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(54) Titre : PROCÉDE DESTINÉ A DETERMINER LES VARIATIONS DE L'ÉTAT D'ATTENTION ET L'ÉTAT D'ATTENTION GENERAL
 (54) Title: METHOD FOR DETERMINING FLUCTUATION IN ATTENTIONAL STATE AND OVERALL ATTENTIONAL STATE

(57) **Abrégé/Abstract:**

The invention provides methods for determining shifts in the attentional state of a subject. These methods are useful for diagnosing subjects with a psychological or behavioral disorder. The invention also features methods for determining the effect of a therapy on the overall attentional state and shifts in the attentional state of a subject.



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(54) Title: METHOD FOR DETERMINING FLUCTUATION IN FUNCTIONAL STATE

(57) Abstract: The invention provides methods for determining shifts in the attentional state of a subject. These methods are useful for diagnosing subjects with a psychological or behavioral disorder. The invention also features methods for determining the effect of a therapy on the overall attentional state and shifts in the attentional state of a subject.

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**METHOD FOR DETERMINING FLUCTUATION IN ATTENTIONAL
STATE AND OVERALL ATTENTIONAL STATE**

5 Background of the Invention

A subject's visual attention can be tested by displaying a series of visual stimuli, to which the subject is instructed to respond. Typically, the stimuli are of two types, and the subject is instructed to respond to only one of them. Data are collected for each stimulus presented including the type of stimulus,
10 whether or not the subject responded, and if so, how long the subject took to respond. The continuous performance attention task has been in use since the mid 50's (Rosvold et al., 1956, J. of Consulting and Clinical Psychology, 20: 343-350), with computerized versions available in the 1970's (Greenberg, 1987, 23: 279-282). The previous methods of analysis of the raw data
15 generated from these methods have typically distilled the data into a few numbers which do not capture the subject's fluctuations in attention.

Another method for assessing the visual attention capabilities of a subject involves determining how long a particular visual stimulus must be present before a subject can detect it (5,801,810). This method does not reveal
20 the attentional state of the subject, rather, it requires the subject to be fully attentive.

Other reported methods determine a subject's intensity of focused attention, concentration, and/or interest by measuring signals naturally emanating from the brain (5,983,129 and 5,377,100). These brainwaves vary
25 across subjects and even within the same subject; thus, these methods do not provide a reliable, well-defined number for classifying attentional states.

A diagnostic assessment of psychological conditions can be made by conducting a sequence of continuous performance tasks where information is recorded to reflect the number of target stimuli correctly identified, the number of target stimuli missed, the number of responses to non-target stimuli, the number of non-target stimuli correctly missed, and the final interstimulus interval (5,940,801). This method can be used in a clinical setting, as well as remote locations such as the home, school, or workplace. Using this method in remote locations is useful for psychological and behavioral problems that are highly stimulus-dependent and may not be manifested in a clinical environment, such as depression, anxiety, schizophrenia, addiction, eating disorders, attention deficit disorders, attention deficit and hyperactivity disorder. This method does not provide a way to classify performance into states.

The aforementioned methods do not accurately quantify a subject's attentional state. None classify a subject's behavior into specific well-defined states or examine fluctuations in attention over time.

Summary of the Invention

Various embodiments of this invention provide a method for diagnosing a psychological, neurological, or behavioral disorder in a subject, said method comprising: (a) providing from said subject scoring data that has been collected by (i) presenting to said subject
5 a sequence comprising target and nontarget stimuli during a continuous testing period; and (ii) scoring the response of said subject on the number of targets responded to and the number of nontargets responded to; (b) on the basis of said scoring data, (i) dividing said sequence into epochs and classifying the attentional state of said subject during each epoch, and (ii)
10 calculating the number of shifts in the attentional state of said subject during said continuous testing period; and (c) on the basis of the results of step (b), diagnosing said subject.

Various embodiments of this invention provide a method for diagnosing a psychological, neurological, or behavioral disorder in a subject, said method comprising: (a) presenting to said subject a sequence comprising target and nontarget stimuli during a continuous testing period, recording the responses of said subject to produce subject data, and
15 transmitting said subject data to a computer for analysis; (b) receiving the results of said analysis, wherein said analysis comprises (i) scoring the response of said subject on the number of targets responded to and the number of nontargets responded to; and (ii) on the basis of said scoring data, (b1) dividing said sequence into epochs and classifying the attentional state of said subject during each epoch, and (b2) calculating the number of shifts in the attentional state
20 of said subject during said continuous testing period; and (c) on the basis of the analysis of step (b), diagnosing said subject.

