

### 3.3 Leveraging Game Consoles for the Delivery of TBI Rehabilitation

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**Abstract.** Military personnel are at a greater risk for traumatic brain injury (TBI) than the civilian population. In addition, the increase in exposure to explosives, i.e., improvised explosive devices, in the Afghanistan and Iraq wars, along with more effective body armor, has resulted in far more surviving casualties suffering from TBI than in previous wars. This effort presents the results of a feasibility study and early prototype of a brain injury rehabilitation delivery system (BIRDS). BIRDS is designed to provide medical personnel treating TBI with a capability to prescribe game activities for patients to execute using a commercially available game console, either in a clinical setting or in their homes. These therapeutic activities will contribute to recovery or remediation of the patients' cognitive dysfunctions. Solutions such as this that provide new applications for existing platforms have significant potential to address the growing incidence of TBI today.

#### 1.0 INTRODUCTION

Military personnel are at a greater risk for traumatic brain injury (TBI) than the civilian population. In addition, the increase in exposure to explosives, i.e., improvised explosive devices, in the Afghanistan and Iraq wars, along with more effective body armor, has resulted in far more surviving casualties suffering from TBI than in previous wars. For example, 14-18% of Vietnam veterans had a brain injury while from 2003-2005, Walter Reed Army Medical Center reported 31% of those combat casualties admitted had a brain injury [1]. Such injuries can leave Service members physically scarred and cognitively challenged.

#### 2.0 BACKGROUND

The research team, comprised of members from MYMIC LLC, Old Dominion University, and Eastern Virginia Medical School, designed an intervention for individuals with TBI as a result of a Phase I SBIR award. The Brain Injury Rehabilitation Delivery System (BIRDS) is designed to deliver rehabilitation games via a commercial game console and assess performance over time

from a baseline measurement throughout treatment. The vision for BIRDS is to provide medical personnel treating TBI a capability to prescribe game activities for patients to execute using that game console, either in a clinical setting or in their homes. These therapeutic activities will contribute to recovery or remediation of the patients' cognitive dysfunctions. BIRDS design is initially focused on TBI resulting from combat; however, our vision includes its application for treating injuries resulting from other activities (e.g., sports or accidents) and age-related dysfunctions. This paper details our research findings and described the implementation of the BIRDS concept prototype.

#### 3.0 DESIGN

##### 3.1 The Microsoft Xbox 360 platform

Microsoft Xbox 360 is the second-generation game console released by Microsoft. It supports multiple interface devices, such as the keyboard, joystick, and racing wheel Both wired and wireless controllers, Figures 1(a) and (b), provide user interaction via buttons, thumb sticks,

triggers, and a directional pad. The joystick, Figure 1(c) also provides these options, though in a different configuration and with greater emphasis on the joystick function. The racing wheel devices, Figures 1(d) and (e), can track both hand, arm, and foot motions as well as hand-foot coordination.

The freely available Microsoft XNA Game Studio is an integrated environment for game development for Xbox 360, personal computer, and the handheld Microsoft Zune Player XNA Game Studio consists of two major components: XNA Framework and a set of tools and templates to facilitate rapid game development. The XNA Framework is a set of optimized cross-platform libraries for game development based on the Microsoft .NET Framework Technology. It encapsulates low-level details involved in developing games and allows game developers to focus more on the content and high-level gaming experience.

### 3.2 Mapping platform capabilities to TBI rehabilitation skills foci

We mapped the capabilities of the Xbox 360 to a selection of cognitive and motor skills foci in clinical TBI rehabilitation settings. Based on these data points, we selected a limited set of skills to be addressed in the concept prototype.

The features and capabilities of both Xbox360 hardware and software that are associated with the interface between the system and the human were analyzed with respect to their applicability to TBI rehabilitation foci, including cognitive and fine or gross motor functions. Table 1 contains these mappings, as well as some example task suggestions on how to realize skill rehabilitation within multiple modalities.

In this research we identified the joystick as a promising interface for the intended user population because of its ability to support gross motor, as well as fine motor movements and cognitive skills. For example, a patient lacking fine motor capability (e.g. controlled finger movements) can engage larger muscle groups, i.e. arm muscles, to work the joystick. However, while Xbox360 itself supports different input devices, including the joystick, Microsoft XNA Game Studio currently supports only game controllers, keyboard, and mouse. Therefore, the BIRDS concept prototype was developed for the game controller device. This device can support both fine motor and cognitive skills. Future goals will include adding support for using gross motor skills in BIRDS.



Figure 1. Xbox 360 input devices. (a) Wired controller. (b) Wireless controller. (c) Joystick. (d) Racing wheel. (e) Pedal.

