CAN YOU KNOW, IF SOMEONE IS TOO TIRED TO DRIVE SAFELY?

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Abstract

This pilot study has two aims: The first is to measure and document drops in cognitive functions which are relevant to driving over a twenty four hour period. The second aim is to see if PUI (pupillary unrest indicator) is suitable to measure and predict drops in driving relevant functions which are due to fatigue. The results based on six students who performed tests from the Vienna Test System and were tested for fatigue using the PSTeco show, that there is a significant and relevant loss in cognitive capabilities due to fatigue and that PUI was a reliable tool to predict this decline.

Introduction

No one would doubt the statement, that fatigue, be it caused by sleep deprivation, monotony or sleep disorders is detrimental to human's levels of cognitive functioning. Hardly anyone would be surprised to learn, that fatigue is associated with work (Akerstedt, Fredlund, Gilberg & Jansson, 2002; Cropley, Dijk & Stanley, 2006; Nylen, Melin & Laflamme, 2007) or air traffic accidents (Pruchnicki, Wu & Blelenky, 2011). This is because fatigue is known to have an impact on alertness, vigilance, decision-making and other cognitive capabilities (Lewis, 1983; Haimov, Hanuka & Horowitz, 2008; Walker, 2008).

Estimates show that fatigue is one of the reasons for more serious and fatal crashes than DUI (Driving under the influence of alcohol or drugs) (Phillips & Brewer, 2011, Costa et al., 2012), speeding (Peden et al., 2004) or sending text messages (Hoel, Jaffard & Van Elslande, 2010) whilst driving. Studies in the United Kingdom have shown that 9-12% of bus drivers admit to having fallen asleep whilst driving and others claim that between 29% and half of all serious accidents are related to drivers being too tired (Jackson et al., 2011). Drivers at high risk include long distance truckers who are forced to drive for very long hours, are frequently not very healthy, frequently suffering from unhealthy nutrition and sleep disorders and who drive heavy vehicles which, if they are not controlled, can easily cause disasters (McDonald, 1984). Studies have indicated that fatigue or subjective sleepiness appear to be less reliable screening instruments among the population of professional drivers, who generally tend to minimize admission of health problems (McDonald, 1984).

In most countries laws and regulations have been instituted to control real hazard behaviors such as driving under the influence of alcohol or drugs, exceeding the speed limit or using cellphones whilst driving but fatigue is rarely mentioned specifically. Usually fatigue is taken care of under the general title of being fit to drive since it is not mentioned specifically, no controls, penalties or consequences are postulated. In many countries like those of the European Union (Germany, Austria, Poland, e.g.), drivers are required to have the vehicle stopped and parking for a specific number of hours a day or as is practice in Israel certify that the driver was not behind the wheel for at least six hours. One implicitly assumes, that these measures will cause the truck or bus driver to rest and be fit to continue but such regulations do not relate to the fact that different people need different periods of sleep or that the driver might be working somewhere else or doing something else which is tiring instead of sleeping.

One might wonder why fatigue does not appear more prominently within the rules and regulations of traffic agencies all over the world. Reasons appear to be:

- The belief that most people (not only professional drivers) can “deal with” fatigue or the lack of knowledge, to what extent fatigue actually is detrimental to ones capabilities.

- The lack of a clear definition, how tired one can be to continue driving.

- The apparent lack of a valid and reliable tool to measure fatigue. One tool, the PST (Pupillographic Sleepiness Test) has been documented in some studies (e.g.Wilhelm et al., 2001), but has yet been shown to be sufficiently associated with drops in functioning over a period of time.

Thus, the present study had two main objectives:

1. The first was to examine how detrimental fatigue really is to driving relevant capabilities. We planned to examine whether fatigue cause ones reaction times to grow and or cause cognitive problems and or narrow your useful field of vision and or limit your capability to function under external pressure. All of these cognitive functions are, as mentioned above, relevant to safe driving. Limited capacities in these areas have been shown to be associated with accident involvement.

