User requirements of games designed for people with developmental disabilities

Taylor Gotfrid
University of California, Santa Cruz
1156 High Street
Santa Cruz, California
tgotfrid@ucsc.edu

ABSTRACT

This study presents the work on the development and evaluation of web based applications for people with developmental disabilities (DD) in collaboration with Hope Services, a California based non-profit organization that provides services to improve the quality of life for individuals with DD. These web applications are HTML-5-based and designed for Android and Windows tablets. These web applications are targeted towards people with DD of all ages. The system includes two games, one that aim to teach basic skills such as object relations (e.g. smaller, larger, less, more) and another that aims to help users learn about causality and or improve upon cognitive skills (e.g. memory, focus, and problem solving). User evaluation suggests that these games provide a good platform for people with DD to increase their independence, provide an additional or alternative learning system, as well as improve their life satisfaction.

1. INTRODUCTION

For people with DD performing daily tasks that come easy to people with normal cognitive health, can be difficult if they never successfully developed these basic skills. As a consequence, people with DD rely heavily on other people, such as those in charge of their care, to perform basic activities for them. However this dependance limits their independence, participation within society, and their overall life satisfaction.

Most applications that are currently available and similar to these applications are designed for children, cost money, or simply do not exist. We designed two games so opportunities would be more widely available for adults who were denied learning experiences. We also designed these games so adults could play and learn skills while remaining engaged with age appropriate material.

Current technologies have the ability of assisting people with DD in academic, employment, and independent living environments, and by designing games such as the two in this study, people with DD would be able to have a more significant role in society. Studies have shown that current technology has the ability of improving how people with DD perform academically [1][5]. Before touch screen technology was invented, studies showed that computer-aided systems promoted independent task completion as opposed to card-based system [2].

The study by G.E. Lancioni et. al examines whether a computer-aided system or a card system would improve independent task performance for six individuals with severe DD. The first system was card-based and had images to describe instructions. The second system was computer-based system and also had images to describe instructions, but these instructions were shown on a portable device. The results of this study show that users had a larger percentage of correct steps using the computer based system over the card-based system [2]. The study by Michael L. Wehmeyer et. al [3] conducted a single-subject design meta analysis of technology use by people with cognitive DD to support employment activities. This study examined thirteen studies conducted over the last 25 year. The technology in these studies ranged from audio prompting devices, video assisted training, desktop computers, and augmentative and alternative communication. These technologies were applied to address a range of employment related activities such as social skills, task sequencing and transition skills, vocational task performance and completion, food preparation skills, vocational assembly skills, general cleaning skills, and computer use. This study indicated that technology use coupled with individuals with DD resulted in fair effects regarding employment related situations.

The study by Patricia O'Malley, M. E. B. Lewis, and Clair Donehower [4] investigates whether iPads in an academic environment increase task completion, improve basic math skills, or reduce noncompliant behaviors of several students diagnosed with autism spectrum disorders. This study also aimed at identifying the advantages and disadvantages of using an iPad in addition to classroom instruction. This study found that students demonstrated greater independent task completion while using the iPad, as well as an increase in their math scores. The results also indicated that this technology was socially valid, improving the student's engagement, independence, and interest in content.

The purpose of this study is to evaluate an alternative method of providing basic skills to people with DD. This study evaluates the effectiveness of two web-applications' abilities to evaluate the user's cognitive capability. This paper describes the process used to create the two games, but only evaluates the player's portion of the web-apps, not the interface meant for caregivers. The purpose of the Concept Game is to assess the user's understanding of object relations such as longer, shorter, fuller, emptier, etc. The purpose of StarBlaster is to assess the user's understanding of causality and improve their cognitive skills such as focus, memory, and problem solving. This study also evaluates the appropriateness of the game and its target demographic, determines if performance in game transfers to improvement performance in the target real-life tasks, and identify areas of improvements for both games.

2. METHODS

Here we present the methods that were used to gather the system requirements for these alternative methods of providing lessons on basic skills and games that improve cognitive skills to people with DD. Then the final primary system requirements are presented.

2.1 Gathering System Requirements

Current systems that are similar to the Concept Game are designed for children, which was the main motivation behind creating this game. These systems are appropriate for teaching children these object relations, however for adults, these games are demeaning, not motivating, and boring. Regarding StarBlaster, there are no games that currently exist that are designed for assistive technology. In regards to both of these games, no current systems track player statistics for caregivers or doctors to analyze.

