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Real-Time Neurocognitive Monitoring of Executive Functioning Tasks with and without Gamification Using Emotiv Insight

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Abstract

Objective: The present study aimed to compare the levels of executive functions in the gamified and non-gamified task using emotiv insight in a group of students.

Methods: A cross-sectional study was conducted on 60 participants. Data was collected by placing the Emotiv headset on the participant's heads and they were instructed to perform the gamified (Trail making test) and non-gamified task (scrabble). The task took approximately 1-2 minutes. For each task, results were obtained on the Emotiv Insight mobile application in the form of six performance indices: percentages for stress, excitement, focus, engagement, interest, and relaxation. Scores were compared for both tasks.

Results: The study findings indicated that there is no significant difference in percentages of stress, focus, excitement, engagement, and relaxation among students, who completed both gamified (Scrabble) and non-gamified (TMT) tasks, but there is a significant difference in percentages of interest among students who completed both gamified (Scrabble) and non-gamified (TMT) tasks.

Conclusion: Performance metrics (stress, focus, engagement, excitement, and relaxation) are at the same level in both gamified and non-gamified tasks. However, the interest level was increased while performing non-gamified tasks rather than doing gamified tasks.

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Introduction

The solicits of neurocognitive science are to assimilate how behavior and thought are correlated with brain structure and function [1]. Neurocognition is the intelligent processing unit that manifests as the intellectual action of achieving and interpreting the knowledge related to fluid intelligence and contemplation [2]. Cognitive processes undergo various alterations during mortal evolution and its learning phases [3]. In a recent study, the cognitive domain of the Revised Bloom taxonomy model was used to better understand the cognitive processes. The cognitive domain is further divided into six cardinal cognitive sub domains, each of which encompasses interdependent complicated activities and cognitive processes by starting or inhibiting basic voluntary actions that focus on problem-solving and sophisticated understanding [4].

Executive functions are a subset of cognitive processes that allow a person to participate in goal-setting, self-monitoring, control, inhibition, direction, purposeful action, and mental flexibility [5]. They are controlled by the frontal lobe of the brain and play a significant role in determining students' academic success and fluid intelligence [6]. Students with executive dysfunction have difficulty in planning, organizing, evaluating, and completing tasks. Therefore, the initial recognition of executive functions following the progression of their cognitive processes or executive dysfunction is vital for intellectual growth and development.

There is no established solitary gold standard neuropsychological test or tasks that are used for the assessment of several characteristics of executive function. As a result, the executive function may be examined using a variety of methods, including records review, observations, behavior checklists, interviews, and various types of questionnaires (e.g., video game-experience questionnaires, questionnaires on subject feelings, and so on) [7]. Previous research has demonstrated that including game dynamics into cognitive assessments as a measure of students' executive skills might boost interest and involvement [8].

The Trail Making Test (TMT), (non-gamified cognitive assessment task) is widely used in neuropsychological practice due to its high sensitivity in diagnosing cognitive impairments. It is a component of various test batteries like the CERAD-NP or the Delis–Kaplan Executive Function System. The Trail-Making test also measures executive function, working memory, visuospatial ordering, visuoperceptual skills, and secondarily task-switching ability. The ratio between TMT A and B is an excellent indicator of cognitive flexibility [9].

Gamified tasks have been demonstrated to be effective in improving cognitive ability, response time, and self-esteem in both healthy and cognitively impaired individuals, such as Alzheimer's patients [8]. These cognitive gamified tasks can be time-consuming and repetitions lead to the participation disengagement among students which negatively impact the quality of data being collected and can alter the interventional effects for prospective studies [10]. Games such as scrabble, card shuffling, and others appear to improve working memory, attention, problem-solving, motivation, and emotional control.

Since scrabble is a game that primarily activates executive functions of the brain [11], we employed it as a gamified task in our study to investigate executive function status while utilizing Emotiv insight. Emotiv Insight is wireless 5-channel mobile or portable EEG headset or gadget that detects and records the activity of the Frontal, Parieto-temporal, and Parieto-occipital lobe in the form of brain waves [12,13]. The recorded brainwaves are amplified and digitized before being sent to a cloud database on a cell phone or computer (software that enables real-time EEG analysis). On a cell phone or computer, the Emotiv headset's findings were calculated as percentages for performance measures (stress, excitement, focus, engagement, interest, and relaxation) [14].

Previous research had several limitations, such as a generic evaluation of cognitive processes, only addressing one or a few performance criteria (stress, interest and engagement, etc) [15], investigating the impact of a variety of video games on EFs, including real-time strategy games, commercial brain training games, and board games, as well as relating other factors such as physical activity, motor abilities, academic accomplishment, social-emotional or behavioral performance, and so on [16]. The majority of previous investigations focused on people who had a history or diagnosis of a variety of physical, mental, neurological, and developmental diseases, such as excess saturated fat, schizophrenia, sleeplessness, cerebrovascular disease, and Tourette's syndrome, while only a few were evaluated Executive functions before or after the specific activity [7]. However, the empirical evidence on gamification is relatively cross-disciplinary, heterogeneous, and unclear. The potential of comparison between the efficacy of gamified and non-gamified tasks is to be realized. Therefore, we are using the 5 channel emotiv insight in this research to recognize the real-time neurocognitive executive function status while undertaking gamified and non-gamified tasks.

