## 1. INTRODUCTION

Natural User Interfaces (NUI) enable a varied scope of expressive computer input. The standard paradigm of a mouse and keyboard limits the interaction that can be completed through exclusion of inputs related to more natural physical movement, speech, or even thought. Brain Computer Interfaces (BCI) and the Microsoft Kinect are two examples of technology that can be harnessed to provide NUI. The purpose of this research was to investigate whether BCI can augment the gameplay experience provided by the Microsoft Kinect. Gürök et al. (2012) wrote that many of the BCI games being developed focus on "psychological hypotheses or evaluating the performance of signal analysis and classification techniques". Gürök et al. go on to say that "experience evaluations are almost never carried out". The research discussed in this paper sought to identify the feasibility of low cost equipment for enhanced gameplay activities.

To determine the viability of the combination of inputs three computer game puzzles were created. The puzzles were game tested and a basic user experience evaluation conducted. The user is able to control elements of these games by altering their levels of concentration and relaxation. These levels were determined from an electroencephalography (EEG) reading of Alpha waves captured by an Emotiv EPOC BCI device. The variation in alpha levels provided gameplay augmentation while the primary game inputs were provided by the Microsoft Kinect using speech and skeletal tracking. Participants who took part in this evaluation completed a calibration stage to prepare the system for their specific alpha variations. The games implemented included a tile puzzle which contained a hidden image that could be revealed through BCI interaction and then correctly ordered using gestures. The other two games had the player following a thief down a city street and a river puzzle where the objective was to extract treasure from the river's flow. The puzzles utilised BCI input to adjust the player's speed and reduce the flow of game time. Research conducted by Bos et al. (2008) in the development of the BrainBasher game as well as later work by de Laar et al. (2012) provided a foundation for the exploration of BCI input in games.

15 participants were recruited to take part in the experiment. It was found that there was a high level of challenge particularly in changing mental states. It was suggested there was replay-ability and a medium level of entertainment. In its current form the ease of use was rated poorly, largely due to the inaccuracies of the voice recognition. Limitations of the BCI system were also identified with muscle movement accounted for a very high proportion of the time spent in an apparently relaxed state. In the future it is foreseen that further testing will take place with more complex games and the system will be developed to explore this type of technology's potential in other areas of research (such as, education, health, and disability)

## 2. BACKGROUND

In recent years there have been many studies investigating the usability of brain computer interaction systems. Some of these studies have been focused on interactions in a video game environment. Many of the research projects using brain interaction have used the input as a core element of gameplay. One example of this is a game titled BrainBasher (van de Laar, 2009). In BrainBasher,

**Figure 1**, the player was required to complete actions by using imagined and physical movement of the hands. They would score points based on how quickly and accurately the actions were performed. Games are one of the early adopters for new paradigms due to the drive "by gamers continuing search for novelty and challenges" (Nijholt et al, 2008b).

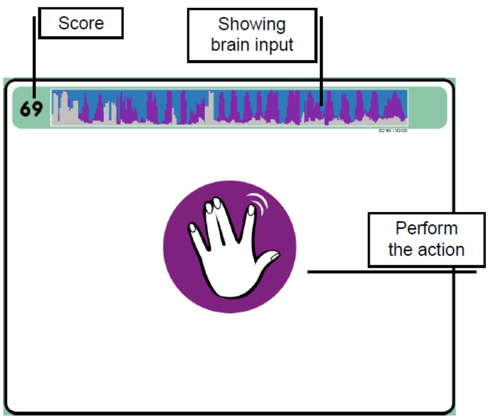


**Figure 1: BrainBasher (van de Laar, 2009)**

Providing natural interfaces that allow the control to be interpreted by the computer is one way that novelty and challenge can be included. The idea of using natural interfaces is one among many other attributes the paper by Nielsen (Nielsen, 1993) suggested as the future for computing. To extend this a step further toward a full body experience is proposed by this paper. Despite the variety of sample tests using brain devices in the area of games development there has not yet been extensive study into the combination those devices with the Microsoft Kinect or similar devices. By combining a device such as the Microsoft Kinect the amount of interaction that can be provided expands.

