Designing Ụbụrụ: The Alpha Stage

Executive Function Rehabilitation Application for Mild Traumatic Brain Injury

Akuadasuo Ezenyilimba
Human Systems Engineering, Arizona State University
National Science Foundation Research Traineeship
Mesa, United States of America
email: aezenyi1@asu.edu

Jennifer Wethe
Psychiatry/Psychology, Mayo Clinic
Mayo Clinic Arizona Concussion Program
Phoenix, United States of America
email: Wethe.Jennifer@mayo.edu

Nancy J. Cooke
Human Systems Engineering, Arizona State University
Center for Human, Artificial Intelligence & Robot Teaming
Mesa, United States of America
email: Nancy.Cooke@asu.edu

Troy McDaniel
POLY, Arizona State University
Center for Cognitive Ubiquitous Computing (CUbiC)
Mesa, United States of America
email: troy.mcdaniel@asu.edu

***Abstract*— Ụbụrụ is an executive function computerized rehabilitation application specifically designed for mild Traumatic Brain Injury (mTBI) individuals. Ụbụrụ utilizes serious games to train cognitive flexibility, planning, and organization. This paper explores the rationale and components behind the alpha stage of the application's development, and its first design iteration. Currently, individuals with a history of mTBI have limited rehabilitation options as a result of lack of knowledge in terms of available services, access, time, or financial and insurance constraints. Due to the invisible nature of mTBIs, perception of injury severity is diminished, individuals are not properly equipped with how to proceed forward with rehabilitation, and awareness of injury can be inadvertently compromised. The intention behind the Ụbụrụ application is to be a computerized cognitive rehabilitation alternative and additive when limitations such as time, finances, or insurance exist.**

Keywords-mild traumatic brain injury; executive function; serious games; computerized cognitive rehabilitation

I. INTRODUCTION

Non-standardization of care for (mTBI) continues to stagnate an individual's ability to have an effective recovery process. Currently mTBIs account for 70 – 90 % of the 69 million Traumatic Brain Injuries (TBI) that occur each year [8]. The common misconception that continues to persist is that all mTBI patients will make a full recovery within a few days of injury onset. Further research has shown that mTBI individuals can still continue to experience Post Concussive Symptoms (PCS) for years if not decades after injury [1]. Of those deemed recovered, at least 25% present with some form of PCS [1].

Symptoms of this nature can delay an individual's ability to return to work and impede individuals with prolonged Executive Functioning (EF) deficits [8]. Subcortical networks and frontal lobe structures are particularly vulnerable in traumatic brain injury. Damage within these areas of the brain can result in varying levels of Executive Dysfunction (ED) that can make it challenging to complete independent, goal-oriented behavior and tasks; thus, infringing on everyday activities [13]. Having a history of a mTBI has demonstrated that individuals can face decrements related to planning, organization, reasoning, set shifting, and monitoring [13].

Less than 30% of individuals with mTBI report seeking or receiving next line care in terms of rehabilitation [2]. With very few individuals actively seeking or receiving treatment, mTBIs can be deemed an invisible injury, leaving people improperly equipped with tools to improve their overall quality-of-life post injury. For mTBI individuals especially it can be hard to accept the severity of a mTBI injury, due to the lack of diagnostic testing to pinpoint shortcoming, and the lack of concreteness surrounding the injury [4]. In addition to the invisible nature of mTBIs, cognitive processes such as awareness and acceptance can be negatively impacted. Impediments of this nature can limit the recovery process. If these processes are not appropriately engaged, successful recovery is less than likely [2]. Many mTBI individuals, especially athletes, report not seeking help because they initially perceived their injury as not being severe enough; they believed symptoms resolved; they were not sure who to contact; or they were unaware that such services were available [3].

In addition to non-standardized mTBI care, the strain of COVID-19 has shed light on confounding factors in the form of present challenges, such as treatment access and the priority of mTBI patients [9]. COVID-19 has put many medical concerns on the backburner to prioritize public safety. Regardless of the present challenges, the needs of the TBI community are still imminent.

With referral rates being as low as 2% for next line care when a TBI is classified as mild, there are not many available options to further rehabilitation [7]. Additionally,

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at least 65% of TBI individuals are discharged without any sort of rehabilitation plan or checkups [10].