Various embodiments of this invention provide a method for diagnosing Attention Deficit Hyperactivity Disorder (ADHD) in a subject, said method comprising: (a) providing from said subject scoring data that has been collected by (i) presenting to said subject a
25 sequence comprising target and nontarget stimuli during a continuous testing period; and (ii) scoring the response of said subject on the number of targets responded to and the number of nontargets responded to; (b) on the basis of said scoring data, (i) dividing said sequence into epochs and classifying the attentional state of said subject during each epoch, (ii) calculating the number of shifts in the attentional state of said subject during said continuous testing
30 period, (iii) identifying epochs in which said subject is in an impulsive attentional state, epochs

in which said subject is in a distracted attentional state, and epochs in which said subject is in an on-task attentional state; and (c) on the basis of the results of step (b), diagnosing said subject.

Various embodiments of this invention provide a method for diagnosing Attention
5 Deficit Hyperactivity Disorder (ADHD) in a subject, said method comprising: (a) presenting to
said subject a sequence comprising target and nontarget stimuli during a continuous testing
period, recording the responses of said subject to produce subject data, and transmitting said
subject data to a computer for analysis; (b) receiving the results of said analysis, wherein said
analysis comprises (i) scoring the response of said subject on the number of targets responded
10 to and the number of nontargets responded to; and (ii) on the basis of said scoring data, (b1)
dividing said sequence into epochs and classifying the attentional state of said subject during
each epoch, (b2) calculating the number of shifts in the attentional state of said subject during
said continuous testing period, (b3) identifying epochs in which said subject is in an impulsive
attentional state, epochs in which said subject is in a distracted attentional state, and epochs in
15 which said subject is in an on-task attentional state; and (c) on the basis of the analysis of step
(b), diagnosing said subject.

In one aspect, the invention features a method of acquiring information about the
attentional state of a subject. The method involves (a) presenting to the subject a sequence of a
predetermined number of stimuli over a predetermined period of time, wherein the sequence
20 includes target and nontarget stimuli, (b) scoring the response of the subject on the percentage
of targets responded to and the percentage of nontargets responded to, and (c) on the basis of
the scoring of step (b), making a determination of the attentional state of the subject.

This method can be used to assess both overall attention and impulsivity. This method can be repeated three or more times to determine the pattern of attentional states and the time spent in each state.

5 This method can be used to diagnose the subject being tested for a psychological, neurological, or behavioral disorder, such as depression, an anxiety disorder, schizophrenia, a drug addiction, an eating disorder, an attention deficit disorder, an attention deficit and hyperactivity disorder, a learning disorder, or Alzheimer's disease, dementia, epilepsy, stroke or traumatic brain injury. This method can be used to identify a subject at risk for
10 a psychological, neurological, or behavioral disorder or to diagnose a subject with such a disorder. Additionally, this method can be used to determine the preferred therapy for the treatment of a psychological, neurological, or behavioral disorder or to correlate the attention state of a subject involved in a clinical trial of a therapy for a psychological or behavioral disorder with the
15 success or failure of the therapy to improve the subject's condition.

This method can also be used to assess the eligibility of a subject to obtain a driver's license or a volunteer or paid position, including those that require a longer than average attention span, such as, an air traffic controller, pilot, emergency room doctor, surgeon, police officer, military officer, or fire-
20 fighter.

In a related aspect, the invention features a method of determining whether a therapy affects the attentional state of a subject. This method involves (a) presenting to the subject undergoing treatment with the therapy a sequence of a predetermined number of stimuli over a predetermined period of
25 time, wherein the sequence comprises target and nontarget stimuli, (b) scoring the response of the subject on the percentage of targets responded to and the percentage of nontargets responded to, and (c) on the basis of the scoring of

step (b), making a determination of the attentional state of the subject. An altered attentional state, compared to either the attentional state of the subject when not undergoing treatment with the therapy or the attentional state of a control subject when not undergoing treatment with the therapy, indicates that the therapy affects the attentional state of the subject.

In one embodiment of this aspect, both overall attention and impulsivity are assessed. This method may be repeated three or more times to determine the pattern of attentional states and the time spent in each state. This method may also further include comparing the effect of the therapy on the attentional state of the subject to the effect of another therapy on the attentional state of the subject. Additionally, this method may further involve comparing the attentional state of a subject diagnosed with a disorder to that of a subject not diagnosed with the disorder.