The Emotiv EPOC was selected as the device for use in this experiment for its cheap cost and larger number of inputs when compared to other devices. The MindFlex Duel (ThinkGeek) a concentration based two player game, and Neurosky (Neurosky) a more open ended platform intended to detect basic states of the brain were identified as other examples on the market of similar capabilities. Novel forms of interaction do need to be cheap or at least have a future where the devices will become marketable for the masses. The significant downside of using devices that are going to be cheap is the reduced quality of output being read from the devices as was found during the course of this experiment.

The Emotiv device as its name suggests is designed with the purpose of detecting emotional states. These states are determined by using a variety of different rhythmic waves such as alpha waves that the brain produces (Niedermeyer and Da Silva, 2004b, Niedermeyer and Da Silva, 2004a, Niedermeyer and Da Silva, 2004c). Alpha waves provide a reference to the mental effort of the user, allowing for a differentiation between relaxed or calm states and active or attentive states.

By simply using relaxation and concentration type emotional states the gameplay experience can be augmented. Additional brainwaves that could benefit the experiment could include beta and perhaps gamma waves. This type of emotional BCI has been researched by Garcia–Molina et al. (2013) who determined a subset of emotions that can be used to derive any other emotion. The area of BCI is continually developing new methods and devices that improve on those that are available by expanding into areas like the development of controlling virtual characters in virtual environments using just a BCI input (Lécuyer et al., 2008). With the improvements to the BCI recognition in coming years it may become a more accessible means for interaction for those with disabilities. Certainly the full body experience with the Microsoft Kinect could be adapted to just be the upper body or a very select set of body parts.

Games such as BrainBasher require low acceptance threshold for the comparison between actual and imagined movement to account for the variation between players. 60% was identified as a threshold that was used successfully in the example of BrainBasher (van de Laar, 2009). Other studies have taken a similar approach to those in BrainBasher using the brain as the primary method of control. An application called AlphaWoW by (Bos et al., 2010) was one of a few applications created by these researchers to test the combination of brain computer interfaces (BCI), and human computer interaction (HCI). Approaches such as “inner speech” (reciting a mental spell), “association” (feeling what you want to be), and mental states were used to change the player’s character between forms. The application was using the game World of Warcraft and simply allowing the changing between a bear form and a humanoid form. Another part of the study used an application called “Bacteria Hunt” (Bos et al., 2010) that utilised the player’s alpha state as a speed modifier to control movement in combination with the keyboard.

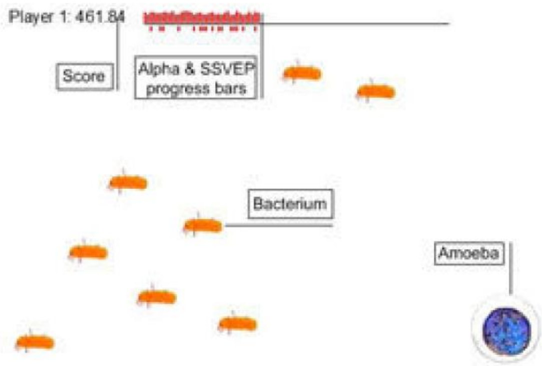


**Figure 2: Bacteria Hunt (Bos et al., 2010)**

Interfaces and HCI methods have been studied at length. The current standard paradigm uses an approach of Windows, Icons, Menus and Pointers (WIMP) as the means for interfacing with computer systems. With the development into areas such as Microsoft Kinect and BCI the standard WIMP interface can be expanded into a wider set of formal interactions. Gesture interaction and natural language interfaces provide for a potentially wider array of options than a mouse and keyboard allow for. Manipulation of shapes using translation, scaling, and rotation are methods that can be seen to be used for testing these types of input methods. For example the research of Hauptmann observed how many fingers or actions participants used to attempt to manipulate graphical objects using the above interactions (Hauptmann, 1989).

Multi-hand input has also been tested using various types of devices in the work of Jacob for example (Jacob, 1996). Multi-hand interaction is something that the Microsoft Kinect is well suited for as it tracks the skeleton and the hands are included. Another example where multiple hands have been used for compound tasks is the work of (Kabbash et al., 1994). In this research it was found that the best performance came from applying existing skills that would be used in everyday life to the problem solving. It also claims that using a (Fitts, 1954) type analysis is not sufficient to determine the performance of an input method. The reason given for this is that the “cognitive load must also be considered” (Kabbash et al., 1994). In addition to all this it was discovered that it is possible for two hands to be worse than just one. The commonly cited issue of trying to tap the head while rubbing the stomach was used as such as example of a case where this is not ideal.

