ASSESSING LAPSES OF ATTENTION IN SLEEP DISORDERS

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ABSTRACT

The consequences of impaired attention are substantial. In Sweden, annual costs from accidents attributed to sleepiness exceed 22.4 million Euro ($15.7 million USD) and result in over 1.6 million lost work-days. 32% of the Swedish population report frequent non-restorative sleep and 10% daytime fatigue. Up to 30% and 48% of all car accidents are attributable to fatigue and to failures of attention[7] respectively. And for every accident that occurs, imperfect attention fosters between 3000 and 40,000 potential accidents (depending on severity)[1]. This paper details the clinical assessment of arousal and attention.

INTRODUCTION

The consequences of impaired attention are substantial. In Sweden, annual costs from accidents attributed to sleepiness exceed 1.7 billion kronor and result in over 1.6 million lost work-days. Driver fatigue is associated with up to 30% of all motor vehicle accidents. Independently of sleep, failures of attention have been implicated in 48% of car accidents [1]. Tellingly, 20% of vehicle fatalities occur in traffic intersections. And for every accident that occurs, imperfect attention fosters between 3000 and 40,000 potential accidents (depending on severity)[2].

While each of us has likely suffered the discomfort of maintaining alertness and attention from inadequate sleep, for many, sleep disturbances are chronic. 32% of the Swedish population report frequent non-restorative sleep and 10% daytime fatigue [3]. One common sleep disorder in particular, sleep apnea, has been associated with highly increased risks for motor vehicle accidents risks in numerous studies [2]. This paper details the clinical assessment of the functional capacity to maintain attention in highly vulnerable people. We believe that many of these individuals may be particularly vulnerable to impaired alertness and attention during wakefulness and are therefore at higher risk for accident and injury. This paper details the clinical assessment of the functional capacity to maintain attention in patients with sleep disorders and complaints of excessive sleepiness and fatigue during wakefulness.

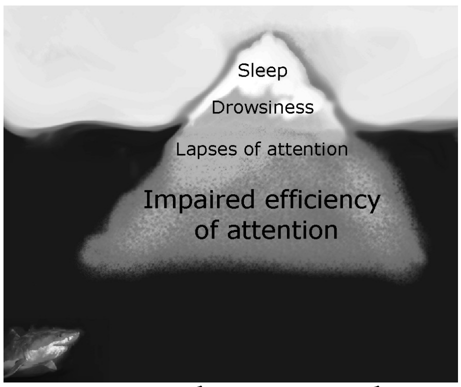

Figure 1: Iceberg metaphor of risk factor awareness

We conceptualize the risks and burdens using an iceberg metaphor (figure 1). While states of undesired sleep and drowsiness are most obvious to those experiencing them and to those nearby, breakdowns in attention and impairments of the efficiency of attention and other cognitive processes required for optimal and safe performance are more difficult to perceive and to observe. We suggest that, by virtue of their stealth and

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greater exposure over the course of the waking day, deficits of attention contribute to a major public health hazard.

The objective of our laboratory is to assess a person's functional capacities to maintain arousal (i.e., wakefulness) and attention during wakefulness. The clinical patients whom we evaluate are referred with complaints of excessive daytime sleepiness and/or fatigue which impact the quality of their lives and integrity of their work. The majority of these people have been previously diagnosed with sleep disorders, most commonly sleep apnea, and many are under treatment.

METHODS

Our laboratory assessments of clinical patients and research subjects employ a series of 4 short (20-30 minute) tests are administered once during the morning and then repeated in the afternoon. On the night prior to each evaluation, we document the quantity and integrity of sleep patterns (usually at home) using a portable data recorder (Embla A10, Flaga Reykjavik). Each test is designed to probe unique aspects of neurocognitive function including: sustained attention, complex visual information processing, psychomotor performance and the maintenance of arousal/wakefulness. This paper will detail the first of these – the ability to recruit and sustain attention in a stimulation-poor environment.

Subjects

Our clinical population sample (n = 115) is comprised of patients (median age 46 years, Inter Quartile Range 39:56) with sleep disorders and compromised daytime alertness. The majority suffer from sleep apnea. Normal controls (n=12, median age 35, IQR 24:49).

Gosling test of simple attention

We assess the maintenance of attention over a 20 minute test period by presenting low intensity visual stimuli on an LCD computer display for 1 second at random intervals between 3 and 10 seconds (Gosling test). Subjects are instructed to respond as soon as they detect each stimulus by pressing a button. In order to minimize extraneous arousal, the subjects are tested sitting up in a comfortable bed, in a darkened room, and without any indications of time or their performance.

Figure 2: Test environment.

