An Approach to the Measurement of Cognitive Abilities Through the Use of Serious Games

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Abstract: Cognitive abilities are brain-based skills needed to carry out any task from the simplest to the most complex. These are measured using cognitive tests which are generally designed to be administered by an expert, typically initiated by a health care professional rather than being sought out by individuals. This, consequently makes these tests less interactive and engaging. Videogames in general are considered to be inherently engaging and interactive, the application of video game elements in a non-game context, a process known as gamification, is known to improve the experience and the engagement of the user while doing mundane tasks. This study proposes the use of a serious game platform that incorporates gamified cognitive tests to measure a person's cognitive abilities in an effort to improve the engagement and overall experience of the person taking the tests. Preliminary feedback from the system users regarding their overall experience of using both the system and playing the mini-games were obtained. The evaluation from the psychology consultant will focus on the integrity of the gamified cognitive tests while feedback from regular users will be about the system's general user interface, art style, and user experience.

Key Words: Gamification; Cognitive Ability Testing; Serious Games

1. INTRODUCTION

A game, as defined in Abt (1970), is an activity where individuals seek to achieve certain objectives in some context as a form of entertainment. Serious games however have more explicit and carefully thought out educational purpose and are not intended to be played primarily for amusement. Considering its differing intention from the root definition of a game, serious games are designed and developed for use in fields such as education, training, health, research, military, and much more.

Considering that games by nature, engage the player by providing difficult challenges to overcome along with the use of a good narrative structure, complex graphics, as well as interesting rules and objectives, this further immerses the players with whatever they might be playing within game, even beyond the purpose of entertainment. In addition, considering that games help increase several skills like working memory, attentional capacity, and problem solving, it can also be used as a medium to provide a range of benefits (Lumsden et al., 2016).

The overall engagement of the participants is especially important in the field of psychology as the accuracy of the data gathered is integral to the accurate assessment of a person's cognitive functions. In (Locke & Braver, 2008), they were able to show that motivational incentives are associated with better performance and greater cognitive control which emphasizes the importance of keeping the participants motivated and engaged while performing tests that would measure their cognitive abilities.

Various methodologies are commonly used to measure a patient's cognitive abilities, mostly focused

on diagnosing cognitive impairments. These include Mini-Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA), and Confusion Assessment Method (CAM). Typically initiated by a health care professional rather than sought out by individuals and these tests are generally not designed for self-administration or for use by non-clinicians.

Consequently, this makes the current methodologies less interactive, creating little in the way of engagement and entertainment (Tong et al., 2016).

In this study, the researchers developed a game platform for gathering and collecting data about a person's cognitive abilities. Game elements were added into existing cognitive ability tests that were commonly used by professionals in the field of psychology. These gamified tests were then incorporated into a game platform that featured additional game mechanics that would increase the game's overall replay value.

The application of gamification concepts in gamifying cognitive ability tests can improve the participants' engagement in taking these tests and be used in order to collect different information about the subject. Weaving together the existing methodologies in gathering data about a person's cognitive abilities and proper game design elements without sacrificing its scientific value can improve the quality of the gathered data, increase the effectiveness of these tests and improve the overall experience of the participant.

This study demonstrates the potential of the utilization of serious games in the field of research as a medium for gathering and analyzing data, especially in the field of cognitive science. This provides researchers in the field of psychology a new interactive medium where they would be able to administer tests for their patients. A tool, which will extract the data collected within the game, will also be developed and be made available to researchers in the field of cognitive science.

It should be noted, however, that the purpose of the developed system is to create a medium or an instrument which experts could use as a possible alternative for the collection and measurement of relevant data with regards to their patients' cognitive abilities. No actual assessment or data processing is to be performed within the system as the subject will no longer be within the research's scope and objectives.

2. RELATED LITERATURE

Cognitive Ability is the person's ability to perform mental operations, to pay attention, to remember and to communicate about something that a person learned (Oswald, 2010).