Evaluation of games provides an additional factor of complexity. (IJsselsteijn et al., 2007) have suggested that the flow of gameplay and the immersion of the player within games need to be considered in addition to the usability during evaluations. Thus, as part of the testing the participants were asked in the questionnaire to respond to questions that correlate to these types of evaluation methods as part of the qualitative data. (Gürkök et al., 2012) was an inspiration for the experience based evaluation taken in this study.

# 3. METHODOLOGY

## 3.1 GOALS FOR TESTING

The experiment discussed in this paper was designed to evaluate the potential use of alpha waves as input into a gaming system. This was a core component of a larger project currently under investigation looking at improving a subject’s ability to control a relaxed or concentrated state. The intention is to develop tools for training a person’s mental states.

For the experiment presented here there were a number of specific goals that were to be addressed:

- determine if the inclusion of BCI with the Microsoft Kinect provides any modification (positive or negative) to the: entertainment, challenge, replay-ability, and other similar attributes.
- determine which brain waves captured by the Emotiv EPOC brain device will be useful for determining the qualities required to play the outlined games.
- determine how readily individuals can control their own brain waves for their own success.

### 3.2 TESTING APPROACH

Participants of the study were required to play through a series of three different puzzles using the Microsoft Kinect and Emotiv EPOC to provide the necessary input so that they may overcome the challenges. The puzzles provided a method of comparison by providing varied interaction using the Microsoft Kinect and Emotiv EPOC. Participants had the interaction methods explained to them prior to each of the puzzles. They would position themselves at a distance of 2m from the Microsft Kinect sensor facing a display while wearing the Emotiv EPOC. The applications were developed with a combination of Microsoft XNA with C#, and a MATLAB server receiving the BCI input that was then relayed to the game application.

After engaging with the puzzle games the participants were asked to complete a questionnaire. The questionnaire provided qualitative and quantitative feedback in areas relating to the individual's background, relevant experience with similar devices, usability, playability, workload and other attributes using a Likert scale (using 0 to 10) and a NASA Task Load Index. The target group were students and academics at Flinders University. It was anticipated that there would be previous exposure to video games.

### 3.3 APPLICATION OVERVIEW

The application provided a set of three different puzzles. These puzzles were named: Tile puzzle, Street puzzle, and River puzzle.

When a participant was ready they would start the game from the main menu and complete each of the puzzles listed above in the order provided. Each puzzle was designed to test the participant in a different way and force them to "think" differently. For all the puzzles the participants were provided with an information screen prior to the gameplay. This screen set the scene providing the goal to the user and explained how to complete the puzzle. These screens were brief as to not overwhelm the participants. Once the participant confirmed they were ready, the relevant puzzle would begin. A function to pause gameplay using either keyboard or verbal command was included, but not indicated to participants. This was to keep the factors the same for all participants.

The puzzles were loosely joined together with a simple storyline. The tile puzzle set the scene and had the participant trying to unlock a secret chamber of a tomb. Upon opening the tomb the player was required to chase the thief (who had already stolen the treasure) in the streets of a market. When they caught up to the thief, treasure is thrown into the river and during the river puzzle the player must collect as much as possible before it has floated away.

#### 3.3.1 TILE PUZZLE

The first puzzle that participants encountered was the tile puzzle. This puzzle was designed to be the easiest and give participants the most freedom to overcome learning curves involving the Microsoft Kinect and the Emotiv device. The aim of the puzzle was to arrange a grid of 3x3 tiles into the correct configuration in the shortest possible time. This may, under traditional input systems be considered a simple task using a mouse and keyboard alone. This task required the participant to use simple physical interactions (hand gestures) to manipulate a cursor, vocal interactions to provide the direct engagement, and mental interactions requiring concentration to 'reveal' the solution to the puzzle.

