Game Design for Pre-screening Patients with Mental Health Complications Using ICT Tools

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Abstract. Mental health disorders are significant contributors to the global burden of diseases. Conventional approach to mental health screening involves administration of specially designed questionnaires and tests by mental health professionals. In the current global scenario where adequate mental health professionals are not available, video-games can serve as an important aid for mental health screening. This paper discusses a framework for designing games for cognitive assessment and using the ubiquitous nature of computing to serve as a platform for mental health screening. Neuropsychological tests can be embedded within the game structure for cognitive assessment. To establish the viability of this concept a pilot study was carried out. A game was developed with an aim to assess the player's stress levels. Stress affects working memory and attention span. The prison game implements the Digit Span test for attention span and working memory assessment. The validity of such a game is demonstrated through an experiment. The results of the experiment analysis indicate that the short term stress experienced by the players can be successfully predicted based on the performance in the cognitive game.

Keywords: mental health, stress, video games, neurocognitive assessment, EEG, PCA.

1 Introduction

Mental health is an integral part of every individual's fitness. WHO defines Mental Health as not just the absence of mental disorder but as a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community. But despite being such an important aspect of health, mental health scenario has been in a dismal state for many decades the world over. The awareness about the prevalence of the mental/cognitive disorders and its treatment is negligible. It goes undiagnosed in most cases. About 76-85 % of people with severe mental disorders receive no treatment for their health problems in low and middle income countries while in high income countries the range is 35-50%.

Although there have not been many conclusive epidemiological studies, psychiatrists estimate that in India around 7 % of the population suffers from mental disorders. As per the WHO-AIMS report, in terms of resources, India has 0.25 beds

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per 10,000 population (0.2 in mental hospital and 0.05 in general hospitals) while there are 0.2 psychiatrists per 1,00,000 people. The scene in rural areas is worse. Due to the social stigma associated with being mentally sick most of the people do not go to a psychiatrist or seek any medical help.

In such circumstances, ICT and video games offers a new approach towards bridging the gap between the need and available resources for mental health. The ubiquitous nature of computing technologies can be translated into a medium of affordable, easily and widely available tool for screening people for mental health problems by assessing their cognitive abilities. Besides making mental healthcare more accessible, pre-screening patients can effectively ease the load on existing infrastructure for mental health.

Gaming and cognitive assessment has been a subject of many studies. Games are affordable and can be scaled to large deployments as they are offered on commercial platforms and are robust. They are engaging and are designed for long term usage. Mental fitness is divided into its constituent components such as attention, long term memory, short term memory, intermodal coordination etc[1-2]. A game for cognitive assessment employs the foundations of neuropsychological testing. Neuropsychological assessment is an active research area in medicine where meticulously designed tests are employed to measure cognitive abilities of patients [3-7]. This is done primarily to evaluate abilities of patients with stroke, neural disorders and neural trauma. Based on these tests, several compendiums have been established that help evaluate baseline cognitive abilities of patients and the normative population. Lezak et al. have developed a list of several such tests.

For a game to serve as a more effective and efficient tool for assessment of desired cognitive skill-set, it needs to be designed such that the game events and the implicit cognitive elements are mapped, standardized and the game flow is able to adjust dynamically in response to the cognitive feedback. The proposed framework is shown in Figure1.

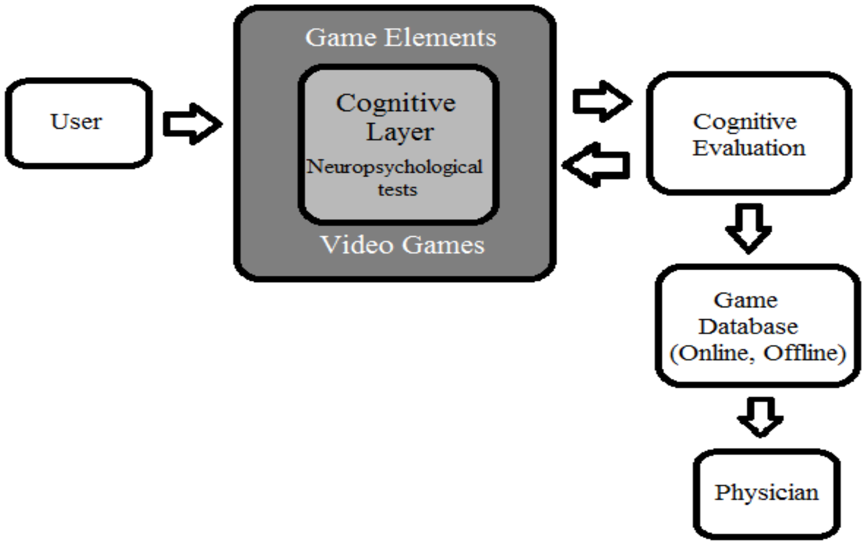

Fig. 1. Framework for designing games for cognitive assessment

The assessment results obtained through the game can be sent online to a physician specializing in mental health in case there are any indications of mental health impairment.

This paper introduces a prison themed game that has been developed based on the above discussed framework and has been designed with an aim to assess the player's level of stress. A number of different research studies have shown that stress impairs working memory formation [8], [10]. There are many neuropsychological tests that give a measure of working memory such as the digit span task, Sternberg item recognition task, n-back test etc. The digit span test [6] requires memorizing a sequence of numbers presented visually or through audio and recalling those numbers either immediately or after a time gap. The prison game represents an implementation of the test in gaming scenario where a player has to remember the sequence to accomplish certain action. Thus, stress levels of a person can be identified by assessing working memory and attention span through this game.

