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SUBJECTIVE AND INDIRECT METHODS TO OBSERVE DRIVER'S DROWSINESS AND ALERTNESS: AN OVERVIEW

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Abstract

The measurement of drivers' workload has great interest these days due to the following reasons: high numbers of accidents seemingly ineradicable, very costly, and largely attributable to the human factor. The objective of this review is to assess the current status of fatigue performance and detection technology research and to identify any pertinent issues. Twenty-six relevant studies were identified and chosen from electronic databases, dating as far back as 1997. Fatigue, drowsiness, alertness, sleepiness, subjective, direct method and driver were the keyword search terms for this paper. Past studies demonstrated various purposes and implementation of subjective and indirect assessment among the driver for evaluating fatigue. It provides a better understanding for future researchers and industry to deal with fatigue issues among drivers. This review will provide a critical discussion on the designs used, discuss the findings in the search of directions for future studies, as well as provide insights into the use of counter measures for preventing fatigue-related accidents.

Keywords: Fatigue, Drowsiness, Alertness, Sleepiness, Subjective and Indirect Method, Driver.

Abbreviations

EEG	Electroencephalography
EOG	Electrooculography
SSS	Stanford Sleepiness Scale
KSS	Karolinska Sleepiness Scale
VAS	Visual Analogue Scale

1. Introduction

Distraction while driving can reduce the capacity to focus which in return can seriously impair driving performance. Fatigue is one of the identified internal source of driver distraction that can disrupt sustained attention over the driving duration [1]. According to Bartley [2], fatigue is an experience of tiredness, boredom, and unwillingness to continue. Fatigue can be measured by evaluating its effects based on numerous types of methods, such as on self-rated feelings, driver performance and changes in physiological state. Nevertheless, the best method to make fatigue assessment is still being debated [3].

2. Objective Methods Versus Subjective Methods

In order to evaluate human fatigue, there are many credible methods have been proposed, some based on objective methods while the others are based on subjective methods. Some researchers called objective methods as direct measures and subjective methods as indirect measures [4-6]. In most cases, objective methods are preferred because it provides more reliable reports with regards to the assessment conditions. Furthermore, it is often use to validate findings from subjective methods or indirect measures. However, it is quite time consuming, more expensive and place a higher degree of liability to the researchers when conducting the experiments with subjects [4]. Subjective methods may have some bias problems due to differences in perceptions and awareness among the respondents when recording the data. In addition, wrong interpretation of the questionnaires also may provide wrong data [3-4].

Nevertheless, there are other advantages for using the subjective methods. Subjective or indirect methods are far quicker, cheaper and simpler to use than objective or direct methods and they can be used repetitively with large numbers of respondents in the study [3-4]. For example, a subject's state of drowsiness can be measured objectively and continuously by monitoring the electroencephalography (EEG) and electrooculography (EOG). However, it requires the attachment of electrodes and not suitable for routine use in daily life. Therefore, nowadays, most research has combined the objective methods and subjective methods to get clear and in-depth observation on the studies. In addition, a few studies used different subjective methods to compare the results based on the observation. It was conducted either in the same circumstances or in the different circumstances.

The aim of the present study is to determine and compare subjective or indirect methods used to evaluate the driver's fatigue, drowsiness and alertness in the past studies. There are several well-established subjective measures, including Standford Sleepiness Scale (SSS), Karolinska Sleepiness Scale (KSS), Visual Analogue Scales (VAS), Response to individual questions about sleepiness, Sleep-Wake Activity Inventory, Adjective checklist, Samn-Perelli seven-point fatigue scale (SPS) and Epworth Sleepiness Scale (EPS) [3,7]. In addition, this paper will explains several commonly used methods for driving assessment purpose, including SSS, KSS, VAS, and checklist. In past studies, these subjective methods are usually combined together with objective methods with the intention to provide more accurate and reliable reports.

3. Methods

A list of English articles dating as far back as 1997 was compiled from Science Direct and Google Scholar. “Fatigue”, “drowsiness”, “alertness’, “sleepiness”, “subjective and indirect method”, and “driver” were the keyword search terms for this paper. In addition, a secondary search was performed by using bibliography of retrieved articles in order to support the first retrieved paper. Twenty-six relevant studies were identified and chosen from electronic databases, dating as far back as 1997.