In various embodiments, the subject is diagnosed with a psychological or behavioral disorder, such depression, an anxiety disorder, schizophrenia, drug addiction, an eating disorder, attention deficit disorder, attention deficit hyperactivity disorder, a learning disorder, Alzheimer's disease, dementia, epilepsy, stroke, or traumatic brain injury. In other embodiments, the subject is involved in a clinical trial of a therapy for a psychological, neurological, or behavioral disorder. This method may be also used to determine the preferred therapy for the treatment of a psychological, neurological, or behavioral disorder.

In one desirable embodiment of any of the methods of the invention, the stimuli are visual symbols or audio sounds. The symbols can be individual numbers, letters, or shapes, or a combination of the above. Preferably, the stimuli are presented using a computer screen or speaker and the subject's responses are recorded using a computer. In another desirable embodiment of

the invention, the stimuli number 15, 20, 30, or greater within each analysis period. The test may be conducted in a clinical setting or across a network.

Brief Description of the Drawings

5 Figure 1 is a table showing the assessment of the attentional state of children diagnosed with attention deficit hyperactivity disorder (“ADHD”) and the attentional state of normal children not diagnosed with ADHD (“NL”) using traditional continuous performance task (CPT) parameters and using the method of the present invention.

10 Figure 2 is a bar graph of the probability of entering into one attentional state (*i.e.*, “On Task,” “Impulsive,” “Distracted,” or “Random” state) from any other attentional state based on 989 state entries in the premedicated state and 513 state entries after treatment with methylphenidate.

Detailed Description

15 The invention features a method of assessing the attentional state of a subject and measuring the fluctuations in the attentional state of the subject. This method determines both the impulsivity and overall attention of the subject and classifies the subject’s attentional state accordingly. The invention also includes the novel method of determining and classifying the types and
20 time course of fluctuations in attention state. Additionally, the invention includes a novel method of determining the effect of a therapy on the attentional state of a subject. The invention gives greater insight into the nature of the attentional process than prior methods which summarize the entire session or larger segments of the session into a set of measures.

This simple and rapid method of classifying behavior involves presenting a subject with a sequence of a predetermined number of stimuli over a predetermined period of time. These stimuli can be visual symbols or audio sounds, and they can be presented to the subject using a computer. The response of the subject is scored based on the percentage of target stimuli responded to and the percentage of nontarget stimuli responded to.

The following examples are to illustrate the invention; they are not meant to limit the invention in any way.

Assessment of Attentional State during a Computerized Task

A sequence of 15 stimuli are presented sequentially at two second intervals, over a total duration of 30 seconds. Each of the stimuli is either a target or a non-target stimulus, chosen randomly with equal probability, and chosen independently of the other stimuli. Although the total number of symbols remains fixed at 15, the numbers of target and non-target symbols vary, but generally do not differ by more than about 5. The percentage of targets to which the subject responds is calculated, and denoted T . Similarly, the percentage of responses to non-targets is denoted N .

If a subject does not discriminate between targets and non-targets, then the two percentages T and N will be similar. A subject is defined to be “Randomly” responding if N and T differ by less than 25%, and the subject responds to most of the stimuli. Conversely, a subject is “Minimally responding” if N and T agree within 25% but the subject responds to less than half of the stimuli.

For a perfect response, T is 100%, and N is 0%. A subject is defined to be “On Task” if T is 85% or greater, and N is 20% or less. An impulsive subject typically responds to target stimuli with good accuracy, but exhibits

errors of commission. If T is 85% or greater and N exceeds 20% (and the subject is not Randomly responding), then the subject is defined to be "Impulsive." A subject who misses more than 15% of the target stimuli (T is less than 85%), responds to a greater percentage of target than non-target stimuli (T is greater than N) and is not Randomly or Minimally responding, is defined as "Distracted."

Finally, a subject could respond to more non-target than target stimuli, either intentionally or through confusion. If N exceeds T by more than 25%, then the subject is defined to be "Contrary."

The above procedure is repeated using additional blocks of symbols of the same length. Thus, the attention state can be recorded after each block and used to determine the amount of time spent in each state, the pattern of attention states, and the range of attention states occupied by the subject.

Comparison of the Fluctuations in Attentional State of Subjects Diagnosed with Attention Deficit Hyperactivity Disorder to that of Normal Subjects

The attentional state of subjects diagnosed with attention deficit hyperactivity disorder (ADHD) and the attentional state of normal subjects were measured using a computer-driven vigilance task coupled to a high precision motion analysis system. The vigilance task required subjects to respond to the presentation of eight pointed stars and to withhold response to five pointed stars. These symbols were presented at random screen positions every other second for a period of 200 milliseconds (450 stimuli per test with a 50% probability of the target stimuli). The accuracy and response latency to each stimulus was recorded. For each successive 30 second segment, the response was divided into "On Task," "Impulsive," "Distracted," "Random Responding," "Minimal Responding," and "Contrary Responding" attentional

states, based on the percent responses to targets and non-targets using the criteria described above.