A pilot study was carried out to test the effectiveness of the prison game developed to assess stress levels. The following sections describe the methodology and results obtained.

Fig. 2. Prison Game

2 Methodology

2.1 Participants

14 subjects engaged in different white collar jobs, aged 22-41 years volunteered to be a part of the experiment. Written informed consent was obtained from the subjects before starting the experiment and the study was approved by Public Health Foundation of India, Institutional Ethics Committee.

2.2 Experimental Setup

Game description: The prison game has been developed using the unity game engine. The story line revolves around a soldier that has been captured in the enemy territory. The player's task is to help in rescuing the soldier and bring him back to homeland. The first level opens in the high security prison cell where the soldier is confined. To unlock the cell door the player needs to enter the electronic key codes that the trapped soldier tries to reminisce. For each correct code the soldier gains health points and moves a step further in the rescue. Three incorrect codes set the prison alarms ringing and rescue mission fails. The profiles of each player were maintained in the game. An offline on-disk as well as an online server based record of the players' performance was also maintained.

Stress Assessment: a couple of stress questionnaires and self-reporting was used as direct measures of stress levels of the player. In self reporting the subjects were asked to rate the stress levels they experienced just before playing the game, an hour before gameplay, 1 day before gameplay and their average levels of stress, on a scale of 1-10.

Assessment of working memory and attention span: The game itself implements the neuropsychological test: digit span which gives a measure of working memory and attention span. However, to test and validate the implementation, another test known as the N-Back Test was used for direct assessment. The N-Back test requires the subject to report when a stimulus item (visual or auditory) presented serially is the same as an item 'N' steps back for the time at hand. For the 2-back condition if the sequence were 8-7-1-8-6-3-6, the subject would indicate his response verbally by saying 'yes' after the second 6. In this experiment, a 2-Back test was used with visual stimuli.

Physiological Correlates: During game play physiological data in the form of EEG (electroencephalography) was collected using the Emotive Epoc headset. The EEG headset allows data to be recorded from 14 scalp locations viz. AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4. The data was sampled at 128 Hz.

Protocol: After the informed consent forms were signed and collected, each subject was asked to fill the stress questionnaire and self-reporting questions. Then they were subjected to the N-Back test. Following this the subjects were required to play the prison game for a minimum of three sessions (~15-20 min). After the gameplay the subjects were debriefed. The EEG data was recorded during the entire game play.

3 Analysis

The different variables such as scores of the stress questionnaires and self-reporting, the number of correct numeric key codes entered to open the door of the prison cell, the length of the codes, the accuracy in the game, N-Back test scores, average time to respond in the N-back test etc., were subjected to statistical analysis. The variables were checked for correlation using SPSS. The following equation is used to calculate the Pearson's correlation coefficient:

$$r = \frac{\sum(x * y)}{N * \sigma x * \sigma y}$$

Where,

r = Karl pearson's co-efficient of correlation
x = mean deviation of X
y = mean deviation of Y

σx= standard deviation of X
σy = standard deviation of Y
N = number of pairs of observation

The EEG data epochs corresponding to different game events such as the time period when each numeric code was displayed on the screen, the response time of the user etc. were isolated. Each isolated epoch was filtered and divided into the 5 frequency bands viz. delta(0.5-4 Hz), theta(4-8 Hz), alpha(8-13 Hz), beta(13-30) and gamma(>30) using 6th order butterworth bandpass filters. This EEG data was then subjected to principal component analysis.

4 Results

The reported stress levels before playing the game were found to be negatively correlated with total number of attempts, accuracy in the game, maximum length of the numeric key codes in each game session and N-Back test scores. The scores of the questionnaires are positively correlated with the average levels of stress as reported. Table 1 shows the different variables and values of correlation coefficient.

The principal component analysis indicates that the immediate stress levels can be predicted with an accuracy of 87.5 % on the basis of the player's EEG during epochs corresponding to the time when the numeric key codes are displayed. This game event is a part of the implementation of the neuropsychological test digit span.

Table 1. Correlation analysis

		Pearsonian Correlation	Sig.(2-tailed)
TA	ISL	-0.614	0.02
AGP	ISL	-0.741	0.002
MLAvg	ISL	-0.615	0.019
N-Back Test Scores	ISL	-0.589	0.027
N-Back Test Scores	AGP	0.814	0.000
N-Back Test Scores	TA	0.795	0.001
N-Back Test Scores	MLAvg	0.863	0.000
SQAvg	AvgSL	0.653	0.011

ISL = Reported Stress levels immediately before Gameplay
MLS1 = Max. length of numeric key codes in Session1
MLS2 = Max. length of numeric key codes in Session2
MLS3 = Max. length of numeric key codes in Session3
MLAvg = Average Maximum Length
SQAvg = Average Score in Stress Questionnaires
AvgSL = Average levels of stress experienced by the subject as reported
AGP = Accuracy in Gameplay
TA = Total Attempts

5 Conclusions

The focus of this analysis is to investigate the possibility of developing customized games for cognitive assessment based on the proposed framework. To fulfill this aim a prison game was developed to assess a player's stress levels. Significant co-relation was found between many of the analyzed variables.

Stress affects working memory and attention span. By assessing these cognitive components, the stress levels of a subject can be estimated. The scores of the N-Back test were positively correlated with game accuracy and average maximum code length. This validates the implementation of the digit span test in the cognitive game developed. The results of the analysis indicate that the short term stress experienced by the players can be predicted based on the performance in the game as well as the EEG signals of the player during game-play.

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