Although current research is limited, it has been demonstrated that computerized cognitive rehabilitation can be an effective tool in assisting mTBI individuals during their recovery [14]. Presently one of the main focus areas for mTBI rehabilitation, and computerized training is vision-based interventions, for instance oculomotor rehabilitation [5]. Of those interventions that do not solely focus on vision related training, there are only aspects of cognition, for example Lumosity, that do not feature EF specific training [13]. Furthermore, other challenges related to current mTBI interventions include studies being conducted only at the military level that do not include civilians, thus continuing to add to the ongoing limitation of limited knowledge or awareness provided to the general public for mTBI rehabilitation. Lastly, current computerized interventions do not have the ability to equip individuals with the necessary tools to transfer skills learned in rehabilitation to activities of daily living that stem beyond motor skills, such as reading [5].

In order for mTBI individuals to be able to make the most out of their recovery process it is important to be able to: 1. have a sense of individual autonomy, 2. have access to available resources and services, and 3. have knowledge of available services and resources. Furthermore, rehabilitation initiatives and programs need to address dysfunction-specific mechanisms associated with mTBI (i.e., executive function). Tailored programs that pinpoint areas of ED are necessary and would be most beneficial for sustainable long-term outcomes [13]. This paper will further explore how to incorporate the aforementioned needs and objectives to make mTBI rehabilitation more attainable through the implementation of an EF computerized rehabilitation application that utilizes serious games. The proposed application will be described in its alpha stage.

The purpose of this paper is to: 1. further explore rehabilitation limitations facing the traumatic brain injury (mTBI) community 2. address the needs of mild Traumatic Brain Injury (mTBI) individuals specifically, and 3. explore a proposed intervention in its alpha stage.

With the proposed intervention being in its alpha stage a potential limitation to consider moving forward is the fact that the application is internet/Wi-Fi dependent. The following paper will first discuss in section two the application overview related to the proposed application's objectives, the incorporation of EF training through serious gamification, the rationale behind the initial application assessment, and the intended serious games and other application features for EF rehabilitation. The third section of the paper will discuss the anticipated experimental procedures. Finally, the fourth section of this paper will highlight the intended next steps for the development of the application.

II. Application Overview

The following sections will describe the components of the proposed application in detail. Within these sections the application objectives, executive function focus, and serious gamification approach will be explained.

A. *Application Objective*

Ụbụrụ (pronounced Oh-bow-roo; from the Igbo language; English translation: brain; see Figure 1) is an EF rehabilitation application intended to be an alternative and/or additive to rehabilitation for the mTBI community. The aim of Ụbụrụ is to help individuals mitigate common areas of ED for mTBIs through cognitive flexibility, organization, and planning training. The goal of Ụbụrụ is to allow mTBI individuals to have awareness and control during their rehabilitation journey by actively being able to 1. see progress and/or regression, 2. receive feedback, and 3. set realistic goals on a weekly basis.

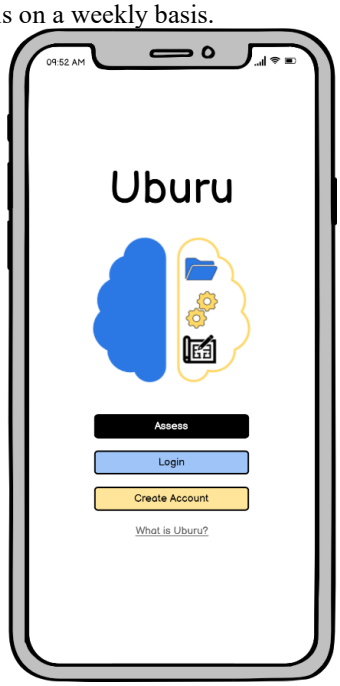

Figure 1. Ụbụrụ start page.

With many mTBI individuals not being fully aware of their limitations, due to their inherent nature to adapt to their new normal or simply not being aware of the severity of their ailments, Ụbụrụ's design aims to bring awareness to the forefront of its training [4]. In addition to goal setting, Ụbụrụ seeks to overcome awareness challenges through feedback in the form of scores, tips, and weekly self-report surveys. Ụbụrụ is also designed to actively encourage participants to seek and take advantage of other local resources by 1. providing recommendations, if necessary, at the end of each EF game session, and/or 2. having a readily available and accessible resources page built into the application.

