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Foust et al.

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(54) **TECHNIQUE FOR DIAGNOSING ATTENTION DEFICIT HYPERACTIVITY DISORDER**

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Related U.S. Application Data

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(51) **Int. Cl.**[7] **A61B 5/00**
(52) **U.S. Cl.** **600/549**; 600/300
(58) **Field of Search** 600/26–28, 300, 600/544, 546, 549, 481, 500, 509, 558; 128/897, 898

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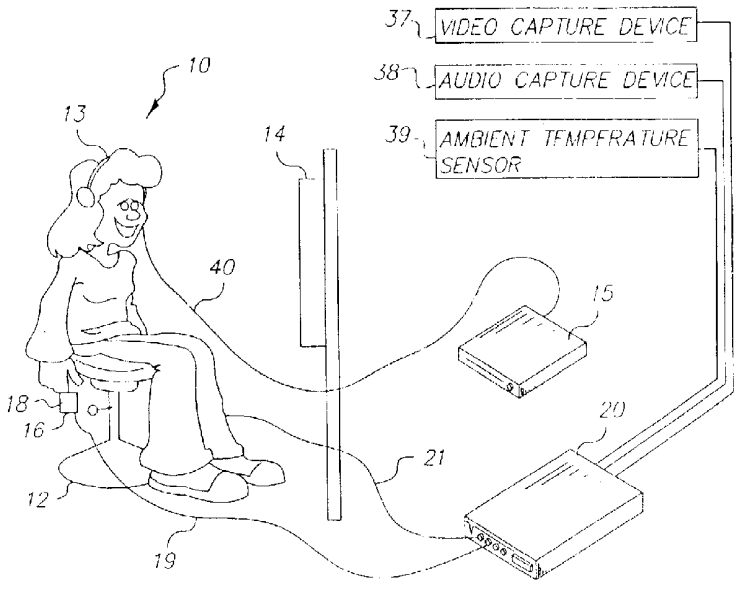
Primary Examiner—Charles Marmor

(57) **ABSTRACT**

This invention features a method of determining whether an individual has Attention Deficit Hyperactivity Disorder by sampling the peripheral skin temperature of an individual in an inactive state and manipulating the resulting temperature data to produce a value which is indicative of whether or not the individual has ADHD.