To assess the effects of racemic methylphenidate (MPH, also called Ritalin) on attention, 60 boys (10.1 ± 1.3 years of age) with ADHD (DSM-IV combined subtype based on standard diagnostic methods using K-SADS-E, which is the children's version of the schedule for affective disorders and schizophrenia) were studied off all medication. These children had previously taken MPH as their only treatment but had not taken MPH for at least 24 hours prior to this study. Thus, these children had an undetectable level of MPH in their bloodstream. The children were also retested 120 minutes after administration of a probe-dose of MPH (0.4 mg/kg PO). Comparisons were made to a new group of eight healthy normal male controls (11.3 ± 2.0 years of age; $p > 0.2$) without ADHD (based on an assessment using the K-SADS-E criteria) (Fig. 1).

On average, unmedicated children with ADHD had 12.8 shifts between different attention states compared to only 5.4 shifts in controls ($F[1,66] = 19.2, p < 0.0001$). Following treatment with MPH, the attentional state of the children with ADHD shifted only 7.0 times per test ($F[1,59] = 67.7, p < 10^{-10}$), which was not significantly different than the number of times the control children without ADHD changed attentional states ($p > 0.4$). Prior to treatment with MPH, children with ADHD were "On Task" during only 42.6% of the 30 second epochs vs. an 82.4% "On Task" rate for control children ($F[1,66] = 12.9, p < 0.001$). After treatment with MPH, the "On Task" rate increased to 75.4% ($p < 10^{-11}$). As shown in Fig. 1, the number of shifts in attention state ("Shifts" row) and the percent of attention states that satisfied the "On Task" criteria ("Time on Task" row) were more robust indicators of the differences between ADHD children and normal controls ("NL" column)

than traditional continuous performance task (CPT) parameters.

MPH markedly increased the likelihood that children with ADHD would persist in an "On Task" state (Chi squared, $p < 10^{-20}$) and attenuated their proclivity to persist in a "Distracted" state (Chi squared, $p < 0.003$).

5 MPH did not significantly affect the probability that they would persist in an "Impulsive" or "Random" response state (both $p > 0.2$). However, MPH significantly attenuated their proclivity to enter into an "Impulsive" or "Random" states from another attentional state (both $p < 10^{-15}$; Fig. 2). These results illustrate the ability of the methods of the present invention to determine
10 the effect of a therapy on the attentional state of a subject.

Other Embodiments

From the foregoing description, it will be apparent that variations and modifications may be made to the invention described herein to adopt it to
15 various usages and conditions. Such embodiments are also within the scope of the following claims.

Claims

What is claimed is:

1. A method for diagnosing a psychological, neurological, or behavioral disorder in a subject, said method comprising:

(a) providing from said subject scoring data that has been collected by (i) presenting to said subject a sequence comprising target and nontarget stimuli during a continuous testing period; and (ii) scoring the response of said subject on the number of targets responded to and the number of nontargets responded to;

(b) on the basis of said scoring data, (i) dividing said sequence into epochs and classifying the attentional state of said subject during each epoch, and (ii) calculating the number of shifts in the attentional state of said subject during said continuous testing period; and

(c) on the basis of the results of step (b), diagnosing said subject.

2. A method for diagnosing a psychological, neurological, or behavioral disorder in a subject, said method comprising:

(a) presenting to said subject a sequence comprising target and nontarget stimuli during a continuous testing period, recording the responses of said subject to produce subject data, and transmitting said subject data to a computer for analysis;

(b) receiving the results of said analysis, wherein said analysis comprises (i) scoring the response of said subject on the number of targets responded to and the number of nontargets responded to; and (ii) on the basis of said scoring data, (b1) dividing said sequence into epochs and classifying the attentional state of said subject during each epoch, and (b2) calculating the number of shifts in the attentional state of said subject during said continuous testing period; and

(c) on the basis of the analysis of step (b), diagnosing said subject.

3. The method of claim 1 or 2, wherein said disorder is depression, an anxiety disorder, schizophrenia, drug addiction, an eating disorder, attention deficit disorder, attention deficit hyperactivity disorder, a learning disorder, Alzheimer's disease, dementia, epilepsy, stroke, or traumatic brain injury.

