2008-5435/14/63-124-128
INTERNATIONAL JOURNAL OF OCCUPATIONAL HYGIENE

IJOH 8: 124-128, 2016

ORIGINAL ARTICLE

Comparison of Two Instrumental Assessment of Mental Fatigue

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Received May 17, 2016; Revised May 27, 2016; Accepted July 13, 2016

This paper is available on-line at *http://ijoh.tums.ac.ir*

ABSTRACT

Mental fatigue (MF) is considered as a contributor factor in incident, even catastrophic one. Electroencephalography measurement has been the most acceptable method to assess MF by neurologists. However, this method could be hardly feasible in real work setting. Flicker fusion device, by contrast, is more usable at work setting. The purpose of this study was to compare the Critical Flicker Fusion Frequency (CFFF) with Electroencephalograph (EEG) alpha band changes (as indicators of mental fatigue). The study took place in Zanjan (2015) and the participants included 35 volunteer students that passed a three-step experiment protocol: 1) Measuring MF via CFFF and EEGα, 2) Involving the participants with MF-induced tasks, and 3) Re-measuring MF via the same methods. The results showed that differences of MF assessment by EEG (P= 0.001), and CFFF (P= 0.004) were significant. However, the correlation between them was weak (-0.069) and not significant (P= 0.688). The findings of this study confirmed that the flicker fusion apparatus could measure MF as a before-after test. However, the results of CFFF were not correspondence with the results EEGα. Therefore, more studies need to get conclusion about how the results of these instruments may related to each other. Considering other regions or waves of the brain might be promising.

KEYWORDS: *Mental fatigue, Flicker fusion, EEG*

INTRODUCTION

By entering the third millennium, nature of work has increasingly changed largely from physical or skilled labor, to mental effort [1-2]. Continuous mental effort results in mental fatigue (MF), which has been more and more considered as a factor with great influence on task performance and analytic information processing. Today, MF has been known as a strong putative cause of accident via enhancing human error [1, 3].

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In other words, involving in a mental task for a considerable time is being ascribed to bring about a sequence of chain that initiates with vigilance and arousal decrement, drowsiness and sleepiness enhancement; and continues to attentional capacity reduction, human error increment, and performance deterioration; and may finalize in a catastrophic event.

MF is a psychological phenomenon in nature [4]. However, directly measuring MF needs to understand its physiological characteristics. As there is few knowledge on this issue, the

assessment has been widely established on measuring its symptoms and consequences [5]. The symptoms and consequences of MF, like other psychophysiological conditions, can be exhibited on subjective and objective manifestations [3]. Nonetheless, a trend towards objective measures is appreciated in ergonomic research [6]. This trend has introduced a couple of methods to MF measurement, including: cerebral cortical activity level as EEG, channel capacity or perceptual threshold such as flicker fusion frequency, biochemical variables relevant to metabolic changes or to endocrine regulation, motor skills and others [5]. It seems, however, electroencephalography (EEG) measurement is the most acceptable one and is applied in an extensive domain from a clinical patient fatigue viewpoint to work-induced MF in taxi drivers or ATC controllers [7-9].

However, using EEG is hardly feasible for a real work-setting [10]. A more hopeful apparatus can be flicker fusion device. A century ago, flicker fusion used as a visual perception Index [11]. Five decades later, Colgan (1954) showed the relation between critical flicker frequency and several psychological variable in his dissertation [12]. Then, this apparatus, as a flicker meter, has been used to determine critical flicker fusion frequency (CFFF) and was defined the level of individual sensitivity at the beginning and at the end of light flickering, caused by changes in the frequency of light flashes. Todays, it is accepted that the CFFF level is an indicator of the effect of an activation (arousal) level [13]. Therefore, the changes of CFFF before and after doing a task can show the changes of arousal level of an operator and at the same time implies the mental activation requirements for that specific task. To simplify the assessment of MF at work, flicker fusion apparatus are being increasingly applied [14]. However, there is little research on comparison the result of CFFF with EEG changes. Comparison of the changes of CFFF with EEG alteration may help to understand more about how CFFF measurement should be relayed on a real work setting.

The MF studies based on EEG are mostly considered alpha band. The underlying reason is the relationship between such alterations with drowsiness. In addition, drowsiness, as well as, sleepiness is assumed because of prolonged mental task.