17 Claims, 4 Drawing Sheets



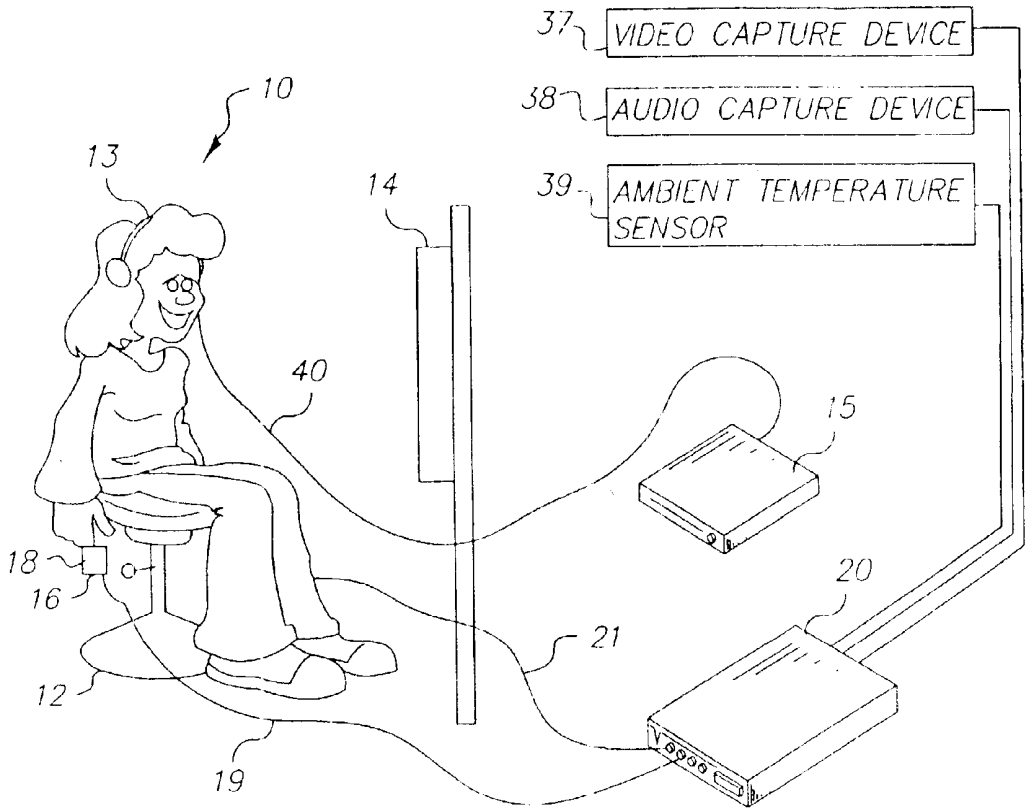

37
VIDEO CAPTURE DEVICE
38
AUDIO CAPTURE DEVICE
39
AMBIENT TEMPERATURE SENSOR
10
13
14
40
15
18
16
20
21
12
19

FIG. 1

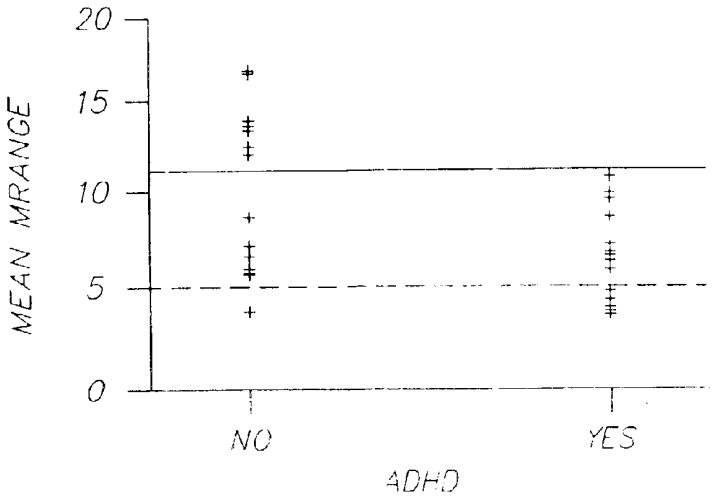

20
15
10
5
0
MEAN MRANGE
NO
YES
ADHD

FIG. 5

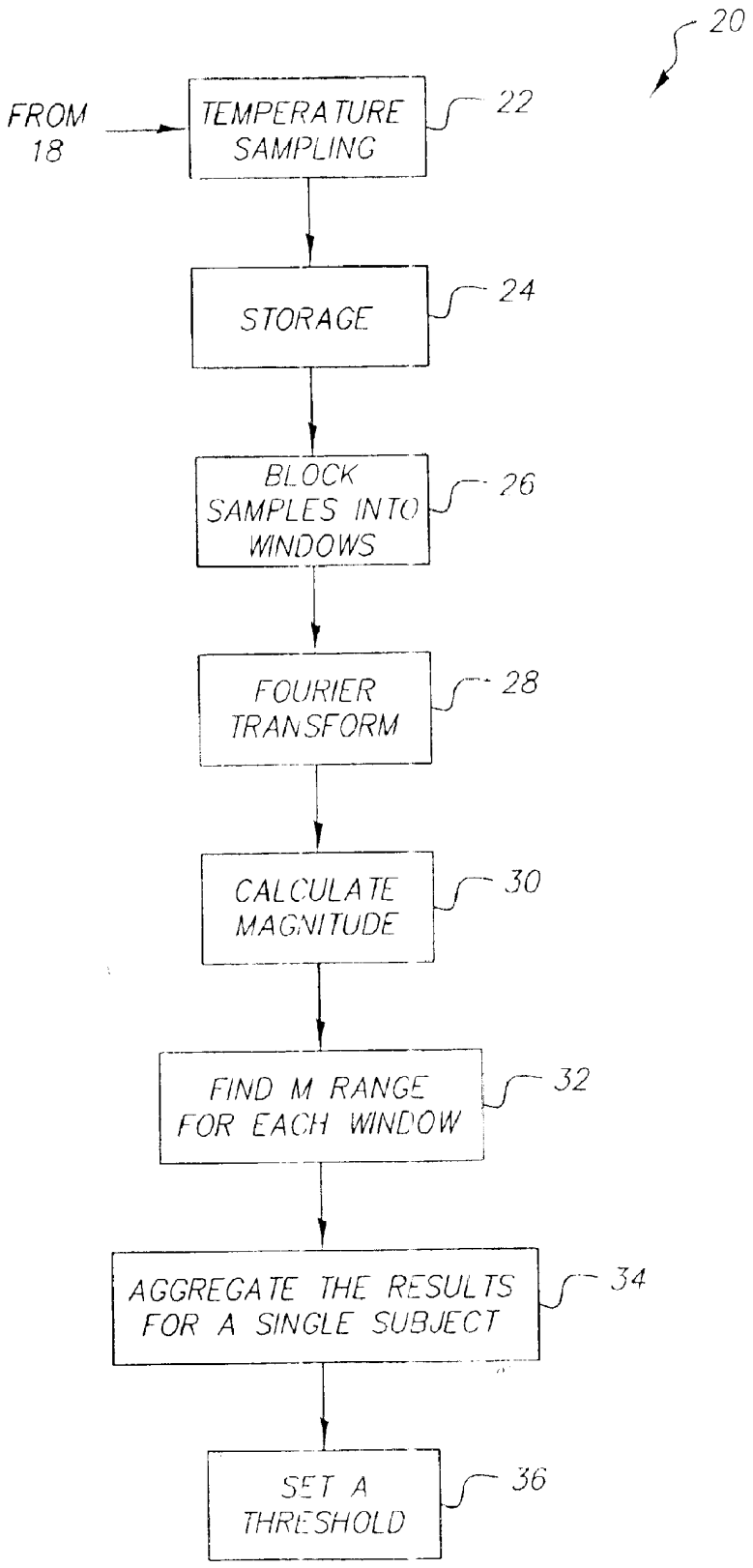

20
FROM 18
TEMPERATURE SAMPLING
22
STORAGE
24
BLOCK SAMPLES INTO WINDOWS
26
FOURIER TRANSFORM
28
CALCULATE MAGNITUDE
30
FIND M RANGE FOR EACH WINDOW
32
AGGREGATE THE RESULTS FOR A SINGLE SUBJECT
34
SET A THRESHOLD
36