**Figure 3: Tile Puzzle (Initial State)**

The tiles of the puzzle initially depicted seemingly random images that individually do not make sense. (Figure 3) The more the player is relaxing the more the hidden images became overlayed to show the solution, Figure 4 demonstrates the semi-transparent overlay. By using the cursor combined with phrases such as “select tile”, “drop tile”, “swap hands”, “rotate tile left”, and “rotate tile right”, the participant was expected to place all the tiles into the correct orientation and position in the grid. Relaxation was used as the trigger so that participants would need to relax long enough to understand what they needed to do next. Then as they began to concentrate on their objective the overlay would disappear. This was to make the task more interesting than having a participant continually concentrating. It also allowed for experience in trying to swap between the two mental states. Table 1 summarises the interaction methods used as part of this puzzle.

| Interaction | Reaction |
|---|---|
| Concentration | The bar will begin to decrease as this state is sustained and the hidden image would fade out. |
| Relaxation | The bar will begin to increase as the state is sustained and the hidden image would fade in. |
| Hand movement | Controls a visible hand cursor indicating what to select and where to place tiles back down. |
| Voice command “place tile” or “drop tile” | When a tile is held by the hand the tile would be placed into that cell. If an existing tile is there it would be swapped with the one in your hand. |
| Voice command “change hands” or “swap hands” | Changes the current hand used for the physical interaction between the left and right hands. |
| Voice command “grab tile” or “select tile” | When no tile is currently held this will attach the tile underneath the cursor to the cursor. |
| Voice command “rotate tile left” or “rotate tile right” | Rotates a currently selected tile by 90 degrees to either the left or right. |

**Table 1: Summary of Tile Puzzle Interaction Methods**

A variety of approaches were attempted in relation to how the BCI input would be handled for this puzzle. Difficulties were found that made the task of sustaining a particular mental state for a period of time too difficult. To initially get around this, methods of artificially sustaining the values were considered. The attempted solutions did not appear to work as intended. So a simplified approach was used that made this puzzle and the other puzzles easier to handle. The approach was based on taking a calibration to set a customised scale of 0 to 1. The calibration took two sets of 20 second readings to determine a minimum and maximum alpha wave reading. At intervals of 1 second during gameplay the application would observe the current reading and rescale it to find if it was closer based on custom thresholds to concentration or relaxation. This would result in a net gain or net loss on a 0 to 100 bar scale that is shown to the left in

Figure 3, Figure 4, and Figure 5. The bar made it simple for participants once explained for them to build up a state and sustain it for long enough to complete tasks.

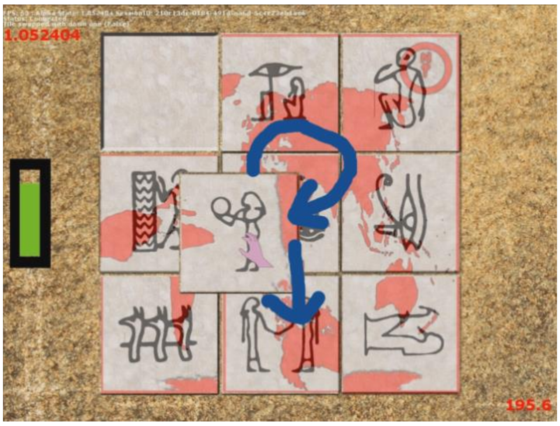


**Figure 4: Tile Puzzle (Revealed and Transitioning)**

The tile puzzle was chosen as the first task for two reasons. The first is that with no time limit they could become used to manipulating the Emotiv device and learning how to interact with the Kinect (particularly if they had never used it before). The other is that although simple, the task provided useful information about the capability of participants to complete static puzzles while considering the factors that are impacting on the game. The puzzle requirements that they had to consider may have been hampered by their need to concentrate to reveal the pattern while still thinking about what the next 'move' will need to be; along with how they are positioning themselves and performing vocally.


**Figure 5: Tile Puzzle (Puzzle Complete)**

One extra point of challenge and frustration was the limitation of the speech recognition. Often it appears to function well; however, it doesn't always recognise accurately what is being said (as was the case for many during this study). This can lead to frustration and loss of concentration. For future experiments the voice component of interaction for this task would be removed in favour of a fully hand gesture based input scheme.

### 3.3.2 STREET PUZZLE

The street puzzle was the second puzzle participants encountered. It required more active thinking than the first tile puzzle, so was made to be very simple so that there was very little learning curve. Gameplay involved the character chasing a thief from a bird's eye view on rails system through a market place. The player had to stay close enough to the thief that they don't lose them, but not so close that the thief would become alerted to them being there. To provide a more interesting experience, the player had to avoid obstacles in the game world, including: market stalls, rivers, bystanders talking, and crates. The thief automatically avoided the obstacles by following a pre-generated path.

