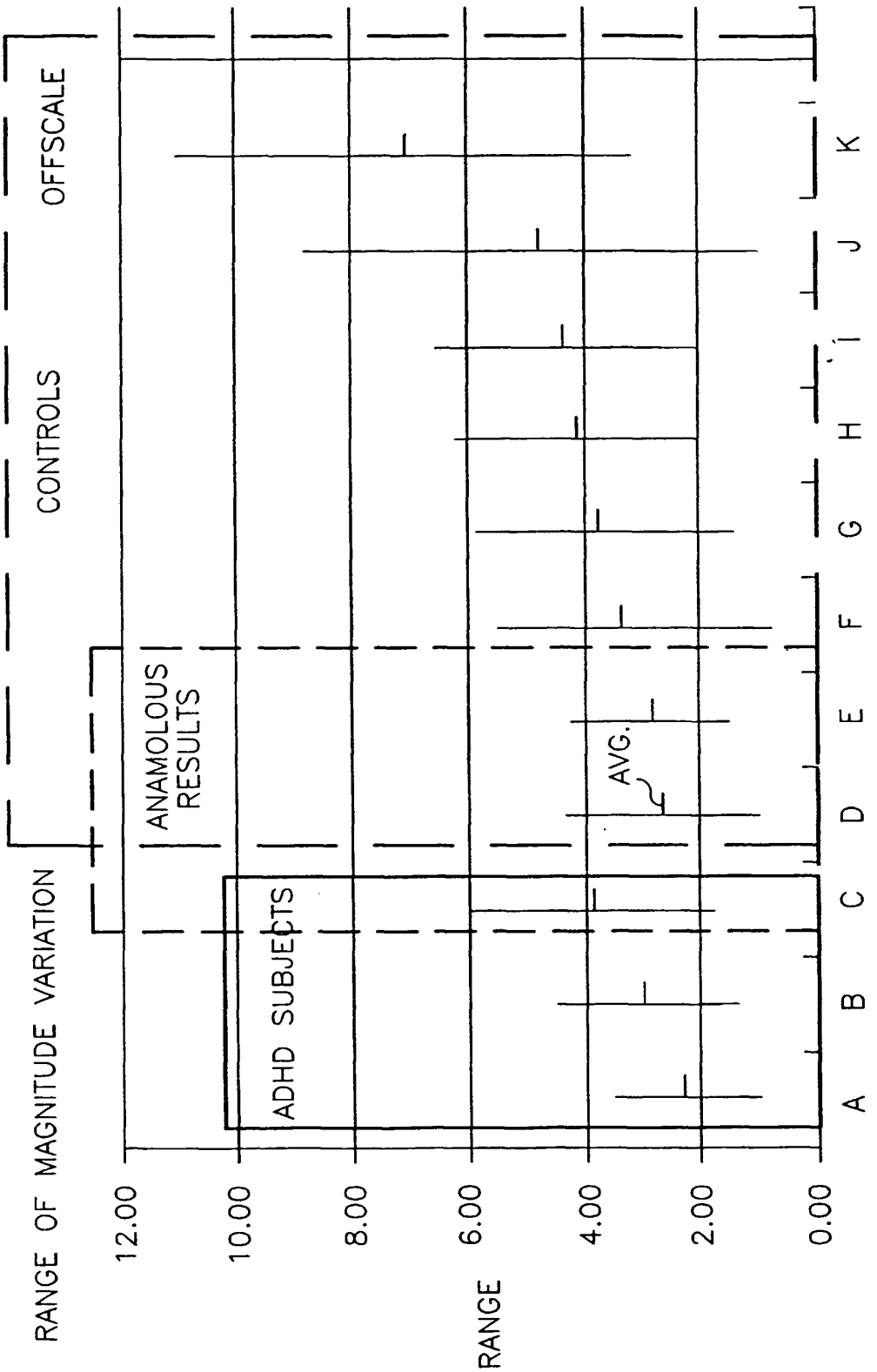
RANGE OF MAGNITUDE VARIATION
CONTROLS
OFFSCALE
ANAMOLOUS RESULTS
ADHD SUBJECTS
AVG.
RANGE
12.00
10.00
8.00
6.00
4.00
2.00
0.00
A
B
C
D
E
F
G
H
I
J
K
SUBJECT NUMBERS