Cognitive abilities are brain-based skills needed to carry out any task from the simplest to the most complex. They have more to do with the mechanisms of how we learn, remember, problem-solve, and pay attention, rather than with any actual knowledge. (Michelon, Pascal, 2006).

2.1 Cognitive Ability Testing

Cognitive Tests also known as Cognitive Ability Tests are tests designed to measure an individual's cerebral activities, which encompass reasoning, memory, attention, and language, in a specific area such as verbal reasoning and awareness (What is cognitive ability testing?, 2016). There are many tests that measure a person's cognitive ability and each with its own purpose.

In this study, we are interested in measuring 4 of the player's core cognitive skills: working memory, response selection, and speed and accuracy through the use of mini-games based on existing cognitive ability tests. The researchers chose cognitive tests that were widely used in the field of Cognitive Science in measuring the said cognitive skills, namely, Go/No-Go Visual Reaction for the measurement of response selection, N-Back Task for the measurement of working memory, and speed and accuracy, Corsi Block-Tapping Task for the measurement of working memory and Eriksen Flanker Task for the measurement of response selection, and speed and accuracy

2.2 Playability Heuristics

Playability is term that can be used to measure both gameplay and evaluation. If a game has good playability, the gameplay of the game is considered enjoyable (Jrvinen et al., 2002). To measure the playability of the game, three components are evaluated, namely, Game usability, Mobility, and Gameplay (Korhonen & Koivisto, 2006). Game usability relates to how the player interacts with the game. The interaction depends upon the visual design of the game and how the game presents relevant information to the player. Game usability also evaluates how the player is able to navigate through the game screens. Finally, game usability also evaluates the feedback of the game as well as how the game keeps the player's attention.

Mobility is defined by how easily the game helps immerses the players into the game world and how the game creates a diverse and interesting environment for the player. The game should be able to allow freedom in the game experience.

Testing the gameplay requires the evaluators or the players to at least have some degree of game design

expertise. The gameplay of the game is not dependent on the platform of the game, but it is dependent on whether the target players can actually follow and have fun with the game.

3. ROBOKUMA SYSTEM

RoboKuma, as shown in Figure 1, is a game that allows players to perform various cognitive ability tests in the form of mini games, as well as to provide researchers and experts within the field of Cognitive Science the raw, quantified data gathered from the players.

The game provides the player a virtual pet to serve as a representation of the player's likeness by reflecting their cognitive skill level and capabilities which are defined by a combination of the different attributes. If the player has weak short-term memory, the pet will be forgetful; if the player has slow reaction time, the pet will be clumsy; if the player is impulsive, either with negative or positive stimuli, the pet will be fidgety; and so on and so forth. For the pet to properly reflect the player's current aptitude, various mini-games based on the cognitive ability tests will be available for the player to access. The mini games may also be automatically initiated at certain times of the day to serve as the pet's training and development.

3.1. Virtual Pet Module

This module features the main objective of the player, which is to monitor and maintain their virtual pet. This module mostly embodies game elements such as pet interaction, customization, achievements and objectives, as well as some few narratives which will motivate user engagement.

For the pet interaction, the virtual pet will act accordingly depending on the player's performance on the mini-games, which are represented as cognitive assessments. Other interactions include swiping, tapping, or holding the virtual pet, who will then respond with varying reactions depending on their current state. The customization feature involves the modification of the virtual pet's equipped accessories and the elements present within the environment. The accessories are unlocked as the player's virtual pet levels up and can be bought with points earned from playing the mini-games or accomplishing objectives. Objectives will also be set for the player to accomplish in order to create a reward based system in which that the player is awarded with either points or customization accessories for accomplishing objectives or reaching certain goals.
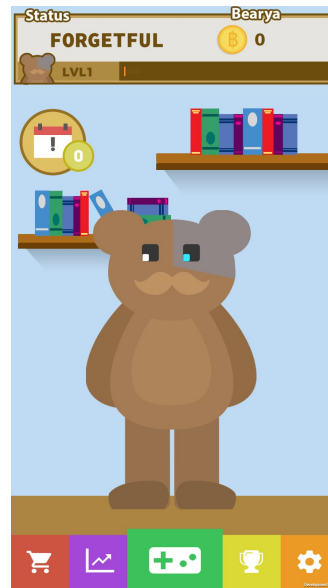

Fig. 1. Screencap of RoboKuma.