FIG. 2

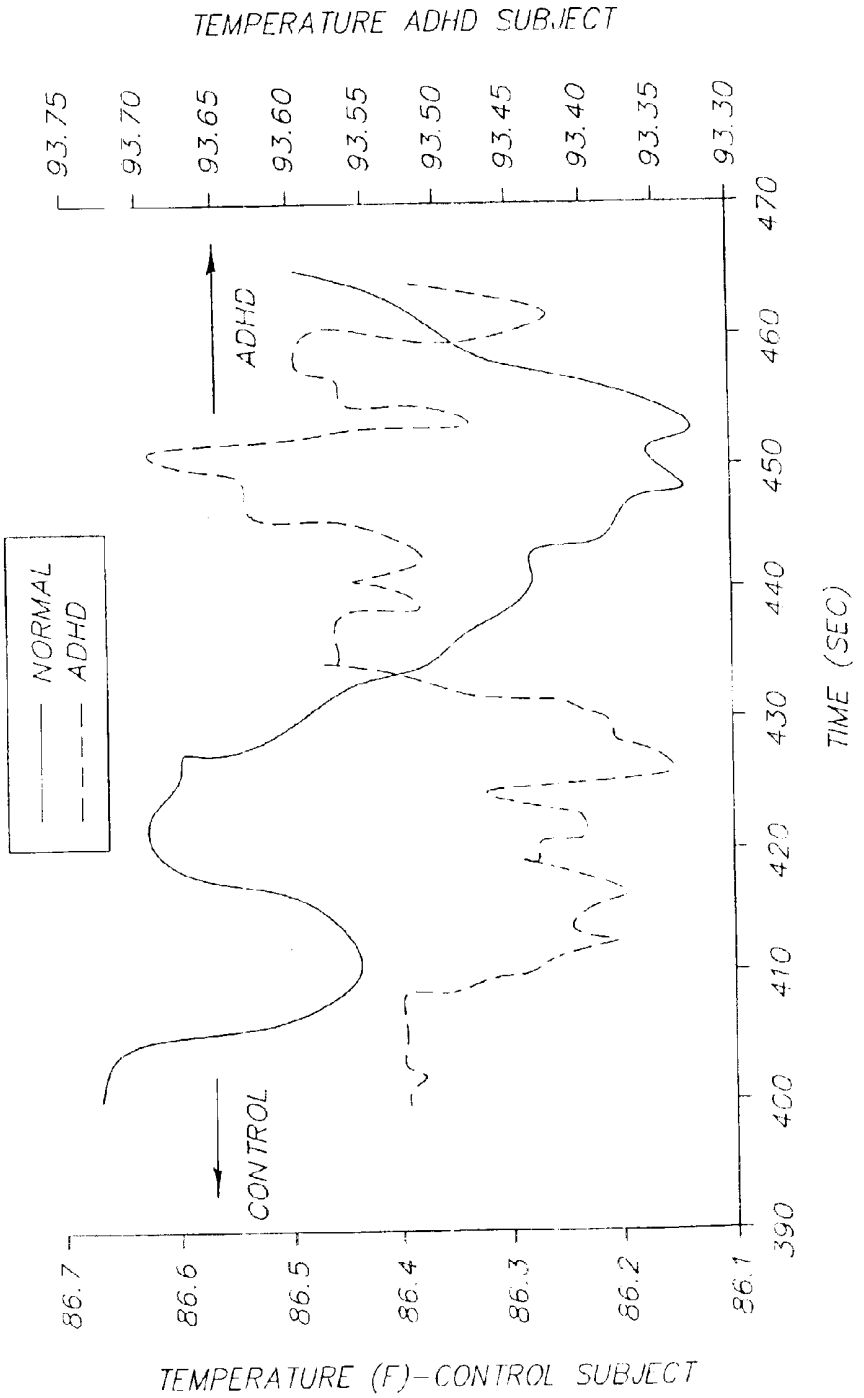
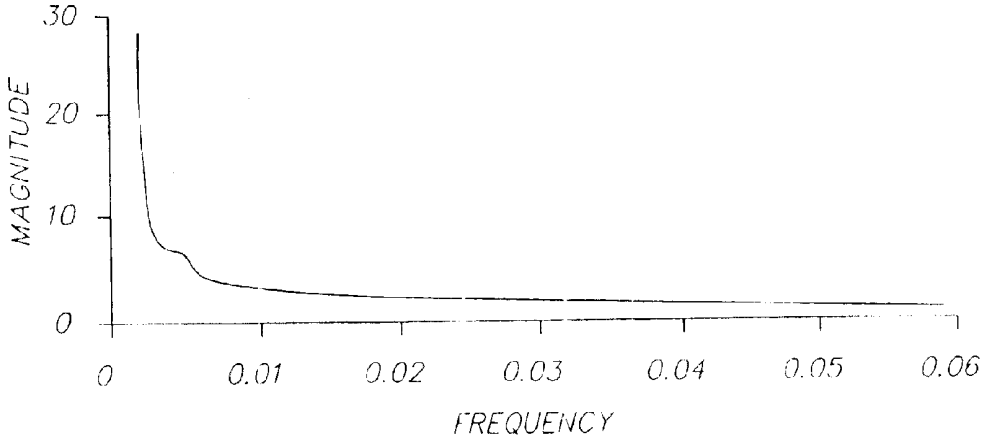

TEMPERATURE ADHD SUBJECT
93.75
93.70
93.65
93.60
93.55
93.50
93.45
93.40
93.35
93.30
ADHD
NORMAL
ADHD
CONTROL
86.7
86.6
86.5
86.4
86.3
86.2
86.1
390
400
410
420
430
440
450
460
470
TIME (SEC)
TEMPERATURE (F)-CONTROL SUBJECT

FIG. 3


30
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MAGNITUDE
0
0.01
0.02
0.03
0.04
0.05
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FREQUENCY

FIG. 4A

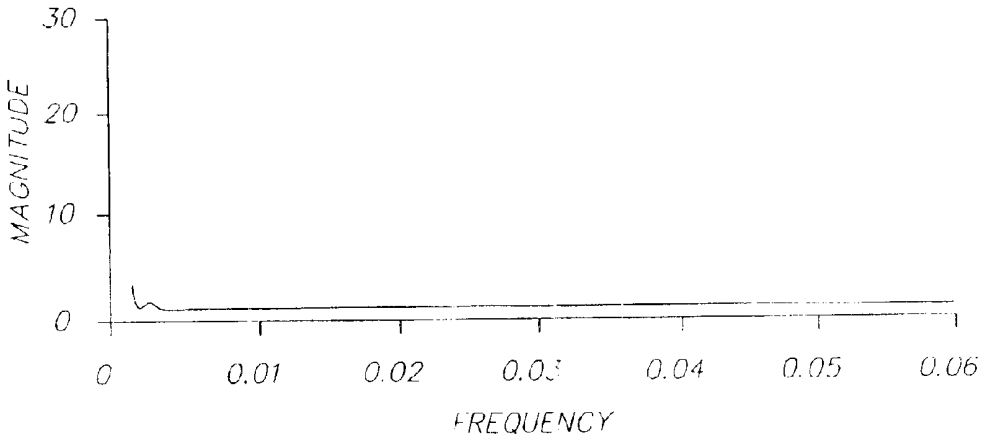

30
20
10
0
MAGNITUDE
0
0.01
0.02
0.03
0.04
0.05
0.06
FREQUENCY

FIG. 4B

TECHNIQUE FOR DIAGNOSING ATTENTION DEFICIT HYPERACTIVITY DISORDER

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a Continuation-in Part Application of U.S. patent application Ser. No. 09/865,902 filed May 25, 2001, now U.S. Pat. No. 6,565,518, issued May 20, 2003.