According to a review of the literature, no prior research has used emotiv insight to undertake real-time neurocognitive monitoring of executive functions using gamified and non-gamified tasks in a cross-sectional comparative study. The aim of carrying out this study was to compare the levels of executive functions in the gamified task and non-gamified task using emotiv insight among physical therapy students as there is supporting evidence on both, though it is uncertain that which one of the two tasks is more effective in the monitoring of executive functions. This study will aid students in self-assessing their poor executive functioning abilities and then improving them through a variety of therapies, while institutes will be able to predict their students' executive functioning in the future without relying on the gold standard EEG due to practical concerns. Instead, Emotiv insight will be used, which does not require the presence of an expert. The interpretation and training of students' cognitive abilities can help them enhance their academic performance.

Materials and Methods

Ethical approval was attained from the Research Committee of Foundation university institute of rehabilitation sciences in the directive of conducting the following study. A comparative cross-sectional study was held and performed in Foundation university institute of rehabilitation Sciences for 6 months (February 11, 2019, to July 5, 2019). Keeping specific vetting criteria and consecutive sampling in mind, 60 participants were included in this study. The participants were enrolled in the study on a voluntary basis according to the following criteria: (Inclusion criteria: Undergraduate students and Age 18 to 26; Exclusion criteria: Visual impairment and history of acute traumatic head injury). In this study, Portable EEG device-Emotiv insight was used as an outcome measurement tool for evaluating performance metrics (focus, interest, engagement & stress levels of a person) while Trail making test (TMT A & TMT B) was

being used as a non-gamified Task and Scrabble game was being used as a gamified task. The accuracy of Emotiv insight is 94.4% as an EEG-based human recognition [17] while the reliability of TMT A is .83 & TMT B is .90 [18]. Before gathering data-informed consent was signed from all candidates and was adequately guided to the procedures of the study. The same and constant environment was provided to all of the members without noise and with proper lighting as needed. Before the placement of the Emotiv headset, the procedure was described to participants along with the gamified (scrabbles) and non-gamified (TMT) tasks and the information recommended by Emotiv about EEG recording and insight system. The headset was placed such that frontal sensors were three fingers width above the forehead, one on the parietal lobe, one on the occipital lobe and the reference sensor was placed behind the ear. To ensure maximum connectivity sensors were attached to bare skin directly or indirectly with the help of conductive gel or saline solution (to enhance conduction). The device was connected via Bluetooth with the mobile application My Emotiv. Relaxation time was observed with eyes open then closed for 15 seconds to get the baseline readings. Participants were then instructed to perform TMT –A and TMT-B which took 1-2 minutes on average and the results of the Emotiv headset showing on android were noted in percentages for stress, excitement, focus, engagement, interest, and relaxation. Candidates were then instructed to play a scrabble game (gamified task) for up to 3 minutes and the values for the six performance indices were again noted in percentages. Next, both the scores of TMT and scrabble game were compared.

Results

Data were analyzed with the help of SPSS 21. **Table 1** signifies the normal distribution of demographics (age, gender, marital status and dominant side). The normal distribution of performance metrics (stress, focus, interest, engagement, excitement and relaxation) through the normality test (Kolmogorov-Smirnov Test) is shown in **Table 2** which indicates homogeneity. The normality test illustrates that the data is normally distributed only in two out of six performance metrics (i.e. relaxation and excitement). Since the data for relaxation and excitement were normally distributed as expressed in table 2 below, the paired sample T-test (parametric test) was used to measure the mean score difference among performance metrics (i.e. relaxation and excitement) of students with the gamified and non-gamified task. On the other hand, as seen in table 2, the data for stress, focus, engagement, and interest was not normally distributed, the related Sample Wilcoxon Signed Test (non-parametric test) was used to measure the median score difference between performance metrics (stress, focus, engagement and interest) of students with the gamified and non-gamified task. As illustrated in **table 3** (paired sample T-test) and **table 4** (related Sample Wilcoxon Signed Test), the analysis revealed that no significant differences were found in the real-time executive functions assessment of stress, focus, excitement, engagement and relaxation of students for both gamified (Scrabble) and non-gamified tasks (TMT) as p-value was > 0.05 while in the real-time executive function assessment of interest of students, a significant difference was found between both tasks as p-value was < 0.05.

Table 1: Distribution of demographics.

VARIABLE	RESULT
Age (Mean ± SD) (years)	21.38 ± 1.668
Gender [n (%)]	
Male	16(26.7)
Female	44(73.3)
Marital Status [n (%)]	
Married	1(1.7)
Unmarried	59(98.3)
Dominant side [n (%)]	
Right	57(95)
Left	3(5)

Table 2: Test of normality for quantitative variables.