4. Results and Discussion

Figure 1 shows a summary of fatigue evaluation from twenty-six past studies. In past studies, performance test is the popular subjective method used for evaluating fatigue. Based on Figure 1, there are three popular subjective methods to measure alertness/ drowsiness among drivers; standardised subjective fatigue or sleepiness, checklist, and performance test. Subjective scales are more demanding than filling in the checklist, but can usually be completed in a shorter time. Performance test is usually based on the response and behaviour of the respondents when conducting the experiments.

Referring to Figure 1, some past studies had used combination of several measuring scales and subjective methods to evaluate human fatigue. For example, Marsalek [8] had applied KSS, SPS, checklist, and performance test to be used in driving test to check the driver’s fitness in a transport company. In this test, the drivers used handheld computer that have been programmed with all these measuring scales and validated by simultaneous recordings of some objective methods, such as EEG and EOG. Meanwhile, another study conducted by Philip et al. [9] had used ESS and questionnaire as subjective methods to identify risk factors of performance decrement among automobile drivers. Respondents were required to fill out a set of questionnaire about their journey, sleep/wake patterns and performed a 30 minutes test on a driving simulator.

Some past studies used only one subjective method to assess human fatigue. For instance, Jiao et al [10] had used self-reporting method after the simulated task in their study. In their questionnaire, subjective fatigue symptoms have been provided to evaluate respondents’ fatigue condition.

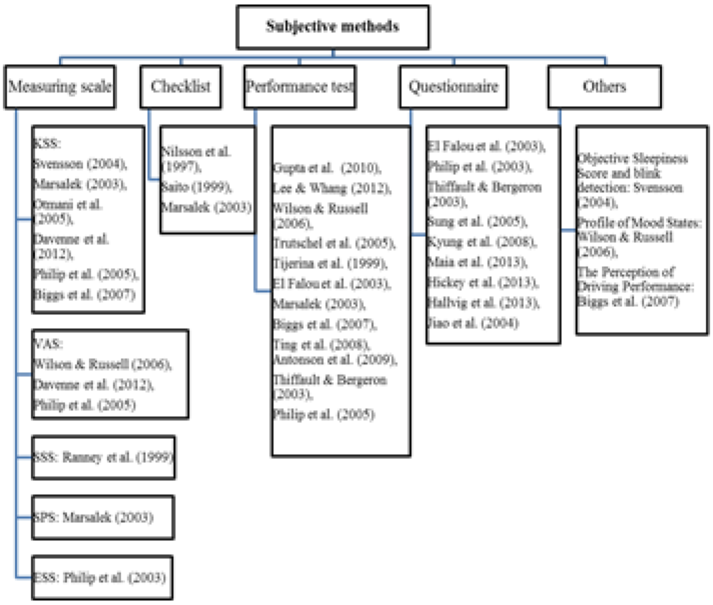

Fig 1. Summary of past studied related to subjective methods

4.1. Standardised Subjective Fatigue or Sleepiness

Based on Figure 1, there are five standardised and well developed subjective fatigue or sleepiness methods to study human fatigue or sleepiness. There are SSS, KSS, VAS, SPS and EPS. Details of each measuring scale will be presented as follows.

4.1.1. Stanford Sleepiness Scale (SSS)

SSS was developed by scientists at Stanford University in 1973 to measure the level of alertness. The respondent is required to choose which conditions based on seven statements (Figure 2) that describe his/her feelings and alertness level at the time (Johns 2014). The scale is a self-administered, paper-and-pencil measure requiring one to two minutes to complete (Shahid et al 2012b). Generally, the purposes of SSS are to study the effects of sleep deprivation, sleep fragmentation and circadian rhythms (Stepanski 2002; Monk et al. 1983).

Stanford Sleepiness Scale

Using the scale below, indicate the single number that best describes your level of alertness or sleepiness at each time:

1: Feeling active, vital, alert, and wide awake.

2: Functioning at a high level but not at peak performance. Able to concentrate.

3: Relaxed and awake, but not fully alert. Still responsive.

4: Feeling a little foggy and let down.

5: Foggy and beginning to lose track of things. Difficult to stay awake.

6: Sleepy and prefer to lie down. Woozy.

7: Almost in reverie and cannot stay awake. Sleep onset is imminent.