FIELD OF THE INVENTION

This invention relates in general to methods for improving the reliability of a technique for diagnosing Attention Deficit Hyperactivity Disorder (ADHD) and more particularly to a technique for measuring an individual's peripheral temperature to determine values indicative of ADHD by recording environmental conditions such as noise during the test procedure.

BACKGROUND OF THE INVENTION

ADHD 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 ADHD. Moreover, in the general population, 9.2% of males and 2.9% of females are found to have behavior consistent with ADHD. Upwards of 10 million adults may be affected.

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

Diagnosis of ADHD involves a process of elimination using written and verbal assessment instruments. However, there is no one objective, independently validated test for ADHD. Various objective techniques have been proposed but have not yet attained widespread acceptance. These include:

1. The eye problem called convergence insufficiency was found to be three times more common in children with ADHD 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, Mass. to diagnose ADHD 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 ADHD are described by Lubar (*Biofeedback and Self-Regulation*, Vol. 16, No. 3, 1991, Pages 201–225).

4. U.S. Pat. No. 6,097,980, issued Aug. 1, 2000, inventor Monastra et al, discloses a quantitative electroencephalographic process assessing ADHD.

5. U.S. Pat. No. 5,913,310, issued Jun. 22, 1999, inventor Brown, discloses a video game for the diagnosis and treatment of ADHD.

6. U.S. Pat. No. 5,918,603, issued Jul. 6, 1999, inventor Brown, discloses a video game for the diagnosis and treatment of ADHD.

7. U.S. Pat. No. 5,940,801, issued Aug. 17, 1999, inventor Brown, discloses a microprocessor such as a video game for the diagnosis and treatment of ADHD.

8. U.S. Pat. No. 5,377,100, issued Dec. 27, 1994, inventors Pope et al., discloses a method of using a video game coupled with brain wave detection to treat patients with ADHD.

9. 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 ADHD.

10. U.S. Pat. No. 6,053,739, inventors Stewart et al., discloses a method of using a visual display, colored visual word targets and colored visual response targets to administer an attention performance test. U.S. Pat. No. 5,377,100, issued Dec. 27, 1994, inventors Patton et al., discloses a system of managing the psychological state of an individual using images. U.S. Pat. No. 6,117,075 Barnea discloses a method of measuring the depth of anesthesia by detecting the suppression of peripheral temperature variability.

There are several clinical biofeedback and physiologic monitoring systems (e.g. Multi Trace, Bio Integrator). These systems are used by professional clinicians. 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 ADHD. (See: Biofeedback and Self-Regulation, Vol. 20, No. 4, 1995).

As discussed above, the primary method for diagnosing ADHD is the use of a bank of written and verbal assessment instruments designed to assess criteria established by the American Medical Association (AMA) as described in the Diagnostic and Statistics manual (DSM-IV) and administered by the school psychologist or other licensed practitioner. In some cases those individuals who meet DSM-IV criteria for ADHD diagnosis are prescribed a drug such as Ritalin. Behavioral observations of the patient while on Ritalin are conducted to assess the impact of prescribed medication.

There is thus a need for a simple, inexpensive, and reliable technique for assisting in the diagnosis of ADHD.

SUMMARY OF THE INVENTION

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

According to a feature of the present invention, there is provided a method of determining whether an individual has Attention Deficit Hyperactivity Disorder, comprising: sampling the peripheral skin temperature of an individual during a pre-determined time interval when the subject is in an inactive state to provide sampled peripheral skin temperature data; dividing the data into a series of windows of equal time intervals across the pre-determined time interval; for each window applying a fast Fourier Transform algorithm (FFT) to produce a data set of FFT magnitudes and determining a range of FFT magnitude variation, which is the difference between the FFT magnitude at a frequency f_{max} and the FFT magnitude at the minimum frequency f_{min}; aggregating the magnitude ranges for one of or less than all of the windows to produce an aggregate magnitude range

value which is indicative of whether or not the individual has ADHD; wherein prior to sampling, if one or more of the following noises are present it is eliminated through manual or automatic means: self diversion, external stimulation, technical problems, sleep problems.

ADVANTAGEOUS EFFECT OF THE INVENTION

The invention has the following advantages.

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

BRIEF DESCRIPTION OF THE DRAWINGS

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.

FIGS. **3**, **4***a* and **4***b* are graphical views useful in explaining the present invention.

FIG. **5** is a diagram of an example of finding the proper threshold θ to separate ADHD subjects from non-ADHD subjects.

DETAILED DESCRIPTION OF THE INVENTION

According to the invention, it has been found that a signature of ADHD is hidden in fluctuation of the temperature of the skin as measured at the extremities such as at a fingertip. It is well known in the art that as a person's stress level increases the blood vessels in the body constrict, (as is evidenced by the fact a person's blood pressure increases as their level of stress increases.) As the blood vessels in the body constrict, blood flow is restricted. This is most evident in the extremities such as the fingers, because the blood vessels in the extremities are small and furthest from the heart. A direct result of decreased blood flow to the blood vessels in the extremities is a decrease in the peripheral temperature of the extremities. Conversely, as a person's stress level decreases and one relaxes the blood vessels also relax and dilate causing blood flow to increase. As the blood flow to the vessels in the extremities increases, the peripheral temperature of the extremities increases. When a subject with ADHD is subjected to sensory deprivation such as being made to look at a blank screen or an obscured image, the lack of stimulation increases and their level of anxiety and their stress level increases. As their stress level increases their blood vessels constrict and the peripheral temperature of their extremities decreases. 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 ADHD.