The Gosling is implemented on a Windows-XP/PC platform using programs developed for the DMDX psychophysiological experiment software [6]. The subject response button is a sensitive 2-paddle Morse-code key which requires minimal physical pressure and a lateral finger movement of only 0.1 mm to activate. DMDX measures response times with 1 millisecond accuracy. If no response is made within 2 seconds of the onset of the stimulus, the trial is identified as a missed response or “lapse”. If more than 1.5 minutes of continuous sleep are detected in the concurrent EEG recording, the test is aborted and the subject is awoken in order to prevent the effects of a “recovery nap” on subsequent tests.

The outcome measures from the Gosling are derived from (1) the speed of the subject's response to the onset of the stimulus (reaction time, RT) and (2) the occurrence of lapses.

Physiology
We record brainwaves (EEG), heart activity (EKG), eye movements (EOG) and respiration during testing in order to verify wakefulness, detect drowsiness and microsleep-episodes, and examine cardiovascular responses.

Subjective alertness and arousal
We assess daytime sleepiness using the self-report Epworth Sleepiness Scale (ESS) [8]. The ESS is an 8-item questionnaire which asks the likelihood of falling asleep in common situations (e.g., sitting on a sofa or as a car passenger). We also assess perceptions of fatigue, which is characterized by tiredness or exhaustion, without necessarily being related to sleepiness, using the Swedish translation of the 30-item Fatigue Impact Scale (FIS) [5,4]. Both of these scales are retrospective and reflect generalized "trait-like" self perceptions of life experiences. In order to query aspects of well being under testing, subjects rate their perceptions of alertness, sleepiness, stress, difficulty fighting sleep, task difficulty and their task performance using a visual analog scale (VAS) after each test trial.

Statistics
The processing and statistical analyses of all study data are performed were performed using software written in the R statistical language [10]. Analyses of lapse occurrences are made using general estimating equation models (GEE) with Poisson links and are reported by the robust Z statistic and associated P value.

OUTCOMES

Patients with sleep disorders exhibit considerable heterogeneity in their ability to sustain attention under testing although only approximately 25% perform within the expectations for healthy control subjects. We have observed that patients with poor attentional performance fall into 1 of 2 general patterns. Most commonly seen are sporadic and short-term lapses without any evidence of sleep or drowsiness in the EEG record. Over the course of the 20 minute test, these lapses often recur at progressively shorter intervals. The second pattern is associated with sleep and drowsiness and is characterized by relatively long lapse periods (i.e., consecutive missed responses) and slowed response times. Figure 3 is representative of the predominant pattern of response behaviors in patients complaining of daytime fatigue and sleepiness. Breakdowns in attention manifest as failures to respond to isolated stimulus trials (lapses), usually without corresponding sleep or slowing of reaction times.

Lapses
Typically, and in even the most severe cases, the response performance of subjects is good within the first 5 to 10 minutes of testing. In impaired subjects, lapses then emerge with varying frequency and durations. Figures 3a and 3d illustrate the cumulative counts of lapses and the time intervals between lapse occurrences. Figure 3 shows accumulations of missed responses (e.g., fig 3a) from the entire study population. To facilitate interpretation, the total number of missed responses are also expressed as the total distance a car traveling 90 km/hr would have covered in the equivalent amount of time (estimated at 3 seconds per lapse). Note that approximately 50% of the patients had lapses exceeding the equivalent of 1.5 km travel. The differences in the distributions of lapses between patients and normal control subjects are illustrated in figure 3 and table 1. As is evident from figure 4, the variability of lapse severity among patients is considerable. Although approximately 25% are within the expected ranges for normal controls (~2 missed trials), the remainder of

patients have unambiguous deficits.

Response reaction times

Response reaction times over the 20 minute test are shown in figure 3d with a superimposed “trend” as well as a boxplot summary. Occurrences of missed responses are shown in the “rug” along the bottom time line. Lapse periods are seldom accompanied by a generalized slowing of reaction times.