Since, it has been approved for a long time that taking valium can make significant changes on CFFF [15], it would be logic to assume that the results of CFFF is in accordance with EEGα alterations. The purpose of the present study was to test this hypothesis.

MATERIALS AND METHODS

A before-after experiment performed to determine whether the results of CFFF on MF are in accordance with the EEGα alterations. The protocol of the study was approved by the Ethics Committee of Zanjan University of Medical Sciences, Zanjan -2015, Iran.

The participants included 35 (20 females, 15 males) volunteer students who gave written informed consent. They were all healthy, with normal visual acuity or corrected less than 2 for astigmatism cases. No one was under medical treatment or suffering from color blindness. They were also requested to avoid drink or eat caffeine or theine -containing beverages, at least 12 h before taking part in the experiment. Cell phone use was prohibited during the experiment to prevent any interruption. The study carried out in Dr. Ghorieishi Psychiatric Clinic, which is a private one, with enough rooms, in the morning when there was no visitor or patient. Therefore, a quiet environment was provided for the experiment. Besides, to avoid seasonal rhythm [13], all the tests were completed in two weeks.

The experiment consisted three consequent phases, as followed (Fig.1.):

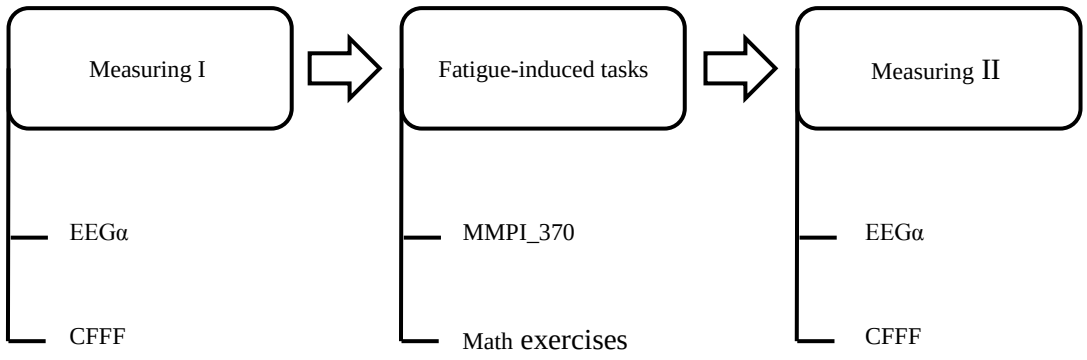

Fig.1. Experimental design

Published online: September 25, 2016

Phase 1: Measuring MF via CFFF and EEG: Two methods were used to measure MF by two different operators. In all cases, flicker fusion test followed by EEG. EEG activity was recorded based on Russian EEG equipment (Mitsar, Ltd.) with 21-channel montage and using American electrocaps. Alpha waves measured for closed-eyes participants. A monopolar montage of occipital channels in $O_1 - A_2$ and $O_2 - A_2$ were applied, as the following traits:

- Low cut: 0.3 Hz
- High cut: 30 Hz
- Notch: 45.55 Hz
- Gain: 150 μV

Alpha waves were counted for three seconds and divided by three. The Data were analyzed offline by a blinded neurologist.

The flicker fusion apparatus was made as Shankar and et.al described [16], under support of Zanjan University of Medical Sciences. The device consists of two main parts. The first part is a red LED lamp which is embedded in the center of a standing 50 × 50 centimeter white Plywood. The second part is a programmed electronic circuit, which provides the possibility of flickering for the lamp in a few seconds based on the examiner initial setting. The flickering frequency and the duration time between two sequential frequencies are shown on the LCD of this part.

Phase 2: Performing fatigue-induced tasks by the participants, which included:

- Answering computerized MMPI_370 questionnaire, which is a long-lasting and boring test because of 370 questions. Since the participants were enthusiastic about knowing their personal characteristics, we awarded them a psychiatric check of the result of MMPI; as a motivator to real answering.
- Calculating computerized math exercises, which consists of a successive series math calculation (using four basic operations), which was lasting for 20 min. To encourage participants to avoid arbitrary answering, they were awarded for extra mark in one of their courses based on the percent of correct calculation.

Phase 3: Re-measuring MF via the same instruments: Finally, the data correlation (bivariate) test was used to analysis the result at the acceptance level of .05 in SPSS 11 (Chicago, IL, USA).

RESULTS

Thirty five volunteer students took part with overall mean age of 21.7 yr (±1.96 SD), (Table 1).