The narratives involved in the system mainly revolve around the backstory of the virtual pet and are presented throughout the player's progression within the game.

3.2. Mini-games Module

This module features the gamified cognitive ability tests, as shown in figure 2, available for the player to play in order to level up their virtual pet as well as determine the player's cognitive performance which will be represented by the virtual pet's performance state. The cognitive ability tests present within the system were implemented such that it would incorporate various elements from game design and engaged learning theories, to ensure player motivation and engagement. The mini-games will increase in difficulty once the player is able to finish the task properly. The cognitive ability tests were implemented as follows:

- *Go / No-go Visual Reaction*

The player is to tap the positive stimuli whenever it appears while ignoring the negative stimuli. The difficulty of this minigame increases through the introduction of positive stimuli and negative stimuli in the game. The player should not respond to the negative stimuli and continually respond to the positive stimuli as the mini game progresses in difficulty.

- *N-Back Task*

A series of stimuli will be presented at the screen one at

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a time, and the player is to tap the corresponding stimuli if it has appeared a specified *n* number of times before. As the player progresses, the difficulty of the N-Back tasks increases by increasing the value of *n*, requiring the player to remember more stimuli as well as take into account which ones have appeared before.

- *Corsi Block-Tapping Task*

The player is to tap the correct boxes in correct sequence which was shown to the player before the game starts. The difficulty of the Corsi Block-Tapping task increases as the player progress through the mini-game. The difficulty is increased by lengthening the sequence that the player has to remember and to tap in the correct sequence.

- *Eriksen Flanker Task*

The player has to swipe in the direction that the arrow at the center of the screen is pointing to. As the player progresses through the mini-game, its difficulty increases by introducing additional incongruent arrows, arrows that does not point to the same direction with the arrow in the center, making the arrow at the center of the screen less noticeable.

3.3. Cognitive Assessments and Data Gathering Module

This module is used for the collection of data about the various cognitive functions of the player for research analysis. Considering that the mini-games implemented into the system are the gamified versions of their respective cognitive ability tests, each corresponding mini-game will yield and collect different cognitive attributes depending on the test being represented. The player's performance or result from playing the mini-games are reflected into the listed attributes as follows:

- Response Selection - Rate of selecting positive response as opposed to negative response.
- Memory - Rate of successfully recalling past stimuli.
- Speed - Response time to given stimuli regardless of correctness.
- Accuracy - Rate of proper response towards incoming stimuli.

Once the corresponding data has been collected, the cognitive skill level of the player will be then reflected into their virtual pet. And although the system aims to represent the effectiveness of the actual cognitive tests by being as similar as possible when it comes to both methodology and data gathering, some game elements must be incorporated into the system in order to ensure continued replayability from the player.
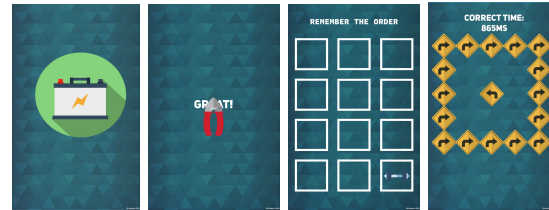

Fig. 2. Screencap of the Mini-games. From left to right: Go/No-Go, N-Back Task, Corsi Block-Tapping Task and Eriksen Flanker Task.

Despite recording the cognitive attributes of the player as accurate as possible, a point deduction mechanic was introduced such that if the player fails to maintain the condition of their pet by playing any of the mini-games at least once per day a random value will be decreased to any of the cognitive attributes which will then in turn affect the performance state of the virtual pet. This however does not affect the actual data being gathered.