FIG. 5

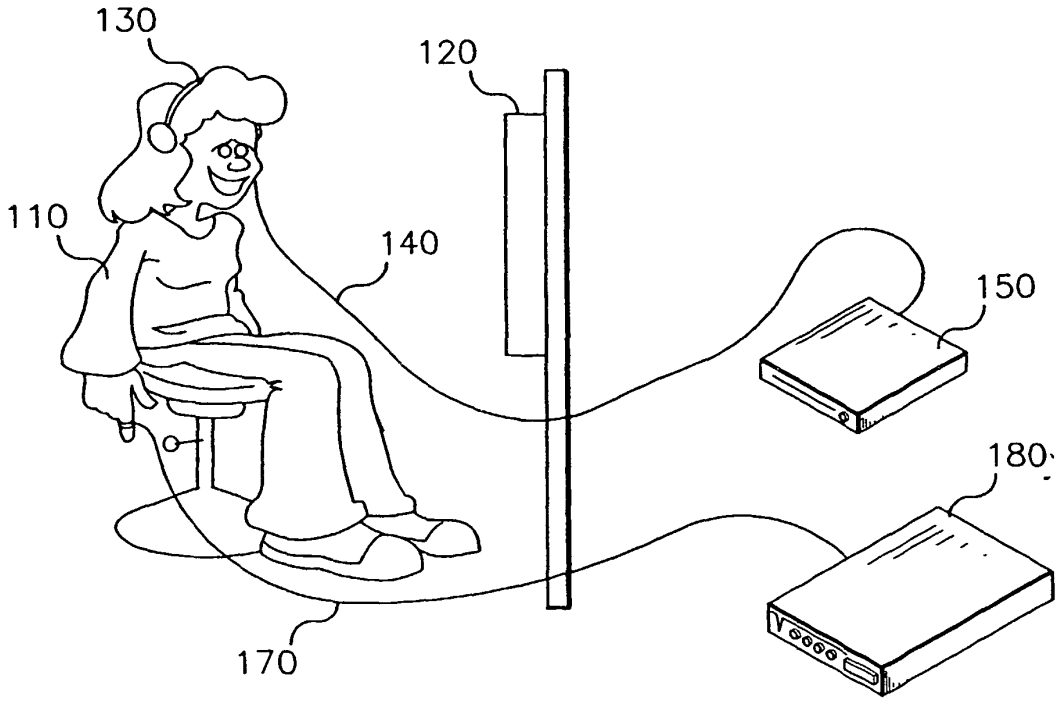
130
120
110
140
150
180
170

FIG. 6

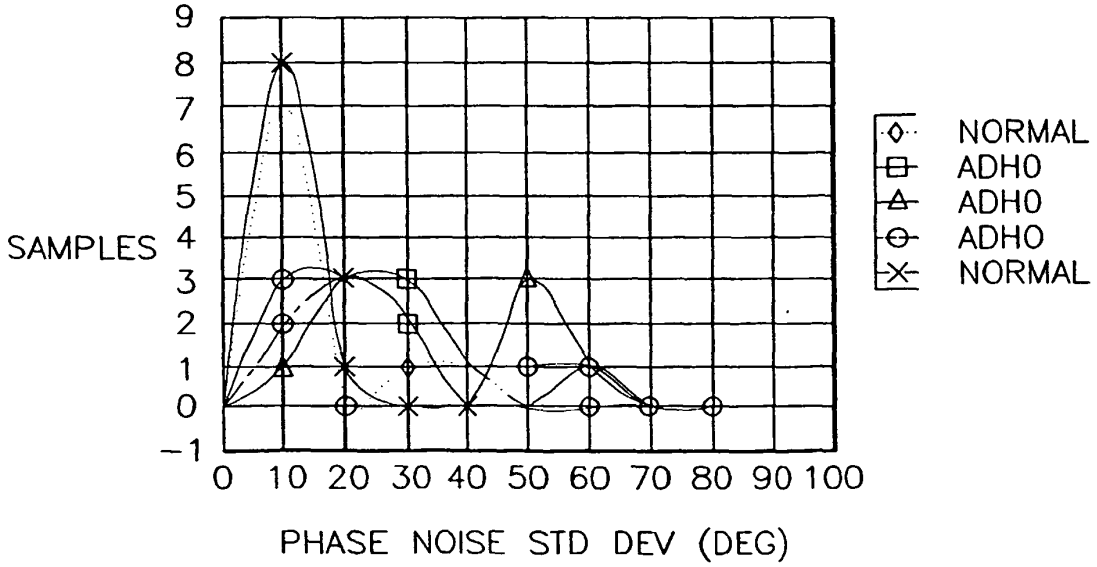
SAMPLES
9
8
7
6
5
4
3
2
1
0
−1
0 10 20 30 40 50 60 70 80 90 100
PHASE NOISE STD DEV (DEG)
NORMAL
ADH0
ADH0
ADH0
NORMAL

FIG. 7

专利名称(译)	用于诊断注意力缺陷障碍的装置		
公开(公告)号	EP1166711B1	公开(公告)日	2006-09-20
申请号	EP2001202200	申请日	2001-06-08
[标]申请(专利权)人(译)	伊斯曼柯达公司		
申请(专利权)人(译)	伊士曼柯达公司		
当前申请(专利权)人(译)	麦克莱恩医院CORPORATION		
[标]发明人	BLAZEY RICHARD N PARKS PETER A PATTON DAVID L		
发明人	BLAZEY, RICHARD N. PARKS, PETER A. PATTON, DAVID L.		
IPC分类号	A61B5/00 G06F19/00 A61B5/16 A61B5/01 A61B3/113 A61B10/00		
CPC分类号	A61B5/01 A61B3/113 A61B5/0002 A61B5/168 A61B5/7257 A61B5/726 G16H15/00		
优先权	09/597610 2000-06-20 US		
其他公开文献	EP1166711A3 EP1166711A2		
外部链接	Espacenet		

摘要(译)

一种确定个体是否具有注意力缺陷障碍（ADD）的方法，包括：在受试者处于非活动状态的预定时间间隔内对人受试者的外周皮肤温度进行采样，以提供采样的外周皮肤温度数据;并且分析针对预选参数的采样的外围皮肤温度数据，以确定所述预选参数是否具有指示ADD的值。