2. The second was to examine whether PUI (Pupillary Unrest Index) (Wilhelm et al., 2001) is a valid tool one can use to measure fatigue. To examine whether a raise in PUI significantly associated with a drop in cognitive functioning?

For this reason we designed and performed this basic pilot study in which we used a small, homogenous group of students and in which we did not offer any incentives to perform well or manipulate the functional capabilities of the test subjects over time.

Method

Participants

In this study, which was approved by the Ethics Committee of Emek Yezreel Academic College six young, males participated. The average age was 24.5 (Sd=1.38). No subject reported suffering from a sleep disorder. No subjects required regular medication.

Measurements

1. Actigraph: Objective sleep-wake patterns were monitored by actigraphs for five days before the experiment day. The actigraph is a small solid-state computerized movement detector, determine sleep duration and sleep quality, attached to the non-dominant hand. Actigraphic sleep measures are: sleep onset time, wake-up time, sleep duration, sleep efficiency (Sadeh, Sharkey & Carskadon, 1994).

2. The pupillographic sleepiness test (PST): Spontaneous pupillary oscillations provide objective and quantitative measures of tonic central nervous activation, which is a precondition for higher level mental performance. In this study the PST measured sleepiness thru 5 minutes recordings of pupil diameter by infrared video pupillography of the sitting participant, followed by automated data analysis. The parameter of analysis is the pupillary unrest index (PUI), for which a normal value data base is available. In sleepy subjects the pupil shows spontaneous oscillations with a predominantly low frequency component and amplitudes reaching several millimeters (Helmle, 2011).

3. Vienna Test System (VTS): The VTS tests used in our study included four driving-related ability tests whose results can be combined for a valid overall assessment. The tests have been developed specifically for use in traffic psychology and are thus precisely tailored to the issues involved (See Table 1) (Schuhfried, 1996).

Table1: Variables used for measuring cognitive functions relevant to driving

Test and Variable Name	What is measured	Details
Reaction Timer (RT)	Mean Reaction Time	The time which passed between a two bit audio-visual stimulus and the initialization of a motor response
Cognitrone (COG Wrong)	Sum of wrong responses	Number of incorrect reactions in a visual comparison test using relatively simple stimuli
Cognitrone (COG Yes)	Number of correct recognitions	Number of target stimuli which were correctly recognized.
Peripheral Perception Test (PP UFOV)	Angle of useful field of vision in a test requiring splitting attention between peripheral and central tasks	Amount of peripheral information the test subject can react to whilst paying attention to a central task
Peripheral Perception Test	Quality of performance on a central tracking task	Number and extent of mistakes on a central tracking task whilst following peripheral

(PP DEV)	whilst paying attention to peripherally presented stimuli	stimuli
Determination Test (DT)	Number of correct stimuli when functioning under external pressure	Quality of performance whilst functioning under external pressure. Program is adaptive becoming more stressful the better the subject is

Procedure

After a normal night's sleep which was monitored by actigraphs, participants came to the Emek Yezreel college and stayed in the rooms of the Center for Psychobiological Research for 24 hours beginning at 11 a.m.. Every three hours during this period the participants were tested with a battery of computerized tests from the Vienna Test system (Reaction Timer, Cognitrone S7, Peripheral Perception Test and Determination Test) which are known to be significantly correlated with accident involvement and with the PSTecho. The PUI scores used for data evaluation were those of the last, the fifth minute of testing.

Between tests participants filled in questionnaires and performed leisure activities. They were not permitted to sleep or doze. Participants could eat and drink from a large variety but caffeine containing or vitalizing beverages were not permitted.

After the 24 hour period all participants were debriefed and taken home by taxi.

Computation of Results

Psychological test data and PUI values were recorded eight times over 24 hours but for part of the evaluations only seven measurements, numbers two thru eight were used. This is due to the fact that the tests do have a learning effect and thus the first measurement was always unreliably weak.

Results

Average results of the chosen Vienna Test System tests for measuring points one (11 a.m.) through eight (twenty one hours after study begin) are presented in table 2 together with average PUI measurements.