Figure 6: Street Puzzle

| Interaction | Reaction |
|---|---|
| Concentration | The bar will begin to increase as this state is sustained and the player would speed up. |
| Relaxation | The bar will begin to decrease as the state is sustained and the played would slow down. |
| Raising two hands above shoulders | Halts movement of the player character. |
| Stepping from side to side | The further to the left and right a player steps will change the lane the player is in. |

**Table 2: Summary of Street Puzzle Interaction Methods**

To control movement, the player's hip centre was used to determine the centre of their body. To change lanes the player would step a proportion worth of the screen to the left or right. Failing to step aside to avoid obstacles resulted in a collision and slowed movement; risking losing the target. The player's in-game character speed was conversely related to their relaxation state, for example the higher the relaxation the slower the speed. Periodically the thief could randomly stop for a short period of time. It was particularly important that the participant kept distance during this time, so there was a way to make their character stop completely. By raising both hands above their shoulder height and keeping them there as if to surrender the character would stay stationary until hands are lowered.

The purpose of this challenge was to determine whether the participant was capable to keeping track of multiple actions at the same time while maintaining a certain level of brain functionality. They needed to consider how their position was changing relative to the thief while still ensuring they were not colliding with too many other objects.

### 3.3.3 RIVER PUZZLE

The river puzzle was the last puzzle that participants had to complete. The aim was to collect as much treasure as possible from the river. Complicating the task was the combination of valuable and junk objects moving relatively fast across the screen. Junk awarded the player with no rewards, and so it was best avoided. To assist the interaction with this puzzle, the player needed to relax. The input from the Emotiv EPOC caused time to appear to speed up or slow down. Relaxing caused time to slow down with a lower speed of 0.5x speed, and concentrating would speed the motion up to a potential high of 1.3x normal speed. To grab the treasure the player used a cursor controlled by their hand and selected then dragged those items into an 'inventory' area located at the bottom of the screen. Treasure was coloured yellow and junk coloured black to make it easy to distinguish the two. The puzzle can be seen in Figure 7.


Figure 7: River Puzzle

| Interaction | Reaction |
|---|---|
| Concentration | The bar will begin to increase as this state is sustained and the time would appear to speed up. |
| Relaxation | The bar will begin to decrease as the state is sustained and the time would appear to slow down. |
| Placing the hand over an object | Holding the hand over an object for a short time would attach it to the hand. This object could be deposited in the inventory at the bottom of the screen before collecting another. |

**Table 3: Summary of River Puzzle Interaction Methods**

## 4. RESULTS

The testing phase of this research had 15 participants. 47% of participants were in the range of 21 to 30 years of age with the remainder split evenly between 18 to 21 and 31 to 40 groups. 87% indicated they were heavy computer users with 31+ hours a week spent on the computer. Of those who indicated heavy computer use, 67% indicated they spent less than 10 hours a week playing games. It was indicated by many though the number of gaming hours may have been larger if the study had not taken place during a university semester. 80% were students with the remainder academics. Only 2 of the 15 participants were female.

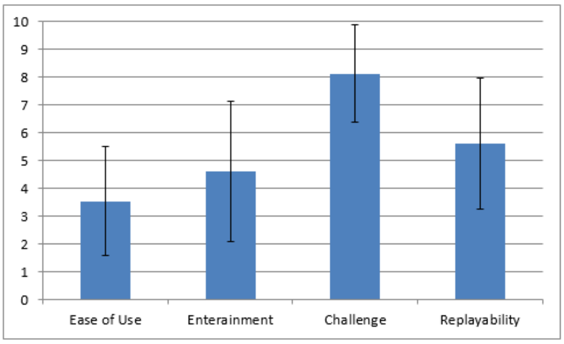


**Figure 8: General Gameplay Responses**

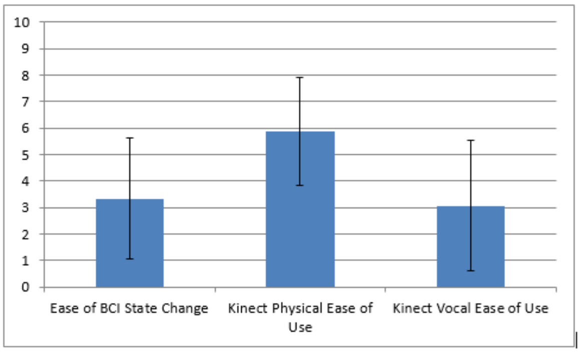


**Figure 9: Ease of use with specific HCI components**

Figure 8 shows that participants indicated on average there was significant challenge found in the puzzles. The ease of use was marked as being particularly low, and a medium level of entertainment. The replay-ability was responded to with a larger score though. This suggests that although there was an inherent challenge and difficulty using the system, the participants had indicated an interest to play the puzzles again or to try the technology out in some similar way.