The differences of MF assessment by EEG (P= .001), and CFFF (P= 0.004) were significant before and after doing the tests (Table 2). Yet, the correlation between two instrument was weak (-0.069) and not significant (P= 0.688).

To find out the possible effect of gender, the results were separately analyzed for female and male participants. Although it seemed a little difference between two groups (Tables 3), it was not significant (r=0.09, P= 0.72).

Table 1. The mean age of participants

Descriptive Statistics					
Gender	**N**	**Age (yr)**			
		Minimum	Maximum	Mean	SD
Female	20	19.70	24.70	20.97	1.17
Male	15	19.70	27.70	22.67	2.47

Table 2. Changes and mean values before-after tests and correlation between the results

Instruments		**Min**	**Max**	**Mean**	**SD**	**Mean differences**	**SD**	P_{value}	**Correlation**
EEG-α	Before	9.00	18.50	10.50	1.60	1.10	1.80	.001	-0.069
(Hz)	After	6.00	12.00	9.50	1.20				(0.688)
CFFF	Before	22.30	38.00	32.70	3.40	2.30	4.50	.004	
(Hz)	After	13.30	39.30	30.40	5.30				

Table 3. Changes and mean values before- after tests and correlation between the results by gender

Instruments Female		**Min**	**Max**	**Mean**	**SD**	**Mean differences**	**SD**	P_{value}	**Correlation** (P_{value})
EEG-α	Before	9.00	18.50	10.85	2.09	1.15	2.21	0.010	0.090
	After	8.00	12.00	9.78	1.08				(0.720)
CFFF	Before	23.67	37.00	32.75	3.16	1.72	4.13	0.080	
	After	19.67	39.33	31.03	4.40				

DISCUSSION

To conduct this study we used alpha waves of occipital region of the brain, because these waves have been widely accepted as an indicator of sleepiness; and sleepiness is the extreme state of MF. It implies that we considered MF equal to sleepiness. Whereas, there is a possibility that gentle states of MF can manifest in other regions or by other waves of the brain. Therefore, the comparison of MF assessment based on CFF and EEG of other regions/waves of the

brain remains for further research. Also, one may use more difficult task to induce drowsiness and sleepiness.

CONCLUSION

This study was aimed to determine the consistency of mental fatigue measurement by EEG and the flicker fusion apparatus. The data could not show an acceptable correlation value (r= -.069), or at least significant (P= .688) (Table 2). Gender sensitivity (r=0.09, P= 0.72) was not accepted, either (Table 3).

Then, it should be concluded that the results of measuring MF via CFFF is not consistent with the results of EEG. It means that in spite of the ability of both device to detect MF, they measure different parameters.

In this study, we assessed alpha waves in occipital region. However, we don't know about the other regions or waves. Chaudhuri & Behan (2004) discussed that cognitive fatigue represents a failure to sustain attention [18]. Attention network theory suggests that attention is not a unidimensional phenomenon; and contrast at least three separate systems or networks: alerting, orienting, and executive control. Each of these systems has been associated with different of brain regions [19]. Thus, it seems to have a better understanding of CFFF ability of measuring MF, we should examine the consistency of the result with EEG of other regions/waves of the brain.

CFF method could be an indicator of rising and falling of central nervous system activation [20]. The findings of this study can confirm that the flicker fusion apparatus, which was made in Zanjan University of Medical Sciences, is able to measure MF as a before-after test (Fig.2.). This finding stand as strong evidence that shows the advantage of this device in regard to compare the difficulty level of two tasks, esp. for complicated tasks which can't be judged about their workload level.

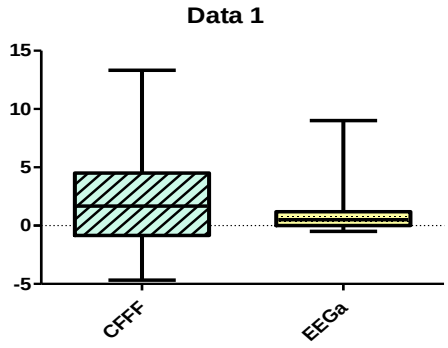

Fig.2. Comparison MF assessment via EEG and CFFF

ACKNOWLEDGMENTS

The authors are pursuing this research as part of the project A-11-56-7 and acknowledge the financial support of Zanjan University of Medical Sciences. There is no conflict of interests in this article.

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Published online: September 25, 2016