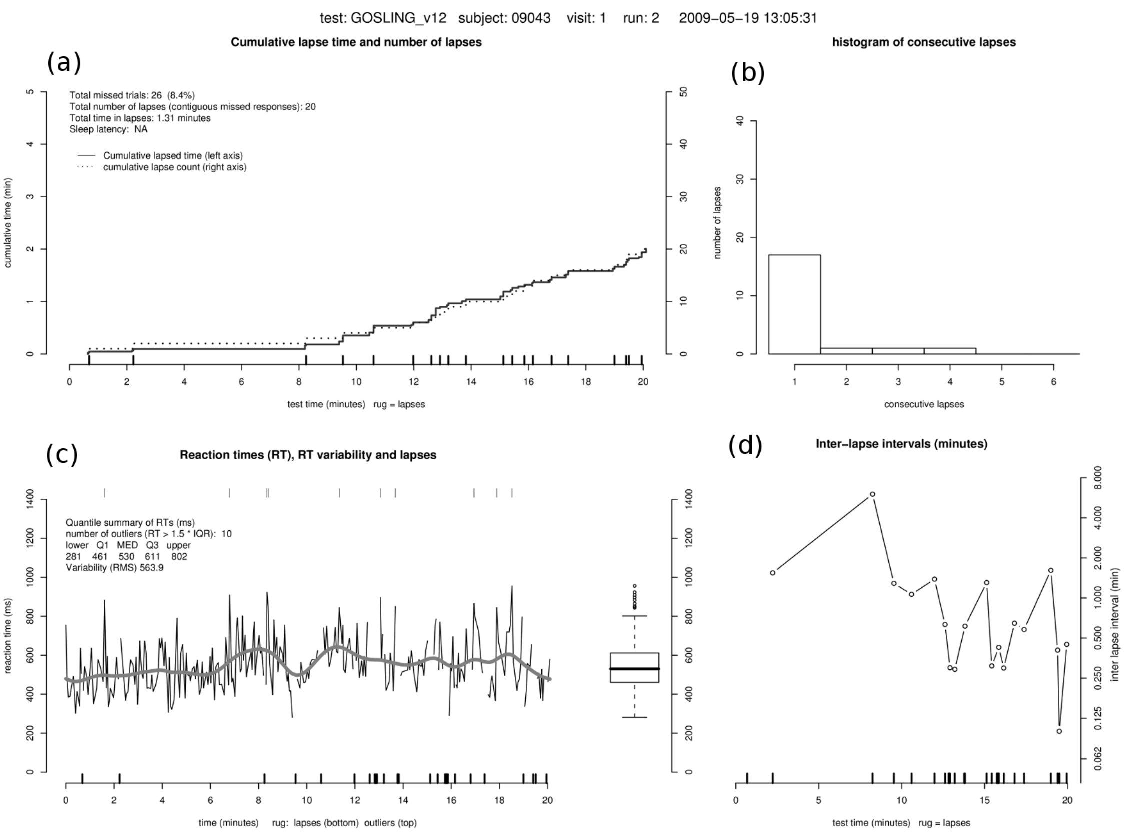

Figure 3: Sample Gosling test summary plots. (a) Running cumulative number of lapses. (b) Histogram of consecutive missed responses. (c) Response reaction times with robust average. (d) Time intervals between successive lapses.

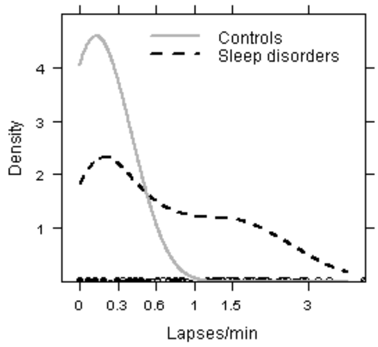

Figure 4: Kernel density estimates of the distributions of lapse incidence by study group. Note x-axis log scaling.

Table 1: Median and interquartile ranges (IQR) of the percentage of missed trials by study group.

% missed trials	median (IQR)
control	0.6 (0 : 1.5)
sleep disorder	4.0 (1 : 21)

Relationships between subjective ratings of fatigue and sleepiness and Gosling lapses

Global “trait” rating of daytime sleep propensity using the ESS ratings of do appear to predict attention performance (*Z 1.2, P 0.2*) (figure 6). Global ratings of fatigue using the FIS, on the other hand, did predict attention (Z 2.6, p. 0.01). Among the VAS ratings administered at the end of each test, “difficulty fighting sleep” (Z 2.2, p. 0.03) was more discriminative than “alertness” (Z -1.8, p. 0.07)