4. The method of claim 3, wherein said disorder is attention deficit hyperactivity disorder.

5. The method of any one of claims 1 to 4, wherein step (c) further comprises comparing the results of step (b) in subjects diagnosed with the disorder and subjects not diagnosed with said disorder.

6. The method of any one of claims 1 to 5, wherein said subject is involved in a clinical trial of a therapy for said disorder.

7. The method of any one of claims 1 to 6, wherein said stimuli are presented using a computer screen or speaker and each subject's responses are stored in a computer.

8. The method of any one of claims 1 to 7, wherein said stimuli are visual symbols that are numbers, letters, shapes, or a combination thereof.

9. The method of any one of claims 1 to 7, wherein said stimuli are auditory.

10. The method of any one of claims 1 to 9, wherein said subject communicates with a test administrator across a network.

11. The method of any one of claims 1 to 10, wherein the number of stimuli is 15 or greater.

12. The method of any one of claims 1 to 11, wherein each of said epochs is the same length.

13. The method of any one of claims 1 to 12, wherein step (b) further comprises identifying epochs in which said subject is in a distracted attentional state.

14. The method of claim 13, wherein step (b) further comprises calculating the amount of time said subject is in a distracted attentional state during said continuous testing period.

15. The method of any one of claims 1 to 12, wherein step (b) further comprises identifying epochs in which said subject is in an impulsive attentional state.

16. The method of claim 15, wherein step (b) further comprises calculating the amount of time said subject is in an impulsive attentional state during said continuous testing period.

17. The method of any one of claims 1 to 12, wherein step (b) further comprises identifying epochs in which said subject is in an on-task attentional state.

18. The method of claim 17, wherein step (b) further comprises calculating the amount of time said subject is in an on-task attentional state during said continuous testing period.

19. The method of any one of claims 1 to 12, wherein step (b) further comprises identifying epochs in which said subject is in a randomly responding attentional state.

20. The method of claim 19, wherein step (b) further comprises calculating the amount of time said subject is in a randomly responding attentional state during said continuous testing period.

21. A method for diagnosing Attention Deficit Hyperactivity Disorder (ADHD) in a subject, said method comprising:

(a) providing from said subject scoring data that has been collected by (i) presenting to said subject a sequence comprising target and nontarget stimuli during a continuous testing period; and (ii) scoring the response of said subject on the number of targets responded to and the number of nontargets responded to;

(b) on the basis of said scoring data, (i) dividing said sequence into epochs and classifying the attentional state of said subject during each epoch, (ii) calculating the number of shifts in the attentional state of said subject during said continuous testing period, (iii) identifying epochs in which said subject is in an impulsive attentional state, epochs in which said subject is in a distracted attentional state, and epochs in which said subject is in an on-task attentional state; and

(c) on the basis of the results of step (b), diagnosing said subject.

22. A method for diagnosing Attention Deficit Hyperactivity Disorder (ADHD) in a subject, said method comprising:

(a) presenting to said subject a sequence comprising target and nontarget stimuli during a continuous testing period, recording the responses of said subject to produce subject data, and transmitting said subject data to a computer for analysis;

(b) receiving the results of said analysis, wherein said analysis comprises (i) scoring the response of said subject on the number of targets responded to and the number of nontargets responded to; and (ii) on the basis of said scoring data, (b1) dividing said sequence into epochs and classifying the attentional state of said subject during each epoch, (b2) calculating the number of shifts in the attentional state of said subject during said continuous testing period, (b3) identifying epochs in which said subject is in an impulsive attentional state, epochs in which said subject is in a distracted attentional state, and epochs in which said subject is in an on-task attentional state; and

(c) on the basis of the analysis of step (b), diagnosing said subject.

Figure 1

MEASURES	ADHD	NL	F(1,66) =	p <	EFFECT SIZE
Standard CPT Parameters					
Errors of Commission	27.9 ± 2.4	11.6 ± 6.6	5.38	0.03	0.89
Errors of Omission	13.1 ± 1.8	1.2 ± 4.9	5.20	0.03	0.87
Latency	537 ± 101	619 ± 28	7.68	0.007	1.06
Variability (S.D.)	179 ± 7.2	134 ± 20	4.82	0.03	0.84
Attention Shift Analysis					
Time on Task (%)	42.6 ± 3.8	82.4 ± 10.4	12.95	0.0006	1.37
Shifts (#)	12.8 ± 0.6	5.4 ± 1.6	19.22	0.00004	1.67

Figure 2