Performance metrics	Gamified task (Scrabble)	Non-gamified task (TMT)
Stress	0.200	0.040*
Focus	0.000*	0.011*
Interest	0.016*	0.000*
Engagement	0.200	0.003*
Excitement	0.200	0.200
Relaxation	0.200	0.074

* P Value >0.05 Statistically significant difference

Table 3: Comparison of Excitement and relaxation.

Performance metrics	Gamified task (Scrabble)	Non-gamified task (TMT)	P value
	Mean ± S.D		
Excitement	46.70 ± 12.399	47.12 ± 9.138	0.809
Relaxation	47.58 ± 14.499	47.30 ± 12.833	0.772

Table 4: Comparison of other performance metrics of gamified and non- gamified task.

Performance metrics	Gamified task (Scrabble) Median (IQ)	Non-gamified task (TMT) Median (IQ)	P value
Stress	39 (10)	41 (7.5)	0.515
Focus	32.5 (11.75)	34 (9)	0.412
Engagement	56.5 (11.75)	58 (9.75)	0.600
Interest	54 (12)	57 (11.5)	0.015*

* Statistically Significant Difference

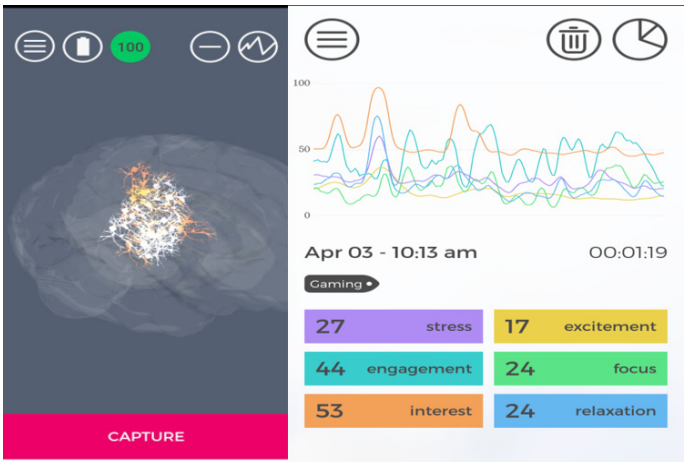
Discussion

Stress

Stress of both gamified and non-gamified tasks is at the same level as the P-value for each task was > 0.05. On contrary to the results of our study, a study carried out by (Carmen V. Russoniello et al) in 2009 showed that stress levels decrease while playing board games such as scrabble, chess, etc. In this study perceived stress scale was used to access the stress level in the older age population and the sample size was 204 [19].

Focus and Engagement

Focus and Engagement of both gamified and non-gamified tasks are at the same level as the P-value for each task was >



Emotiv findings for performance metrics (stress, excitement, focus, engagement, interest, and relaxation)

Figure 1: Data collection via emotiv insight.

0.05. On contrary to the results of our study, research (Suwanviwatana Kananat) published in 2016 with a sample size of 250 demonstrated that an individual focuses more and the mind is more engaged while playing games such as monopoly rather than doing non-gamified tasks. In this study, mental focus scale was used to access the focus level while a discrete emotion questionnaire was used to assess the engagement level in high school students [20].

Excitement and Relaxation

Excitement and Relaxation of both gamified and non-gamified tasks are at the same level as the P-value for each task was > 0.05. However, the same author (Suwanviwatana Kananat) conducted a study in 2018 that emphasized the point that gamified tasks such as monopoly improve mood, increase levels of excitement and relaxation in the young population. In this study cognitive tension scale was used to assess the relaxation level in healthy young adults and the sample size was 196 [21].

Interest

The result of our study reveals that interest is more while doing non-gamified tasks as compared to gamified tasks and a significant difference was found between both tasks as the p-value was < 0.05. On contrary to the results of our study, a study done by (Turkankarakus) in 2008 suggested that the interest level of high school students was more while playing board games such as monopoly, scrabble [22].

Limitation and Recommendation

The limitations of our study were the lack of generalizability of Emotiv data due to limited sensors specifying particular areas of the scalp. A busy clinical setup was used to collect data. Lack of gold standard EEG (Electroencephalography) and experts to interpret EEG waveform was faced due to unavailability of resources was another limitation of this study. The headset has a regular size that does not fit well on all individuals which further reduces the sample size. Since our study sample includes people between the ages of 18 to 26 and majority of our study sample consists of female candidates from a single, large university setting in Islamabad. Therefore, results may not generalize to all young adults from other educational institutions or districts. Further future studies of a larger sample size with more duration from a diverse academic group is recommended. To avoid external artifacts, a sound study setting is recommended. For increasing motivation, decreasing anxiety, increasing engagement, focus, and performance activity gamified tasks should be included in cognitive sciences. Repetitive performance of gamified tasks focusing cognitive domain will consequently increase cognition that will improve the academic and social performances of students.

Conclusion

Stress, focus, engagement, excitement, and relaxation are at the same level in both gamified and non-gamified tasks. However, the interest level is increased while performing non-gamified tasks rather than performing gamified tasks.

Ethical Approvals

Official permission was attained from the Research Committee of Foundation university institute of rehabilitation sciences in the directive of conducting the following study. Proper informed consent was received from all of the participants.

Conflict of interest and source of funding

None to declare

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