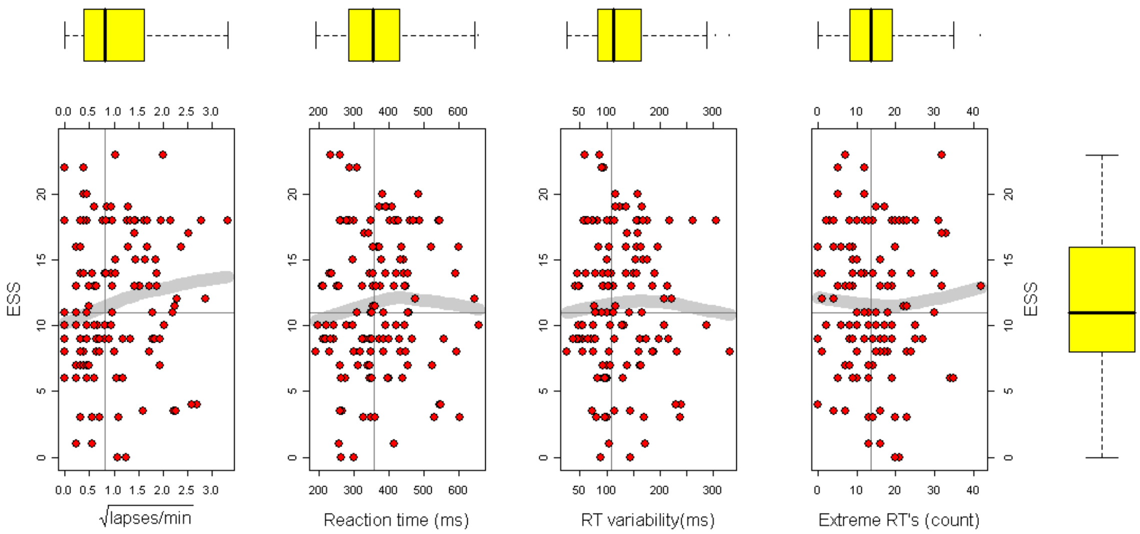

Figure 6: Scatter plots of ESS (daytime sleep propensity) scores and 4 measures of stimulus response efficiency with marginal boxplots. This figure illustrates the insensitivity of the ESS to detect attention related deficits.

DISCUSSION

In contrast to overt drowsiness and sleep, attentional lapses often manifest as transients superposed on a background of efficient responses. This highlights the challenges of detecting and predicting them in operational environments and of evaluating the potential risks they entail. In operating environments like cars, life and death or injury often hang in the balance of responses that need to be made in the blink of an eye. At 90 km/hr (56 MPH), a car travels 25 meters in 1 second and with a 3 degree deviation of the steering wheel, that car travels 12 meters laterally in 3

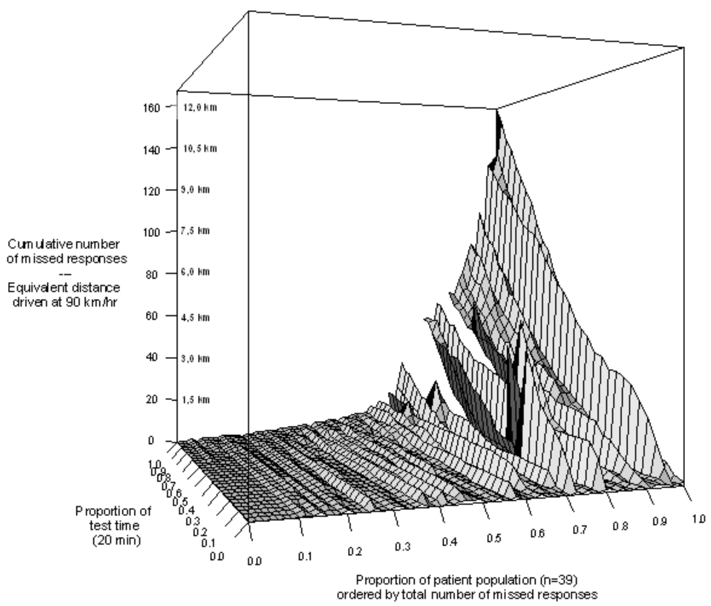

Figure 7: Cumulative number of missed responses from the patient study group.

seconds. Even with ideal responses under good conditions, a freeway bound car requires a minimum of 75 meters to come to a stop. We often take the gamble for several seconds and a hundred or more meters of highway to tune the radio or dial the cell phone when we don't expect contingencies. We may tolerate sleepiness or lack of focus behind the wheel with little regard or awareness for the consequences of not being able to react optimally to that rare and unexpected event. But as traffic conflict analyses reveal, contingencies do occur continuously on the road and avoiding them is often a matter of statistical probability and luck. In Sweden every year, luck runs out for approximately 460 drivers who fail to detect and avoid large animals (predominantly moose) on the road. These accidents result in over 80 (human) deaths and serious injuries [9].

In our experience, the majority of people with sleep disorders and excessive daytime fatigue or sleepiness have a reduced capacity to maintain simple attention over a 20 minute test period. While we don't have yet have sufficient data to establish associations between objective test performance and historical or prospective risks (e.g., diminished occupational performance or car accidents), we are confident in using laboratory test results to inform clinical evaluations and treatments and decisions about occupational fitness. We have found objective measures to be particularly helpful in cases where patient self reports have been influenced by motivations to either minimize or accentuate the extent of their symptoms.

In conclusion, we suggest the potential safety risks posed by people who are at high risk for imapired arousal, whether illness or lifestyle (e.g., shiftwork) related, demand more public awareness and continued public-health policy initiatives which encourage their assessment and treatment [11].

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