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B. *Executive Function Training Through Serious Gamification*

For mTBI individuals, EF is one of the most at-risk cognitive processes [6]. When left untreated, ED via mTBI injury can result in psychological stress that can stem beyond the damage acquired by the initial injury, hindering an individual's ability to engage in everyday functioning. To overcome ED challenges, reduction and monitoring of post concussive symptoms is needed, awareness of available resources within a community are a must, and quality of life needs to actively be considered and improved [6].

To address these concerns, Ụbụrụ takes a serious gamification approach. Through gamification, participant motivation can be increased, and participants will be more willing to participate and are more likely to stay engaged [11]. With Ụbụrụ aiming to be a computerized cognitive rehabilitation alternative when time, access, finances, or insurance are an issue, gamification will allow users to engage in necessary rehabilitation even when a physician is not able to be present. In addition to present limitations hindering recovery, Ụbụrụ aims to have skills acquired during rehabilitation be transferable to activities of daily living. By pinpointing transferability, Ụbụrụ is tailored to reduce the psychosocial stress brought on by vocational, recreational, and / or interpersonal functioning [6].

C. *Ụbụrụ Assessment*

To begin using Ụbụrụ, all participants will start by taking the initial Ụbụrụ assessment. Upon completing the assessment participants will be able to see firsthand their primary, secondary, and tertiary focus in terms of cognitive flexibility, planning, and organization (see Figure 2).

Figure 2. Ụbụrụ homepage.

The initial assessment will contain tasks that test participants ability to engage in the aforementioned EF skills. From here participants will complete weekly EF serious games. There will be a total of five games with varying levels of cognitive flexibility, planning, and organization incorporated.

D. *Cognitive Flexibility Games*

Challenges brought on by additional psychological stress from mTBI can impair the ability to effectively engage in tasks that are dependent on cognitive flexibility. Cognitive flexibility, much like psychological flexibility, is dependent on shifting perspective to adapt to situational demands [6]. Oftentimes mTBI individuals do not have a full understanding of decrements they are facing, resulting in mTBI individuals avoiding tasks that require engagement of EF skills that have been diminished post-injury. Avoidant behavior of this nature consequently results in a misinterpretation whereby individuals believe that they are fine. Since individuals are not actively training these EF skills, persistent decrements continue to hinder activities of daily living [6].

To address cognitive flexibility challenges, Ụbụrụ has users engage in tasks that are designed to train participants to switch between different tasks, while engaging working memory. Within the app there are three cognitive flexibility specific games (Beat the Value, Keeping Track (also incorporates aspects of planning and organization), and This or That). The aforementioned cognitive flexibility games are designed to encourage users to adapt their thinking in order to adjust to their current environment (i.e., the serious games). By encouraging users to actively change their approach when dealing with ongoing challenges that require problem solving, Ụbụrụ, aims to improve the EF skill of cognitive flexibility through, task switching, attention to detail, and maintaining pertinent information.

Beat the Value. One of the main challenges TBI individuals face is being able to problem solve [1]. Beat the Value is designed to help participants sharpen their problem-solving skills through math, while engaging in task switching. As levels continue to progress users will be responsible for maintaining instructions while completing the task.

Keeping Track. Many mTBI individuals with ED face challenges with maintaining and holding on to information to achieve an overarching goal [13]. Keeping Track focuses on training participants ability to differentiate between items while paying attention to detail. Through the game of Keeping Track participants will be responsible for task switching during a subordinate task in order to acquire information for a superior task.

This or That. This or That builds on task switching with an emphasis on paying attention to instruction detail. The focus of this game is to allow participants to maintain relevant information to achieve an overarching goal. As users continue to progress through the levels of This or That

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they will need to be abreast of information related to the task, and prioritize the instructions given to them to complete the task at hand.

E. Organization Game

Deficits with organization can be attributed to issues with early stages of encoding, resulting in ineffective processing of information needed to achieve a task [12]. Challenges with organization can impede the ability to follow and create schedules, prioritize and follow logical steps, and coordinate activities. Additionally, organization deficits can hinder mTBI individuals' ability to effectively break down tasks [1].