In Figure 9 it can be seen participants found the physical aspect of the Microsoft Kinect input to be easy. They found the controlling the BCI input and use of voice inputs to be on average equally difficult. Voice input was for many a particularly taxing task. The first puzzle was the only one to use voice input, but it was the cause of almost all 40% of the participants who failed to pass the task.

Figure 10 indicates the interest in the technologies and how interested they would be in seeing those technologies in the market. The combination of inputs was rated only around 5.3 on average out of 10. This suggests there is a lot more work to be done as indicated in the previous figure with the difficulties encountered. There was a high interest at an average of 7 for BCI being used in marketed products. There was interest shown as well in the combination of inputs being used in the market, more so than the rated score for the interest in the combination itself.

A NASA Task Load Index that was completed by all participants gave results ranging between 58 and 80.7 with a mean average of 69.1. This does indicate a reasonably high load for the task as a whole. The participants indicated the highest areas of difficulty were the mental challenge and frustration. Figure 11 provides a distribution of the overall workload scores recorded by the participants. As seen in the chart, almost all participants observed a workload score between 60 and 79, indicating the effort to complete the tasks was taxing (workload scores are rated from 0-100).

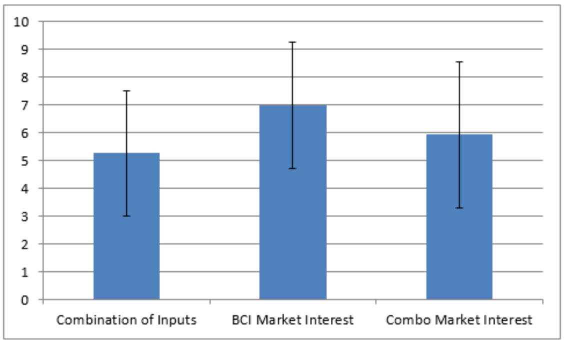


**Figure 10: Combination of Inputs and Marketability**

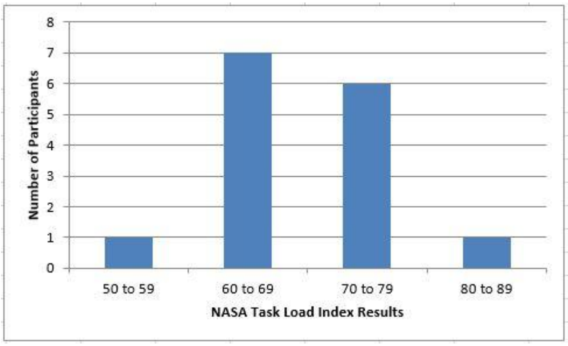


**Figure 11: Distribution of NASA Task Load Index Rankings**

Data was also collected by the application including information about the actions of the player, and details that could be useful if further analysis were done in detail for replaying content. **Figure 12** shows a comparison between the three puzzles based on data collected by the application.

The most difficulty that was had occurred during the tile puzzle. Participants who were successful in completing the puzzle took an average of 983 seconds. For those who were unable to complete it an average of 593 seconds was spent attempting prior to being taken to the next puzzle. There was an average of 4.2 failed voice recognitions per person for those who were successful. Those who failed had an average of 15.8 failed recognitions. 71% of the time was spent in a relaxed state and 29% in a concentrating state. The aim of the puzzle was to become relaxed, so this indicates there was too little challenge or there were other issues occurring. 40.4% of values reported by the BCI input were repeated. This was most likely caused by automatic ignoring due to a threshold maximum. Going over this threshold indicated the input was more likely to be muscle movement causing a peak in EEG rather than real EEG values.