**Table 1. Mapping of Xbox interface capabilities to applicable TBI rehabilitation skills foci.**

Xbox capabilities		Options	Rehab skills foci	Potential tasks
Interfaces	Wired game controller	Buttons - press Joystick - push / pull	Fine motor	- Move object to desired/directed location (large to small objects) - "Thread" a needle through different sized holes (large to small holes) - Coordinate movement (joystick) with selection (button)
	Wireless game controller			
	Joystick	Button - press Joystick - push / pull	Gross Motor Fine Motor	
	Racing wheel	Wheel - turn Buttons - press	Gross Motor	
	Racing pedals	Pedals - press (feet)	Gross Motor	
	Software	Gameplay	Cognitive	
		- Attention	- Introduce stimuli during task (i.e. problem solving)	
		- Memory	- Recall objects from the previous screen	
		- Information Processing	- Determine which 3 of 4 objects are similar	
		- Apraxia	- Sequential instructions	

### 3.3 Identifying performance metrics

We further identified performance metrics needed for clinicians to assess each TBI rehabilitation skill in a meaningful way. This step is especially important as an objective measure of progress and as such, should be supported by existing evidence-based scales, and be relevant to patient functional outcomes. In addition, performance metrics will play an important role in the validation of any computer/console based cognitive and motor skills rehabilitation tool.

In order to do this, standard clinical protocol

for evaluating both motor and cognitive skills in patients was compared with the capabilities of the Xbox360 to determine the applicable performance metrics relative to TBI rehabilitation skills.

The BIRDS concept supports objective performance assessment, as opposed to a more subjective method of determining patient progress, for example, an evaluation such as, "The patient *appears* to be responding more quickly to commands." With the aid of an SME, we determined performance metrics for the TBI rehabilitation skills that were previously identified. Table 2 details these metrics.

**Table 2. Performance metrics for applicable TBI rehabilitation skills foci.**

Xbox360 Interface		Rehab skills foci	Performance metric
Wired game controller	Buttons - press	Fine motor	Accuracy
Wireless game controller	Joystick - push / pull		Accuracy (spatial) Completion time
Joystick	Button - press	Gross Motor	Accuracy (spatial)
	Joystick - push / pull	Fine Motor	Completion time
Racing wheel	Wheel - turn	Gross Motor	Accuracy (spatial)
	Buttons - press		Completion time
Racing pedals	Pedals - press (feet)	Gross Motor	Accuracy Completion time
Software	Gameplay	Cognitive	
		- Attention	Accuracy Reaction Time
		- Memory	Accuracy
		- Information Processing	Accuracy Reaction Time
		- Apraxia	Accuracy Reaction Time Sequence

#### 4.0 DEVELOPMENT OF THE PROTOTYPE

The BIRDS concept prototype (Figure 2) was developed with a focus on cognitive skills and a secondary requirement of fine motor movement. The following cognitive skills were selected with the goal of developing a concept prototype for a minimum of two of these skills. These particular skills were selected because of their foundational role in cognition and information processing. Each of these low-level skills are required if a person is to function normally and/or gain functional independence following brain injury.

- Attention (cognitive): The ability to focus selectively on a specific stimulus, to maintain that focus, and to shift that focus at will.
- Memory (cognitive): The ability to store, retain, and recall information.
- Apraxia (cognitive with some additional fine motor requirements): the ability to follow a sequence of instructions

Each game has two levels of difficulty: easy and hard. In the Attention game, the player

will observe one letter of the English alphabet at a time and will need to respond when the letter 'A' appears by pressing the 'A' button of the Xbox 360 controller. At the easy level, letters are displayed in a consistent location, one after another. At the hard level, distracting graphics are included and displayed, such as stars appearing and disappearing in different sizes and in different locations, while the letters themselves are displayed in random locations. In addition, easy and hard are further differentiated by the length of time each stimulus is displayed. The purpose of the game is to test and improve the player's ability to concentrate on a specific, randomly displayed stimulus.

In the Memory game, the player will first see an image, see Figure 3(a), with the goal of memorizing the image. Then the player will see four images, see Figure 3(b), including the original image, and must select which one matches the original image. Easy and hard levels are determined by the amount of time the original image is displayed. Images from the following five categories are used: animals, food, plants, transport, and weapons.



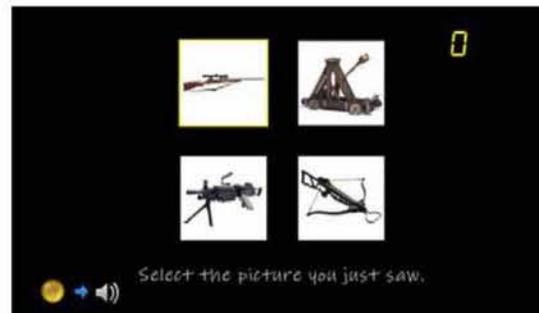
**Figure 2. BIRDS concept prototype screen mock-up.**

Each group contains more than 10 images. During each play, an image from a certain group is displayed first; then three other images from the same group are displayed

in addition to the original image. In Phase II, testing will determine if the player has varied performance for different types of images, e.g., Food or People.