Rank Order. To address problems with organization, Rank Order focuses on teaching users how to break down an overarching event or goal into smaller tasks. The game of Rank Order has participants look at a list of items and then determine where to start first and order events logically. As levels progress, users will also be responsible for deciphering which events are most urgent, flexible, and/or are able to be rescheduled.

F. Planning Game

mTBI individuals are known to face difficulty when it comes to engaging in activities that require planning. Deficiency in planning can lead to plans that are ineffective or poorly developed, resulting in needing more time to correct and redirect plans [1].

Train of Thoughts. The planning game, Train of Thoughts, provides real world scenarios that allow participants to see the end result of their decisions. During the Train of Thoughts game users are responsible for helping a civilian determine the necessary sequence of events (i.e., making it to a doctor's appointment on time) in order for the 'train to leave the station' while utilizing aspects of working memory and prioritization. These scenarios are designed to resemble activities of daily living so knowledge and skills can be applied to the participant's life.

G. Weekly Survey

Weekly Surveys will be made available at the end of the week for all participants once all tasks and sessions are completed. The survey will consist of three types of questions: Likert scale, multiple choice, and open-ended questions. The self-report nature of the survey serves as a check in for user feedback, keeps users aware of progress, and keeps users accountable of their program.

III. Anticipated Experimental Procedure

Prior to the experimental stage Ụbụrụ will undergo usability testing. Upon completion of usability testing the experimental stage will commence. For the purposes of this study Ụbụrụ will be used as a cognitive rehabilitation additive in the form of a web-based application.

During the experimental stage of Ụbụrụ, participants will be able to access weekly tasks via the Executive Function Dashboard (see Figure 3). Ụbụrụ will track participants' performance on a weekly basis and customize treatment plans in the following weeks accordingly.

A. Duration

The study will take place over the span of eight weeks. Each week will contain three sessions. Every week based on participant performance, the level of difficulty will increase, decrease, or remain the same. For study purposes, all participants will complete all five of the Ụbụrụ games.

B. Levels

At the start of the study, all participants will begin at level one and move through the application's levels from there. Based on participants' weekly performance, progression will be customized to each user based on their scores.

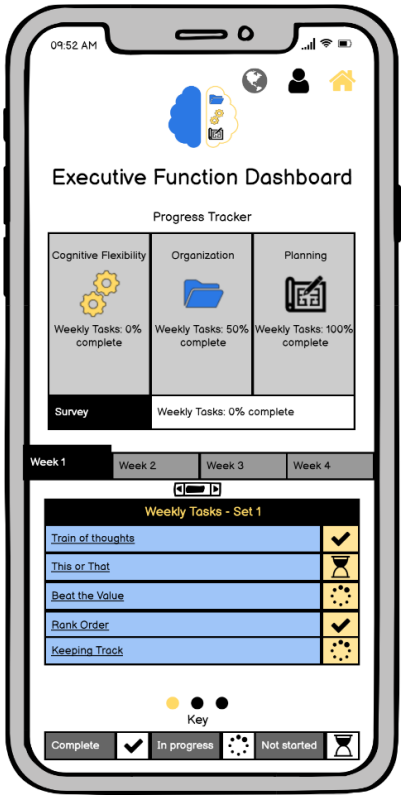

Figure 3. Ụbụrụ executive function dashboard.

In addition to level customization, recommendations for external resources will be provided to participants who need them based on game scores. For participants whose scores do not auto populate an external resource recommendation, a resource page will be readily available throughout the application and provide users with relevant local resources.

C. Measures

Participants' scores on the Ụbụrụ Assessment will be collected at the beginning and end of the study. In addition

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to assessment scores, participant's weekly individual game scores, time to complete each game, and self-report surveys will be points of measure.

IV. CONCLUSION

The future of Ụbụrụ is still underway. As Ụbụrụ begins to enter its beta stage, the development of this application allows for a testbed to further explore ED amongst mTBI individuals. The hope for this application is to begin to narrow the gap for rehabilitation limitations and non-standardization of care for the mTBI community, by testing a new computerized cognitive rehabilitation alternative and additive. Ụbụrụ will explore the potential of a new approach for mTBI rehabilitation, by training specific EF decrements to help mitigate extraneous factors that continue to persist as a result of PCS. With Ụbụrụ as an experimental study, the application will be able to further explore user feedback, mTBI rehabilitation needs, and potential shortcomings.

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