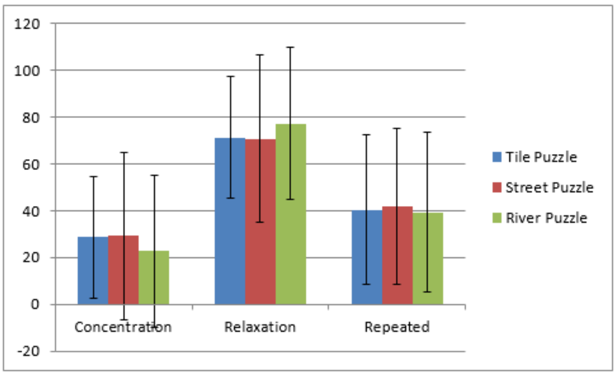


**Figure 12: Comparison of Percent Time Spent in EEG States**

Most people found the street puzzle to be particularly easy and only a couple failed on their first attempt from staying too close to the thief. 29.2% of the time was spent in a concentrating state and 70.8% in a relaxed state. The high movement requirements of this challenge, with side stepping, is assumed to be the reason for high values with a repeated average of 41.8% of values.

Finally, the River puzzle was a time based activity and therefore impossible to fail. 4 participants had 0 concentration readings on this task suggesting some sort of issue. 22.7 % of the time was spent concentrating and 77% in a relaxed state. On average 19.5 treasure objects were collected with 38.9 average missed.

Technical issues encountered with the BCI equipment included:

- Difficult to reliably control your own outputs to the headset from little use.
- Calibration stage can make or break the game depending on how closely it represents an accurate reading.
- One second delay between updates in the system may have reduced usefulness of data.
- Muscle movement heavily contaminated data. For example clenching of the jaw could give 100 times the normal expected value.

## 5. FUTURE WORK

There are a number of areas of development that can be explored for future work for the applications of this research. The most directly related would be the continuation of work presented in this study. Only one possible solution to combining the Emotiv EPOC and Microsoft Kinect was used. There was also only one session per participant. Multiple sessions could be used to establish learning curves and further investigate the viability of this technology.

Another area for future research could compare the input devices used in this study against other devices such as the NeuroSky or another piece of BCI hardware. The Wii remote or Playstation Move could be replacements for the Kinect's gestural input. Although additional methods would need to be used to handle the lack of full skeleton that is used with the Microsoft Kinect implementation. A multiplayer experience is another possible path for this research to take. The difficulties experienced in the single player puzzles could make players feel less disadvantaged if they are competing against another individual. This approach for BCI can be seen already in products such as the Mindflex Duel (ThinkGeek).

Games are only one of many areas for potential future development using this combination of inputs. (Van Erp et al., 2011) provided a list that was presented in a literature review of areas for where BCI might be included. This list included: control of devices, user state monitoring, evaluation, training and education, gaming and entertainment, cognitive improvement, and safety and security. Although the full body type experience provided by integrating BCI with the Microsoft Kinect is a more specialised type of input it could be used for enhanced natural user interfaces. Consider the interfaces presented in movies such as Minority Report (Dreamworks and 20th Century Fox 2002). Minority Report is an example of a science fiction movie including both a multi-touch natural user interface and the use of biometrics as forms of computer input. With the combination of inputs demonstrated in this study the potential for these forms of science fiction interfaces may be realised. Returning to the gaming aspect it could also be developed further for working with people who have different forms of physical and mental impairment. Natural user interfaces allow for expression based on input and could allow sufferers of debilitating illnesses to experience a different form of enjoyment.

More specifically this technology could be applied to education, health and disability in a number of different ways:

- In the area of health this system could be used for a patient analysis of their physical and mental capabilities. Using puzzles as were used in this pilot study would provide something interesting for a patient to do while their ability to complete mental or light physical tasks is assessed. This would be particularly true for if the analysis was to determine the level of stress someone is experiencing from varying levels of complexity.
- Rehabilitation of disabled individuals could be assisted with this form of full body input. Games could be designed that suit people with varying mental and physical disabilities that provide encouragement during their recovery.

## 6. CONCLUSION

In conclusion, the focus of this study was on the inclusion of BCI with the Microsoft Kinect. The interest in this was only rated with a medium level by participants (4.6 out of 10). The issues that were discussed in this paper suggest why this number may be so low. This was only a pilot study, but it has shown the technologies can be used together and allow expansion into new areas. In future studies it is advised that participants where possible should be allowed multiple sessions with the equipment as a form of expanded testing.

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