In addition to peripheral skin temperature and peripheral skin temperature variability as indications of stress and therefore ADHD there are other physiologic measures which are known (or potential) indicators of stress and therefore ADHD such as; bilateral temperature variability, heart rate, heart rate variability, muscle tension (excessive and chronic measured via surface electromyography—sEMG), bilateral muscle tension imbalance, galvanic skin response (i.e., electro dermal response—EDR), eye saccades, blood oxygen (SpO_2), salivary IGA, electroencephalography (EEG), peripheral blood flow (measured via photoplethismography—PPG), and peripheral blood flow variability (PPG).

As shown in FIG. **1**, a subject **10** is sitting on a chair **12** watching a screen **14**. The subject is at rest in an inactive state. The subject **10** is shown wearing a set of earphones **13** connected via a wire **40** to a sound generating device **15**. The earphones **13** may be used to reduce or eliminate the audio stimulus from the environment during the test. The method described in this embodiment of the present invention places the subject in sensory deprived surroundings. Other examples of providing sensory deprivation are to have the subject wear a pair of translucent glasses, goggles or eye mask not shown. The glasses or goggles block any visual stimulus from the subject **10**. A sensor **18** measures the temperature of a fingertip **16** of subject **10**. The temperature readings are supplied to module **20** via a wire **19**. The temperature sensor for the opposite hand is not shown but is connected via wire **21** to module **20**. The temperature can be taken from one hand or both hands and from one or more locations on each hand. Video (video camera) and audio (microphone) capture devices **37** and **38** respectively record test environment and ambient temperature sensor **39** is used to record test environment temperature. This data is fed to module **20**.

As shown in FIG. **2**, module **20** includes temperature sampling circuit **22**, data storage **24**, window blocking **26**, Fourier transform **28**, Magnitude calculation **30**, Mrange calculation **32**, aggregation step **34** and Thresholding step **36**.

In FIG. **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 ten minutes. The temperature data is sampled **22** at a time interval Δt creating a list of n temperature samples, which are stored in storage **24**.

Now referring to FIG. **2**, in block **26**, 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 **30** Fourier Transform (FFT) algorithm producing 2^{m-1} data points spaced equally in frequency space. The values are complex numbers having form

$$FFT(f_m)=A(f_m)+B(f_m)i$$

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

$$\Phi_l(f_m) = \mathrm{Tan}^{-1}\left(\frac{B(f_m)}{A(f_m)}\right) \tag{1.0}$$

and the Magnitude $M(f_m)$ from

$$M_l(f_m)=\sqrt{B(f_m)^2+A(f_m)^2} \tag{1.1}$$

In the equations 1.0 and 1.1 the subscript l refers to the fact that a separate signal is extracted for each hand so the subscript is l for data extracted from the left hand data and r for data from the right hand. FIG. **3** graphically illustrates the temperature signal during one window for a normal subject and a person diagnosed with ADHD.

FIGS. **4***a* and **4***b* graphically illustrate the magnitude transform for the data corresponding with a subject with ADHD and normal subject. The magnitude spectrum undergoes dramatic changes essentially changing from a hyperbolic curve to a flat response.

Referring again to FIG. **2**.

Raw Data

The raw data $T_{k,l}(t)$ is the temperature taken from hand l at a fingertip **16** as shown in FIG. **1**, during the 10-minute

session. The sessions were taken over a period of weeks. Some subjects had as few as 2 sessions and some as many as 5 sessions. k is used to represent the session.

Windows

The data for each session were divided into a series of windows (step **26**) prior to performing the Fourier Transform operation **28**. Call the window width w. In this analysis, the window width was 64 seconds and there were 10 windows spaced at 50-second intervals (the windows overlap) across the 1600 sec baseline spanning the range of 100–500 sec, other values of w can be used. 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.

In step **32** the range of magnitude variation during a window is calculated using equation (1.2) below where 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).

$$M_{range}=[M(f_{max})-M(f_{min})] \tag{1.2}$$

In a further embodiment of this method, other statistics from a Fourier Transform, calculated from the quantities denoted above as $A(f_m)$, $B(f_m)$, $\Phi(f_m)$, and $M(f_m)$ can be used. In addition to using Fourier Transforms, this further embodiment can use statistics derived from a Wavelet transform of the data or other filtering of the data (as in Strang, G. and Nguyen, T. (1996), *Wavelets and Filter Banks*, Wellesley-Cambridge Press, Wellesley, Mass.).

Aggregation of Samples

Samples are aggregated in step **34**. There are 10 samples from each hand from each session. The first step is to choose an aggregation statistic, which can be the mean, median, variance, or other statistic, which is an aggregate of the computed M_{Range} values in each window for each session and each hand. Other statistics that can be used for aggregation include the standard deviation, range, interquartile distance, skewness, kurtosis, Winsorized mean and variance, and robust estimates of mean and variance. Equations below are given for aggregating the mean and the variance. The mean magnitude range for the left hand during session k is found from equation 2.0. where z is the number of windows in the session.

$$\langle M_{k,l}\rangle = \frac{\sum_{j=1}^{z}[M(f_{\max})_j - M(f_{\min})_j]}{z} \tag{2.0}$$

And the corresponding variance is:

$$\langle Var_{k,l}\rangle = \frac{\sum_{j=1}^{z}\{[M(f_{\max})_{j,l} - M(f_{\min})_{j,l}] - \langle M_{k,l}\rangle\}^2}{z-1} \tag{2.1}$$

Combining these session means and variances over both hands and all the sessions s that a subject attended gives an aggregated mean μ and aggregated variance var_i.

$$\mu = \frac{\sum_{k=1}^{s}\sum_{l=1}^{2}\langle M_{k,l}\rangle}{2s} \tag{2.2}$$

-continued

$$\langle var\rangle = \frac{\sum_{k=1}^{s}\sum_{l=1}^{2} Var_{k,l}}{2s} \tag{2.3}$$

Other embodiments of this aggregation step include using the data from only one hand—either the left hand, the right hand, or the dominant hand (and if the subject is ambidextrous, the dominant hand would be defined as the average of both hands.) In addition, these embodiments may not require averaging of several sessions, but selecting only one session for use or using a weighted combination of each session's results. In one embodiment, the magnitude range of one or more windows at the beginning of the predetermined time interval is not used to produce said aggregate range value.