Table 2: VTS and PST results for testing points one thru eight

Measuring point Test	PUI	RT	COG Wrong	COG Yes	PP UFOV	PP DEV	DT
One	7.04	427.17	14.17	118.17	171.90	12.95	253.17
Two	8.57	412.67	11.17	139.83	170.83	12.47	279.50
Three	7.23	420.33	14.00	148.83	169.93	12.30	289.50
Four	6.85	445.67	10.33	151.33	170.02	12.32	288.83
Five	6.37	454.17	16.33	148.50	166.73	12.55	283.17
Six	7.88	446.67	20.50	138.50	150.00	15.33	263.67
Seven	12.06	458.67	34.50	119.50	152.28	16.05	247.33
Eight	11.65	471.50	26.83	124.00	158.85	16.62	257.50

In order to examine whether the average performance of our subjects deteriorate over time with growing fatigue we compared scores for measuring points two and three (two to six p.m.) with measuring points seven and eight (after having been awake and alert for 18 to 24 hours). The results are presented in table three.

Table 3: Differences between early and late testing

	PUI	RT	COG Wrong	COG Yes	PP UFOV	PP DEV	DT
Average difference	3.95	48.58	18.08	22.58	14.82	3.95	32.08
t	-2.063	-1.372	-2.543	1.667	1.648	-2.980	1.93
P<	.04	.025	.001	.013	.044	.001	.006

The results indicate that the PUI values deteriorated significantly the more the subjects grew tired. That is what the measurement was created to do. As mentioned above it is a physiological measurement which has been shown to be a valid indicator of fatigue. The significant deterioration of the Vienna Test System scores might be more surprising. As can be seen from the results in table 3 fatigue on an average slowed down basic reactions by nearly 50 milliseconds, it deducted an average of nearly fifteen degrees from subjects useful field of vision, very significantly hindered their capability to split attention, made scanning and recognizing very unreliable and prevented our participants from successfully dealing with demands of functioning under external stress.

In order to find out if PUI values can predict the deterioration in driving related cognitive functioning we computed the correlations between the various Vienna Test System scores and PUI. The results are presented in table 4.

Table 4: Pearson correlations between Vienna Test System scores and PUI at eight measuring points

	RT	COG Wrong	COG Yes	PP UFOV	PP DEV	DT
R	0.53	.86	-.98	-.61	0.85	-.67
P<	.08	.003	.001	.054	.003	.034

As the data in table 4 show there are significant associations between the changes and deterioration of Vienna Test System tests over time and fatigue as measured by PUI. The connection between PUI and growth in reaction time only approaches significance but all other associations are clearly significant.

Discussion

This pilot study had two aims: The first aim was to document the adverse effects of fatigue on cognitive capabilities which are needed for safe driving. In spite of the small sample our data from the sleep deprivation study show clearly, that driving whilst being tired is very dangerous indeed. The results of our study indicate the a tired participant has slower reaction times, perceives and processes visual information in an unreliable manner, looses significantly on his useful field of vision and cannot reliably deal with external pressures. There is no way around it; driving when you are tired is dangerous. We cannot really compare the extent of the loss of capabilities to drunk driving or texting whilst driving for the simple reason that exact data on the other dangers is currently not available. There have been publications like from the government of South Australia which clearly claim: “Research has shown that not sleeping for more than 17 hours has an effect on driving ability the same as a Blood Alcohol Concentration (BAC) of 0.05. Not sleeping for 24 hours has the same effect of having a BAC of 0.10, double the legal limit". We cannot participate in this debate which might be more of educational than scientific value until replications with alcohol, fatigue and split attention tasks using the same dependent variables, e.g. Vienna Test System tests are available.

The second aim of this study was to see if PUI correlates significantly with cognitive outcomes of fatigue. Our results support this assumption. We suggest performing more studies to see if PUI is valid and reliable enough to be used in police enforcement of tired driving as blood tests or breathalyzors are in the battle against drunken driving today.

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