9.30 am: ___ , 11.30 am: ___ , 1.30 pm: ___

3.30 pm: ___ , 5.30 pm: _____ , 7.30 pm: ___

9.30 pm: ___

Fig.2. Stanford Sleepiness Scale

4.1.2. Karolinska Sleepiness Scale (KSS)

KSS is one of the popular self -report measure that is usually used to study the driver's focus and performance while driving, shift work, jetlag and in clinical setting (Shahid et al 2012b; Kecklund & Akerstedt 1993). It is helpful in evaluating the changes in response to environmental factors, circadian rhythm, and effects of drugs (Shahid et al 2012a). This is a 9-point scale (1 = extremely alert, 2=very alert, 3 = alert, 4=rather alert, 5 = neither alert nor sleepy, 6=some signs of sleepiness, 7 = sleepy, but no difficulty remaining awake, 8=sleepy but some difficulty to keep awake, and 9 = extremely sleepy, great difficulty to keep awake, fighting sleep). There is a modified version of KSS that contains one other item: 10 = extremely sleepy, falls asleep all the time. Scores on the KSS increase with longer periods of wakefulness and it strongly correlate with the time of the day (Shahid et al 2012b). When the KSS was used with EEG or EOG, the changes observed in this equipment with drowsiness do not usually appear until KSS scores reach more than seven point (Gillberg et al 1994).

4.1.3. Visual Analogues Scales (VAS)

VAS is an instrument to measure a characteristic or attitude that is believed to range across a continuum of values and cannot easily be directly measured (Wewers & Lowe 1990). Operationally, VAS is a horizontal line 100 mm long across a page, anchored by word descriptors at each end. The respondent required to put the mark that represents his state along the continuum. According to Babkoff et al (1991), VAS is better compared to SSS. It has been used to rate pain intensity in experimental studies (Gebhart & Schmidt 2013). The benefit of using VAS is due to its simplicity and sensitive to small changes. However, the drawbacks of this scale are the points along the line are not defined and comparison with other studies is difficult (Millar, 2012).

4.1.4. Samn-Perelli Seven-point Fatigue Scale (SPS)

The SPS was used to evaluate levels of fatigue. It consists of seven numbered descriptors, ranging from 1=fully alert, wide awake to 7=complete exhausted, unable to function (Short et al 2013). The Samn-Perelli scale is standardised and has been used mainly in aviation industry for many years (Marsalek, 2003).

4.1.5. Epworth Sleepiness Scale (ESS)

The ESS is a simple tool to assess the likelihood of falling asleep during the day in contrast to just feeling tired (Johns, 1991). ESS is a self-administered eight item questionnaire that is summed to give an overall score of daytime sleepiness (Wright & Lack 2014; Pilcher et al. 2003). It is widely employed in sleep research and clinical practice and has been translated into 52 languages (Buyssee et al 2008).

4.2. Checklist

Checklist is another well-known tools used in fatigue and sleepiness study. Many past studies used this methods to identify feelings and symptoms related to presence of drowsiness or fatigue at particular time. Nilsson et al. (1997), for instance, developed Fatigue Checklist to determine alertness level in their study. Another example is Marsalek (2003), developed a fit-for-driving checklist, which is a form that documenting facts relevant to driver's fatigue. Another study conducted by Saito (1999) provide subjective feeling checklist that is suitable to evaluate fatigue. The checklist provides 30 feelings of fatigue and categorises into five main desctiptors, which are dull drowsy, exhausted, mental decline of working motivation, specific feeling of incongruity in the body and dysfunction of autonomic nervous systems.

Shapiro et al. (2002) had developed FACES Adjective Checklist in his study. FACES is acronym for Fatigue, Anergy, Consciousness, Energy and Sleepiness is another prominent adjectival checklist to distinguish tiredness, sleepiness and fatigue. The scale has been validated with a population of insomnia patients with a mean age of 43.5 ± 13.9 years (Shapiro et al. 2002). Figure 3 shows FACES checklist.

FACES ADJECTIVE CHECKLIST

Below is a list of words that describe feelings people have. Please read each one carefully. Then circle the ONE number corresponding to the adjective phrase that best describes **HOW YOU HAVE BEEN FEELING DURING THE PAST WEEK INCLUDING TODAY**. If you are unfamiliar with any of the words, please circle the question mark (?) to the right of the rating scale. The numbers refer to the following descriptive phrases:

1.	Fatigued	0	1	2	3	4	?		26.	Comatose	0	1	2	3	4	?
2.	Worn-out	0	1	2	3	4	?		27.	Unconscious	0	1	2	3	4	?
3.	Exhausted	0	1	2	3	4	?		28.	Dormant	0	1	2	3	4	?
4.	Wacked-out	0	1	2	3	4	?		29.	Bombed	0	1	2	3	4	?
5.	Drained	0	1	2	3	4	?		30.	Blurry-eyed	0	1	2	3	4	?
6.	Pooped	0	1	2	3	4	?		31.	Vigorous	0	1	2	3	4	?
7.	Overtired	0	1	2	3	4	?		32.	Full of pep	0	1	2	3	4	?
8.	Weary	0	1	2	3	4	?		33.	Lively	0	1	2	3	4	?
9.	Tired	0	1	2	3	4	?		34.	Charged-up	0	1	2	3	4	?
10.	Spent	0	1	2	3	4	?		35.	Wide-eyed	0	1	2	3	4	?
11.	Bushed	0	1	2	3	4	?		36.	Energetic	0	1	2	3	4	?
12.	Out of Steam	0	1	2	3	4	?		37.	Carefree	0	1	2	3	4	?
13.	Frazzled	0	1	2	3	4	?		38.	Active	0	1	2	3	4	?
14.	Limited Endurance	0	1	2	3	4	?		39.	Cheerful	0	1	2	3	4	?
15.	Achy Muscles	0	1	2	3	4	?		40.	Alert	0	1	2	3	4	?
16.	Indolent	0	1	2	3	4	?		41.	Snoozy	0	1	2	3	4	?
17.	Languid	0	1	2	3	4	?		42.	Sleepy	0	1	2	3	4	?
18.	Soporific	0	1	2	3	4	?		43.	Drowsy	0	1	2	3	4	?
19.	Lassitude	0	1	2	3	4	?		44.	Slumber	0	1	2	3	4	?
20.	Supine	0	1	2	3	4	?		45.	Heavy-eyed	0	1	2	3	4	?
21.	Accidie	0	1	2	3	4	?		46.	Half-Awake	0	1	2	3	4	?
22.	Phlegmatic	0	1	2	3	4	?		47.	Sluggish	0	1	2	3	4	?
23.	Line of Least Resistance	0	1	2	3	4	?		48.	Yawning	0	1	2	3	4	?
24.	Jaded	0	1	2	3	4	?		49.	Dozy	0	1	2	3	4	?
25.	Apathetic	0	1	2	3	4	?		50.	Somnambulant	0	1	2	3	4	?

Fig. 2. FACES checklist (Source: Shahid et al., 2012a)

4.3. Performance test

Marsalek (2003) measures the response time to the occurrence of a visual signal. The respondent should react as quickly as possible to any signs as mentioned earlier before experiment that appears on the screen. The measure of the test is the average distance of the cursor from the middle of the screen and the number of so called "control losses" when the cursor reaches the edge of the screen. However, the drawback of this experimental method is the duration of the tests is quite long in order to obtain a better reflection of the driver's fatigue.

Gupta et al., (2010) had performed a study by applying three methods: Visual Response Test (VRT), Auditory Vigilance Test (AVT), facial image & EEG. For AVT, the respondent has to respond to auditory instruction-random sound stimuli & press keys. Trutschel et al. (2011) and Williamson & Chamberlain (2005) had performed a study that used PERCLOS concept. PERCLOS is a video-based method of measuring slow eye closure using trained observers to make judgements of eye closure from moment to moment. It is evaluated against performance measures of lapses in attention using the Psychomotor Vigilance test (PVT). There are reasonable correlations between eye closure and lapses.

5. Conclusions

Based on this review, there has been numerous research performed by researchers in human fatigue management field. This field is still preserve because it is related to the health and safety of the people when performing their daily task either in shift work, driving and etc. Understanding the psychology of fatigue may lead to better fatigue management. In addition, evaluation of human fatigue, drowsiness and alertness is very important.

Furthermore, in this paper, relevant literature related to subjective or indirect methods used for evaluating fatigue has been explored. There are many advantages of subjective scales such as quick and easy to administer, can perform either paper-based or computer-based, and have minimal disruption to the respondent because they do not need to attach equipment on the respondent.

Even though subjective methods are known as simple tool to detect human fatigue, however, it is better to combine this method with objective method to validate the study. For example, in the past, KSS is normally validated with EEG or EOG to evaluate human fatigue. The combination of human fatigue methods can help to provide better and reliable results. Overall, this review has discussed the directions for future studies and for the development of fatigue counter measures.

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