3.4. Measured Data

As mentioned before, the system collects relevant data from the player in each of the mini-games that could be used in future researches. Listed as follows are the relevant data that the system collects that could be used in the analysis of the player's cognitive abilities as specified by Cognitive Group (2006) as well as Dr. Adrianne Galang, a professor from De La Salle University's Psychology Department:

- *Go / No-go Visual Reaction*

The performance of the player in this mini-game affects the pet's response selection, speed and accuracy attributes. For this mini-game, the system collects the data about the percentage of correct and incorrect responses along with the mean reaction time for the correct responses of the player.

- *N-Back Task*

The performance of the player in this mini-game affects the pet's memory, speed and accuracy attributes. For this mini-game, the system collects the data about the percentage of correct and incorrect responses along with the mean reaction time of the player.

- *Corsi Block-Tapping Task*

The performance of the player in this mini-game affects the pet's memory attribute. For this mini-game, the system collects the data about the average number of correct sequences per trial and the average number of correct trials according to sequence length.

- *Eriksen Flanker Task*

The performance of the player in this mini-game affects the pet's response selection, speed and accuracy attributes. For this mini-game, the system collects the data about the percentage of correct and incorrect responses along with the mean reaction times for the correct and incorrect responses.

- *General Player Data*

Other relevant miscellaneous player data to be recorded which will be necessary for the analysis and assessment of the player's cognitive ability as well as overall engagement and interactivity. Such include the player's average play time, most active hours and time logs of each played mini-game.

3.5. Data Extraction Module

This module is used to provide a tool for extracting game statistics for research analysis. With the game statistics being the collected cognitive ability measurements from the players, this module will only be available for authorized specialists within the field of psychology. Although technically still part of the overall system, this module was implemented as a separate tool from the game itself. The tool was implemented as an application that allows authorized users to view, extract, and export raw data collected from the players which have not been analyzed nor preprocessed. Player data will of course be recorded as anonymous and will not contain any personal information from the players themselves. Although playing the game system itself does not require online functionality, it will however attempt to upload data to the online database periodically once enough data has been collected or a certain time frame has been met.

4. RESULTS AND ANALYSIS

Over the course of the research, the game would go through an iterative cycle of testing and development. The researchers took note of the feedback from the participants and do the necessary revisions based from it. For the measurement of player engagement, the game will be introduced to the public, i.e. students, professors, and family members, so that they will be able to play the game at their own pace. The researchers would then analyze the data gathered from the players to measure their level of engagement as well as the replay value of the system as according to the play time and frequency of the players.

Prior to proceeding with any of the usability testing methodologies for the system, the integrity of the gamified cognitive ability tests were first verified with the help of an expert within the field, Dr. Adrianne Galang. The effects of the incorporated game elements,

the modified aesthetics and visuals of the tests, and most importantly, the data being gathered by each individual mini-game were all evaluated and considered with respect to the original methodology and implementation of the tests themselves. In summary, considering that the researchers have consistently taken into account the mechanics of the original tests when developing their gamified counterparts, the consultant has confirmed the validity and effectiveness of the gamified tests, even with the incorporated game design elements, such as the point/scoring system, altered visuals, as well as the overall game platform in which the tests has been implemented in.

For testing the user interface and the user experience, ten (10) select participants, aged 19-21, with a background in Computer Science, were given a set of tasks to perform while operating the system without aid or supervision. They were then asked to provide feedback as well as suggestions with regards to their overall experience of using both the system and playing the mini-games. Considering that basic feedback regarding the system's general user interface, art style, and user experience.

Most of the problems encountered by the participants was the difficulty in understanding the mechanics of the minigames.