Thus, the totality of these embodiments include methods that involve any and all combinations of: statistics derived from Fourier or Wavelet transformations or other filtering, plus any one of many possible aggregation statistics, plus using data from only one hand or the dominant hand or the average of both hands, plus using either all sessions or a subset of the sessions or a weighted combination of each session's results.

Diagnostic Indicator

A Diagnostic indicator is determined by setting a threshold level θ for the aggregation statistic in step **36**. When the subject's measured aggregate statistic is less than the threshold θ, the test indicates the subject has ADHD. When the subject's measured aggregate statistic is greater than the threshold θ the test indicates the subject does not have ADHD. A single threshold may be used for all subjects or the threshold may be set differently for different groups such gender or age.

The method of obtaining the threshold θ is now described. It is similar to a method in the statistical literature called "discriminant analysis". In fact, one could use discriminant analysis c for this data; however this method was devised because it can be enhanced and used for purposes discriminant analysis cannot handle. This enhancement will be described later.

To find the value of θ that gives the highest percentage of correct diagnoses, a simple example must first be illustrated. In this example, there are 32 aggregation statistics, one for each subject in the study. Next thresholds θ=11.5 and θ=5 were considered. The 32 aggregation statistics are shown in FIG. **5**, along with threshold θ=11.5 as the solid line and θ=5 as the dashed line. A different percent of correct diagnosis results when θ=11.5 is used compared to θ=5. Naturally, there are an infinite number of potential values for θ, and a procedure to pick the one that gives the highest percent of correct diagnoses are needed.

Thus, the following procedure was used: Twenty-five equally spaced values, spanning the range of the 32 aggregation statistics, were found. At each of these 25 values, the percent p of correctly diagnosed subjects was computed. A spline is fitted through this data, so that p is now estimated as a smooth function of θ. Then, the maximum value of this smooth function is found, and θ is set to be where the percent of correct diagnoses is maximized. Since this is often an interpolation, the value of the spine function at θ is not used, but instead is recomputed to percent of correct diagnoses at θ.

An enhanced method that works in situations where discriminant analysis does not work calls for replacing the percent of correct diagnoses in the above procedure with a

weighted percent of false positive and false negative diagnosis, and then to minimize this weighted percent. This method allows the flexibility to choose the relative importance of false positive and false negatives, and to have this used in determining θ. One way to set the relative importance is to use the cost of a false negative diagnosis.

Virtually every analysis method tried produced correct diagnoses at a rate that is statistically above chance results at the α=0.05 level, and many methods produced statistically significant results at the α=0.01 level (see Table 1 through Table 8). This indicates that the diagnosis method proposed, using windowed Fourier transforms of hand temperatures, has found a real effect. The diagnoses obtained are significantly better than one would obtain using random chance.

For example, comparing the case where the variance was used on all data with one threshold for everyone, we see the method produces 68.8% correct diagnoses. If the variance is used with gender thresholds, the percent correct increases to 84.4%. Using different thresholds by gender improves the diagnoses when using all data, see Table 1. This is consistent with statements by Raymond, K. B. (1997). *Dissertation Abstracts International*: Section A: Humanities and Social Sciences, 57 (12-A) 5052, and also Katz, L., Goldstein, G., Geckle, M. (1998). Journal of Attention Disorders. 2(4), 239–47, who state that females with ADHD are underdiagnosed. This suggests that a different standard of diagnosis is necessary for females. Age based thresholds improve the percent correct by 3% (see Table 1). Any of the methods of separating thresholds by gender or age or neither, produce diagnoses that are statistically better than chance.

Another result shown in tables reveals that removing noises (as described below) produce the highest percent correct diagnosis. This is consistent with the fact, that the data removed was contaminated and less likely to demonstrate the effect of interest. Further, note that without using gender or age thresholds after removing noises, the variance produces correct diagnoses 84.6% of the time. Using gender or age thresholds after removing noises, or using the mean or median, did not improve the results.

Listed below are the types of noise:

Self Diversion
  Children divert themselves by moving, using mental exercises or external tools such as gum or suckers

External Stimulation
  Noises, Room Temperature, Parents in Room etc.

Technical Problems
  Loose sensors, missing sensors, pauses, computer failures

Sleep problems
  Child falls asleep during the session

Medication Problems
  Child's medication is still active during session or child is on long acting drug

Automatic or manual elimination of temperature data during a noise event can be accomplished by recording ambient temperature, video and audio data during the test. These data are synchronized to the recording of subject temperature data through a time stamp. Automatic or manual analysis techniques can also be used to identify noise event occurrences and either alert the test evaluator of the occurrence for manual elimination of subject temperature data through the time stamp or automatically eliminate suspect temperature data through more advanced techniques. Specifically, video and audio recording can provide historical reference of the test, which can be used by the test evaluator in conjunction with the subject temperature data to eliminate suspect subject temperature data. More sophisticated techniques such as scene change algorithms, and peak noise detection can be used to alert the test evaluator to a noise event to manually eliminate subject temperature data during the noise event. These same techniques in conjunction with the time stamp could also be used to automatically eliminate suspect subject temperature data. Video and audio recording addresses self-diversion, external stimulation and sleep problems. Ambient temperature recording in conjunction with comparison data from the subject temperature data addresses the problems of missing or loose sensors which might cause a loss of temperature data from the subject. In one embodiment, the environment data is automatically evaluated using a loss of temperature signal or abrupt change in temperature signal from the subject.

