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Original Article

The assessment of vigilance: normative data on the Siesta sustained attention test ☆

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ABSTRACT

Objective: In several modern society duties individuals have to maintain their attention or vigilance over prolonged periods of time, even if the monitoring task is monotonous. The aim of our study was to obtain reference data on the 60-minute monotonous Siesta sustained attention test.
Methods: Normative data were gathered in an age-stratified sample of 234 healthy participants (118 men; 116 women) between the ages of 20 and 79 years. The impact of age, gender, time of day, and time on task during performance was analyzed.
Results: At least 20 participants from each age group and gender group were tested either in the morning or in the afternoon. The sample sizes were only smaller in the age group of 70 to 79 years. There was a notable age effect on all performance measures, with an increase in reaction times and false response rates from the youngest to the oldest group as well as a decrease in correct reactions with increasing age. Statistical analysis revealed no differences in speed and accuracy measures between men and women participants. There was no notable time-of-day effect but a clear impact of time-on-task speed and of correct reactions during the course of the test. The vigilance decrement had already occurred during the first half of the test.
Conclusions: Our results provide a normative database of performance parameters for different age groups in healthy adult participants. As sustained attention is sensitive to sleep loss and nonrestorative sleep, our data can be used as a reference for performance-based assessment of daytime sleepiness in participants with hypersomnia.

1. Introduction

Sufficient vigilance for long periods of time is essential to meet daily requirements in maintaining attention and reacting on rarely occurring stimuli, such as driving a car on long highways, performing quality inspection in manufacturing, or maintaining video surveillance of public areas. Impaired vigilance may result from disturbed or insufficient duration of sleep or from irregular sleep-wake rhythms. Vigilance affected by sleepiness is a major risk factor for car crashes [1] and also was a risk factor for catastrophes such as the Three Mile Island, the Chernobyl, and the Challenger disaster [2]. Vigilance or sustained attention refers to the ability of the organisms to maintain their focus of attention and to remain alert to stimuli over prolonged periods of time [3]. Sturm and Willmes [4] argue that in contrast to the term *vigilance* "...sustained attention is used in a more general way, comprising all situations that call for a prolonged state of sticking to a task with considerably more frequent imperative stimuli than under vigilance conditions". Nevertheless, there are no universally agreed-upon criteria for the differentiation of vigilance and sustained attention tests, and most researchers use the terms *vigilance* and *sustained attention* synonymously [5–8].

In a laboratory setting, several subjective and objective methods are available to assess vigilance or sustained attention to evaluate daytime sleepiness, which is closely associated with vigilance decrements. Subjective instruments such as questionnaires depend on the patients' ability to be introspective; however, the tests are susceptible to overestimate or underestimate vigilance performance or the degree of daytime sleepiness. Other widely used objective methods to assess sleepiness rely on electroencephalography but either demand staff or are time consuming. In addition the methods may not reflect daily requirements on vigilance (e.g., multiple sleep latency test and maintenance of wakefulness test) [9,10]. Although the use of driving simulators for sustained attention testing is increasing due to its face validity, the validity

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of these tests is not well-established for real-life performance [11–13].

The first study that applied a vigilance test in a laboratory setting was conducted by Norman Mackworth [14] in 1948. The original task was created to simulate long-term monitoring of radar screens by operators in the British Air Force during World War II to find out how long adequate performance could be sustained. The task was to detect infrequent jumps of a single clock hand moving clockwise during 2 hours of testing [14]. In the first studies on vigilance, Mackworth [14] revealed a prominent deterioration of performance approximately a half an hour after the beginning of his clock test. This essential finding of vigilance research that detection performance declines over time also is known as vigilance decrement. Time-on-task effects became apparent during operational radar monitoring in the work environment [14–16]. Since then tests based on the principle of this first vigilance test designed by Mackworth have been called Mackworth clock tests [17–19]. The Mackworth clock test was further developed and adapted for personal computers in various versions during the last decades and has been applied in several studies on vigilance in healthy participants [20–23], in studies on pharmacological effects [24–26], and on the effects of sleep deprivation on vigilance [20,27,28]. In a number of clinical trials using this kind of vigilance task, patients with severe sleep apnea syndrome demonstrated impaired performance compared to healthy controls [29,30].

Most of these studies used different task durations and stimuli frequencies. In contrast to the large body of experimental work on vigilance, most computer-based assessment tools on sustained attention lack normative data for different age groups. This hampers the diagnostic evaluation of impaired vigilance in participants with chronic daytime sleepiness (e.g., patients with narcolepsy or obstructive sleep apnea syndrome) and hampers the application for screening purposes in examinations of professional drivers.