For Go No-Go some of the participants had a hard time distinguishing between the positive and negative stimuli, as seen on figure 3, based on the description given to them in the mini-game's instructions. The researchers realized that the problem could be attributed to the fact that a visual indicator would be better show than described to the player. Thus, the researchers decided to show them the visual indicator that would indicate the difference between the positive and negative stimuli instead of simply describing it to them.
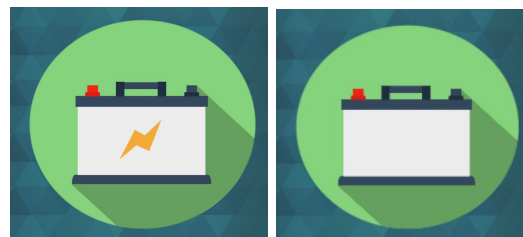

Fig. 3. Go No-Go stimuli. (left) Positive Stimulus. (right) Negative Stimulus. The respondents had a hard time distinguishing the difference between the two based on the instruction given due to a lack of visual content.

Most of the participants also had a hard time understanding the mechanics of N-back task given the

instruction to tap the object that had appeared 2 objects before. This prompted the researchers to give the players a demonstration for them to get a better grasp of the mechanics of the mini-game.

5. CONCLUSION

This paper demonstrates the feasibility of the use of serious games in measuring a person's cognitive abilities. The researchers were able to develop a system which incorporates game elements into existing cognitive ability tests which will allow for a gamified methodology of collecting relevant data from players used for the measurement of a person's cognitive abilities. As for future works, further research will still be performed in order to analyze the possible effects of the implementation of game elements into the existing cognitive tests with regards to the performance of the player as well as compare the developed system to other existing systems.

Furthermore, based on the feedback gathered from both players and the psychology consultant, the system will still be further improved with regards to its usability as well as its overall flow. Providing a better user experience requires constant validation and testing from the players, while at the same time, reaffirming that any suggested or applied modifications to the system will not affect the effectiveness as well as the integrity of the testing mechanisms of the cognitive ability tests as according to the psychology consultants.

Overall, the system's development is still in progress as various tests as well as expert evaluation and validations are still being performed in order to properly assess whether or not the system may be of use as an effective instrument as a means for gathering and measuring data about a person's cognitive abilities.

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7. REFERENCES

Abt, C. (1970). Serious Games. University Press of America 1987.

Lumsden, J., Edwards, A. E., Lawrence, S. N., Coyle, D., & Munaf'o, R. M. (2016). Gamification of cognitive assessment and cognitive training: A systematic review of applications and efficacy. JMIR Serious Games, 4 (2), e11.

Locke, H., & Braver, T. (2008). Motivational influences on cognitive control:Behavior, brain activation, and individual differences. Cognitive, Affective, and Behavioral Neuroscience, 8 (1), 99112.

Tong, T., Chignell, M., Tierney, M., & Lee, J. (2016). A serious game for clinical assessment of cognitive status: Validation study. JMIR Serious Games 2016, 4(1).

What is cognitive ability testing? (2016). Retrieved 2016-05-25, from http://www.hrzone.com/hr-glossary/what-is-cognitive-ability-testing.

Michelon, Pascal. (2006). What are cognitive abilities and skills, and how to boost them? Retrieved 08-07-2016, from http://sharpbrains.com/blog/2006/12/18/what-are-cognitive-abilities/

Oswald, A. (2010). Intelligence: The measurement of cognitive capabilities. Retrieved from https://www.mentalhelp.net/articles/intelligence-the-measurement-of-cognitive-capabilities/

Jrvinen, A., Heli, S., and Myr, F.(2002). Communication and Community in Digital Entertainment Services Prestudy Research Report. University of Tampere, 2002.

Korhonen, H., & Koivisto, E. M. (2006). Playability heuristics for mobile games. In Proceedings of the 8th conference on Human-computer interaction with mobile devices and services (pp. 9-16). ACM.

Cognitive Group (2006). Test summary. http://www.cogtest .com/tests/cognitive int/cpt fv.html. (Accessed: 2016-11-17)