Other analysis methods were tried and found to be less successful, though these methods were significantly better than chance. For example, applying a Butterworth filter to the temperature data as suggested by Shusterman, V. and Barnea, O. (1995). *Biofeedback and Self-Regulation*, 20(4), 357–365 did not produce improved results. Nor did separating the data by session (Table 7) or by hand (Table 8). The highest accuracy is obtained by averaging sessions and averaging two hands for tests. The benefit of using both sessions and both hands is that reduction of variability occurs, enabling more reliable diagnoses. A well-known statistical principle is that the variability of the average of multiple sessions or two hands is less than the variability of one session or one hand. Nor did removing the first two time periods (Tables 3, 4 and 6) improve the percent of correct diagnoses.

The percent of false positive and false negative diagnoses was examined. Using the mean statistic and one threshold for all subjects, a result of 25% false positive diagnoses and 0% false negative diagnoses was achieved. Using separate thresholds by gender and the variance statistic produced a result of 9.4% false positive diagnoses, and 6.3% false negative diagnoses.

The test method was applied to 50% ADHD subjects and 50% non-ADHD subjects; however, if it was applied only to symptomatics (a subset of the population in which most have ADHD), it is shown below that the method test actually will produce higher accuracy. The actual rate of false diagnoses depends on the assumed percent of true ADHD subjects in the population of symptomatics to be tested.

Let p be the proportion of subjects in the study who actually have ADHD. Let f_+ be the proportion of false positive diagnoses of those subjects who do not have ADHD. Let f_- be the proportion of false negative diagnoses of those subjects who do have ADHD. Then the proportion c of correct diagnoses is:

$$c=1-(f_- p - f_+(1-p))$$

The derivative of c is:

$$\frac{\partial c}{\partial p} = f_+ - f_-$$

The derivative is positive whenever f_+ is greater than f_-. Thus, increasing the value of p will increase the proportion c of correct diagnoses.

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 spirit and scope of the invention.

Appendix

The following is a list of tables in the Appendix that show the percent of subjects correctly diagnosed by different

analysis methods, or by using different portions of the data, or by a combination of analysis methods and different portions of the data (note that in all the following cases, sessions whose subjects had medication problems have been removed):

Table 1: all remaining data used.

Table 2: Windows with technical problems (sensor falling off or pause button pushed) eliminated.

Table 3: First two time windows removed.

Table 4: Same as Table 2, but first two time windows are removed.

Table 5: Sessions where there were serious self-diversion problems were removed.

Table 6: Same as 5, but first two time periods were also removed.

Table 7: Same as 1, one threshold for all subjects, but data from only session 1, or only session 2 or both sessions were used.

Table 8: Same as 1, one threshold for all subjects, but data from left hand; or right hand; or dominant hand used.

TABLE 1

Percent of Correct Diagnosis
Subjects with medication problems removed (2822 & 2813 Session 1)
Both Hands/Both Sessions, N = 32
95% Significance is > 65.6% correct, 99% Significance is > 71.9% correct
Data used: All Data

	Statistics Used:		
Thresholds used	Mean % Correct Diagnosis	Median % Correct Diagnosis	Variance % Correct Diagnosis
One Threshold for Everyone	75.00	68.75	68.75
Age Thresholds	78.13	71.88	71.88
Gender Thresholds	81.25	68.25	84.38

TABLE 2

Percent of Correct Diagnosis
Subjects with medication problems removed (2822 & 2813 Session 1)
Both Hands/Both Sessions, N = 32
95% Significance is > 65.6% correct, 99% Significance is > 71.9% correct
Data used: Remove technical problems

	Statistics Used:		
Thresholds used	Mean % Correct Diagnosis	Median % Correct Diagnosis	Variance % Correct Diagnosis
One Threshold for Everyone	68.75	68.75	68.75
Age Thresholds	75.00	75.00	75.00
Gender Thresholds	78.13	68.75	81.25

TABLE 3

Percent of Correct Diagnosis
Subjects with medication problems removed
Both Hands/Both Sessions, N = 32
95% Significance is > 65.6% correct, 99% Significance is > 71.9% correct
Data used: Remove 1st 2 time periods

	Statistics Used:		
Thresholds used	Mean % Correct Diagnosis	Median % Correct Diagnosis	Variance % Correct Diagnosis
One Threshold for Everyone	68.75	65.63	65.63
Age Thresholds	71.88	68.75	65.63
Gender Thresholds	71.88	65.63	68.75

TABLE 4

Percent of Correct Diagnosis
Subjects with medication problems removed
Both Hands/Both Sessions, N = 32
95% Significance is > 65.6% correct, 99% Significance is > 71.9% correct
Data used: Remove technical problems and 1st 2 time periods

	Statistics Used:		
Thresholds used	Mean % Correct Diagnosis	Median % Correct Diagnosis	Variance % Correct Diagnosis
One Threshold for Everyone	65.63	65.63	68.75
Age Thresholds	71.88	68.75	68.75
Gender Thresholds	68.75	65.63	71.88

TABLE 5

Percent of Correct Diagnosis
Subjects with medication problems removed (2822 & 2813 Session 1)
Both Hands/Both Sessions, N = 26
95% Significance is > 65.4% correct, 99% Significance is > 73.1% correct
Data used: Remove tech/external/self-diverted problems

	Statistics Used:		
Thresholds used	Mean % Correct Diagnosis	Median % Correct Diagnosis	Variance % Correct Diagnosis
One Threshold for Everyone	76.92	73.08	84.62
Age Thresholds	84.62	76.92	84.62
Gender Thresholds	76.92	76.92	84.62

TABLE 6

Percent of Correct Diagnosis
Subjects with medication problems removed (2822 & 2813 Session 1)
Both Hands/Both Sessions, N = 32
95% Significance is > 65.4% correct, 99% Significance is > 73.1% correct
Data used: Remove tech/external/self-diverted problems and 1st 2 time pds

	Statistics Used:		
Thresholds used	Mean % Correct Diagnosis	Median % Correct Diagnosis	Variance % Correct Diagnosis
One Threshold for Everyone	73.08	65.38	73.08
Age Thresholds	80.77	76.92	76.92
Gender Thresholds	69.23	73.08	76.92