The aim of our multicenter study was to obtain reference data on a 60-minute monotonous sustained attention test using a computerized Mackworth clock test. A similar version of the test with a shorter duration (25 minutes) was applied in studies on patients with obstructive sleep apnea syndrome [31]. The shorter version did not reveal any differences in performance measures between moderately and severely apneic patients but showed extreme impairments in one third of both groups. It was assumed that a longer version lasting at least 30 minutes would have revealed deficits in a higher number of patients. In the European wide-conducted multicenter study SIESTA (Project Biomed-2 BMH4-CT97-2040 funded by the European Commission), a Mackworth clock test differing from our test by a shorter duration (25 minutes) was conducted in healthy controls and in patients suffering from different sleep disorders as well as in other patient groups [32]. Patients with obstructive sleep apnea syndrome showed significantly impaired vigilance (decreased number of correct reactions and increased number of false reactions) compared to healthy gender-matched and age-matched controls in both evening and morning sessions on 2 subsequent days and nights [33]. In our study normative data was collected in a large adult sample of healthy men and women from the ages of 20 to 79 years. Influences of gender, age, time of day, and time on task on vigilance performance were analyzed.

2. Methods

2.1. Participants

Our sample was comprised of healthy adults stratified into 6 age groups with an age range from 20 to 79 years. We attempted to test at least 20 women and 20 men per age decade. All participants were screened for sleep disorders by the Pittsburgh Sleep Quality Index [34] and the Landecker Sleep Disorders Inventory [35]. Participants were not allowed to participate in the study if they showed signs of depression (self-rating depression scale score >40) [36] or anxiety (self-rating anxiety scale score >36) [37]. Further exclusion criteria were the presence of sleep disorders, shift work, irregular sleep-wake patterns, psychiatric disorders, and chronic illness, as well as the use of central nervous system active substances and excessive caffeine or nicotine consumption.

2.2. Procedure

The study was conducted at 3 sleep centers, Charité – University Medicine Berlin, Germany, University Medical Center Regensburg, Germany, and Medical University of Vienna, Austria. The study was approved by the local ethic committees. All participants gave their written informed consent and were given monetary compensation for participation. Participants were assigned to either a morning or an afternoon test session, depending on their date of birth. Participants with an odd-numbered date of birth were tested in the morning between 9:30 AM and 10:30 AM, and all other participants were tested in the afternoon between 1:30 PM and 2:30 PM. Morning and afternoon test sessions started at 9:00 AM or at 1:00 PM with a pupillographic sleepiness test (PST) [38]. To avoid potential soporific effect of the PST on performance in the subsequent sustained attention test, as participants were required to sit quietly for 11 minutes in a dark room with their eyes wide open, a break of at least 20 minutes with normal ambient light was provided to the participants to reactivate and fill in questionnaires. In addition, subjective sleepiness was controlled by applying visual analog scales on wakefulness and sleepiness (10-cm scale [end point, wide awake = 0 on the left side; end point, sleepy = 10 on the right side]) before and after the test procedures. Subjective sleepiness was not increased during the course of the PST (before median [interquartile range], 2.0 [0.9–3.6]; after median, 2.0 [0.9–3.9]; Wilcoxon signed rank test, $p = 0.335$). After the 20-minute break a slight (median, 1.6 [0.7–3.1]) but significant increase of wakefulness was observed compared to both end points before and after the PST (both Wilcoxon signed rank tests, $p < 0.01$).

Participants were not allowed to drink caffeinated beverages or consume any substances that would interfere with their wakefulness during the day of testing. Smoking before or during the test sessions as well as sleeping or napping on the day of testing was not permitted.

2.3. Sustained attention test

The Siesta sustained attention test is a computer task on sustained attention based on the Mackworth clock test with a total duration of 60 minutes. The test was programmed by the Siesta Group Schlafanalyse GmbH, Vienna, Austria (Europe). On a black screen, 31 small grey circles (12 mm in diameter) arranged to form a larger circle (13 cm in diameter) are displayed. One at a time the small circles are switched to white to give the impression of a bright dot moving clockwise around the large circle at a rate of 1.5 seconds per move. Participants sit in front of the computer monitor and have to press the space bar of a regular computer keyboard whenever a target stimulus occurs (i.e., a double jump skipping one of the grey circles).

In our study the verbal test instruction was read to all participants as follows, "The following task will last approximately one hour. Although the task itself is simple, it is very boring and monotonous. This it is exactly what makes the task difficult, since you should try to stay as alert as possible during the whole time of the test despite the monotony. Imagine that you are driving along a lonesome road. In that case you should under no circumstances fall