(a)



(b)

**Figure 3. Memory game. (a) The player first observes a picture; then (b) selects the picture he/she just saw.**

The apraxia game will require the player to follow on screen instructions (and/or instructions given by a virtual trainer) to complete a sequence of actions. The player will need to use both hands to manipulate several controls (e.g., button, thumb stick) at the same time in order to operate an on-screen instrument to execute the required

task(s). For example, as shown in Figure 4, the player needs to use the left thumb stick to move the forceps to the cherry, Figure 4(a). After the forceps arrive at the cherry, the player presses button A using right hand, Figure 4(b). Then the players uses the thumb stick (left hand) to move the cherry to the basket, while pressing button

A (right hand), Figure 4(c). Finally, the player releases button A to drop the cherry

into the basket, Figure 4(d).



(a) The player is instructed to move the forceps to the cherry.



(b) The player is instructed to pick up the cherry after the forceps arrive at the cherry.



(c) After picking up the cherry, the player needs to move it to the basket.



(d) After moving the cherry to the basket, the player needs to drop the cherry. Note that the cherry becomes redder, signaling that it is in the basket.



(e) After the cherry is dropped in the basket, another cherry appears to begin a new play.

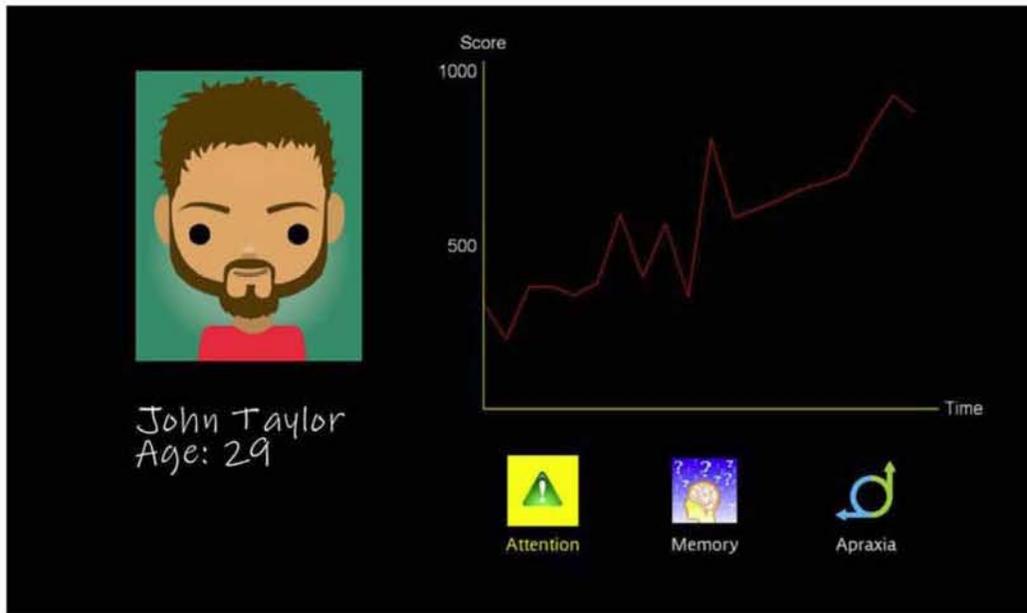


(f) A number of cherries have been collected.

**Figure 4. Apraxia game (cherry picking).**

The difficulty level of the apraxia (cherry picking) game is determined by the time allowed to complete the steps needed to pick up the cherry; in addition, the location

of the basket is not fixed and the starting positions of the forceps and cherries are also randomized to require different motions and avoid repetitious gameplay.



**Figure 5. Example patient profile screen.**

Users can view their overall progress in a given intervention by viewing their profile. Figure 7 shows a sample patient profile screen with actual progress graphed over time. Viewing their profile gives the patient the opportunity to see objectively how they are progressing, which mirrors the feedback given by physiatrists who periodically assess their patients' capabilities. It also provides a snapshot view of progress to the physician.

## 5.0 CONCLUDING REMARKS

The key research findings described in this paper provide a foundation for the development of a videogame console-based system for TBI-related cognitive and motor skills rehabilitation. Such a tool may provide the foundational capabilities that are required for a patient to achieve functional independence in his or her everyday life. In addition, it has the potential to evolve to support higher order cognitive skills, e.g. information processing, and broader motor skills as well. Importantly, patient therapy can then be standardized and progress tracked objectively, providing a rich breeding ground for research in TBI

rehabilitation, enriching the field and potentially resulting in even more effective treatments. Looking ahead, in developing a cognitive and motor skills rehabilitation console-based tool, attention must also be focused on the advances in available technology. For example, product releases such as Project Natal hold significant potential for the future extension and applicability of BIRDS treatment. Such technology could address physical as well as cognitive rehabilitation, providing benefits to a wider range of patients and more closely mimicking a physician's evaluation of a patient.

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