TABLE 7

Percent of Correct Diagnosis By Session
Subjects with medication problems removed (2822 & 2813 Session 1)
Data used: All Data

	Statistics Used:		
Session Used	Mean % Correct Diagnosis	Median % Correct Diagnosis	Variance % Correct Diagnosis
Session 1	68.75	68.75	71.88
Session 2	71.88	65.63	68.75
Both Sessions	75.00	68.75	68.75

TABLE 8

Percent of Correct Diagnosis By Hand
Subjects with medication problems removed (2822 & 2813 Session 1)
Data used: All Data

	Statistics Used:		
Hand Used	Mean % Correct Diagnosis	Median % Correct Diagnosis	Variance % Correct Diagnosis
Both Hands	75.00	68.75	68.75
Dominant Hand	75.00	65.63	65.63
Left Hand	65.63	62.50	71.88
Right Hand	65.63	68.75	68.75

PARTS LIST

10	subject
12	chair
13	earphones
14	screen
15	sound generating device
16	fingertip
18	sensor
19	wire
20	module
21	wire
22	temperature sampling circuit
24	data storage
26	window blocking
28	Fourier transform
30	Magnitude calculation
32	Mrange calculation
36	thresholding step
37	video capture device
38	audio capture device
39	ambient temperature sensor
40	wire

What is claimed is:

1. A method of determining whether a subject has Attention Deficit Hyperactivity Disorder, comprising:

sampling the peripheral skin temperature of the subject during a pre-determined time interval when the subject is in an inactive state to provide sampled peripheral skin temperature data;

dividing the data into a series of windows of equal time intervals across the pre-determined time interval;

for each window applying a fast Fourier Transform algorithm (FFT) to produce a data set of FFT magnitudes and determining a range of FFT magnitude variation, which is the difference between the FFT magnitude at a maximum frequency f_{max} and the FFT magnitude at the minimum frequency f_{min}; and

aggregating the magnitude ranges for one or more of the windows to produce an aggregate magnitude range value which is indicative of whether or not the subject has ADHD;

wherein after said sampling, temperature data sampled during a noise event is eliminated through manual or automatic means.

2. The method of claim **1** wherein said aggregate magnitude range value is the mean of said magnitude range values of all of said windows.

3. The method of claim **1** wherein said aggregate magnitude range value is the median of said magnitude range values of all of said windows.

4. The method of claim **1** wherein said aggregate magnitude range value is the variance of said magnitude range values of all of said windows.

5. The method of claim **1** wherein said aggregate magnitude range value is determined by an aggregation statistical algorithm of said magnitude range values of all of said windows.

6. The method of claim **1** wherein said sampling includes sampling the peripheral skin temperature of said subject during two or more pre-determined time intervals, wherein said aggregate magnitude range value is aggregated for one or more of said pre-determined time intervals.

7. The method of claim **1** wherein said sampling includes sampling the peripheral skin temperature of one or both hands of said subject.

8. The method of claim **1** wherein said the magnitude range of one or more windows at the beginning of said pre-determined time interval is not used to produce said aggregate magnitude range value.

9. The method of claim **1** wherein environmental data including subject motion, audible environment and ambient temperature data are recorded.

10. The method in claim **9** wherein said environmental data is synchronized to the temperature data.

11. The method of claim **9** wherein environmental data are manually analyzed by a test evaluator for the occurrence of one or more noise events.

12. The method of claim **11** wherein temperature data sampled during a noise event is eliminated prior to calculating the aggregate magnitude range value.

13. The method of claim **9** wherein said environment data is automatically evaluated using scene change algorithms and peak noise detection to determine whether a noise event occurred during the sampling.

14. The method of claim **13** wherein automatic analysis techniques are used to alert a test evaluator of a noise event.

15. The method of claim **14** where the test evaluator eliminates suspect subject temperature data if the evaluator is alerted to a noise event.

16. The method of claim **13** wherein said environment data is used to automatically remove specific temperature data sampled during a noise event.

17. The method of claim **9** wherein said environment data is automatically evaluated using a loss of temperature signal or abrupt change in temperature signal from the subject.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,843,774 B2 Page 1 of 1
APPLICATION NO. : 10/301072
DATED : January 18, 2005
INVENTOR(S) : Foust et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4,
Line 38, replace "Fast 30 Fourier Transform" with --Fast Fourier Transform--; and
Line 52, replace "$M_1(f_m) = \sqrt{B (f_m)^2 +_{A(fm)2}}$" with --$M_1 (f_m) = \sqrt{B (fm)^2 + A (f_m)^2}$--.

Column 5, Line 10, replace "1600" with --600--.

Column 8, Line 55, replace "$\partial c/\partial p = f + -f$" with --$\partial c/\partial p = f + -f$--.

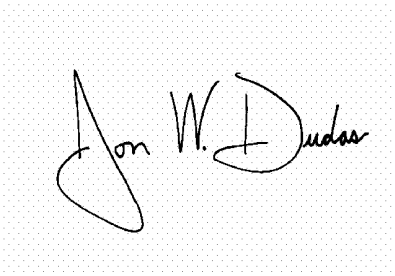
Column 9, Line 7, replace "all remaining" with --All remaining--.

Column 9, Table 1, Line 49, replace "68.25" with --68.75--.

Columns 9-11,
Tables 1-8, replace all instances of "Diagnosis" with --Diagnoses--.
Tables 1-8, replace all instances of "Statistics" with --Statistic--.

Signed and Sealed this

Fifteenth Day of May, 2007



JON W. DUDAS
Director of the United States Patent and Trademark Office

专利名称(译)	诊断注意缺陷多动障碍的技术		
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其他公开文献	US20030120172A1		
外部链接	Espacenet USPTO		

摘要(译)

本发明的特征在于一种通过对处于非活动状态的个体的外周皮肤温度进行采样并且操纵所得到的温度数据以产生指示该个体是否患有ADHD的值来确定个体是否具有注意力缺陷多动障碍的方法。