To define requirements for the games, we consulted with Imagine!, a non-profit organization in Colorado, developed personas, usage scenarios, storyboards, wireframes, and low-fidelity prototypes using IDEO method cards. *Fly on the Wall* was used to observe people with DD playing with iPad applications with the help of their caregiver. The *Personal Inventory* card was used to identify what objects or subjects the user found important. This will influence the positive reinforcements used in a later, more-encompassing system. The *Shadowing* and *A Day in a Life* technique was used to identify the daily activities and limitations of potential users.

We researched existing tablet apps that provide lessons on basic skills or improve cognition that could potentially help people with developmental disabilities. Apps we found that were similar such as (will fill in later) were tailored for children, which would not be appropriate for adults with DD.

We considered possible restrictions that the users may have and tried to create games that would accommodate for a variety of cognitive, physical, or a combination of such limitations. Some of these features include audio prompting, positive reinforcement, and gameplay.

2.2 Primary System Requirements

Before beginning the primary system requirements, there are several details about the current system that need to be addressed:

1. The primary user will be adults with DD.
2. The system currently only focuses on gameplay, the caregiver interface is not currently in place.

The primary system requirements for gameplay are as follows:

- The system must be computer-based.
- The system must be age appropriate for the target audience, therefore the system must not be too childish or demeaning for adults, but not too complex that children cannot also utilize the system.
- It must be accessible for people with DD who also may or may not have other accompanying disabilities such as vision or motor.
- The system must have lessons that can help people with DD can learn basic skills and improve their cognitive skills.
- The games must have different levels of difficulty to assess the users' progression of skill over altering levels of challenge.
- The system must collect user data that analyzes the user's progress. The data must be secure to preserve patient confidentiality. Data would also make the user's progress accessible to their caregivers to thereby tailor future therapies or lessons.
- The app lessons must include:
  - Provide positive reinforcements for the user as incentive to continue the lesson and make it more engaging.
  - Avoid punishing the user for choosing the incorrect answer, and instead use it as an opportunity to teach them.

3. LOW FIDELITY PROTOTYPE

In order to properly plan out the design for the system, an iterative approach was taken to plan out the gameplay step by step. This provided a top-level idea of the game's performance and allowed an evaluation of each step of the design to decide if changes were necessary.

3.1 Storyboard

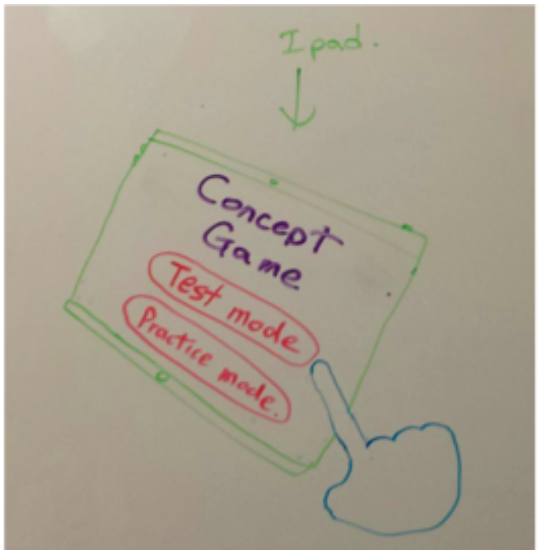
The first step in the iterative design was to create a storyboard. This required us to consider how the caregivers and users would interact with the system. The scenario begins with both the user and their caregiver.

To take into account for any limitations that the user might possess, the system requires the help of the caregivers to set up the gave and to navigate the menus.

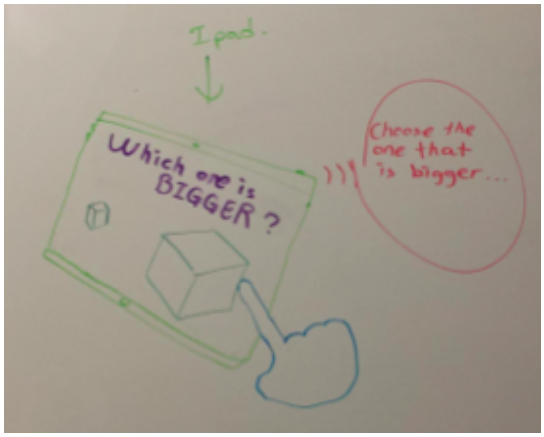
The caretakers would log into the system with their account information and select the player that will then proceed to

play the game. This is necessary in order for the caretakers to be able to track statistics for the particular player.

After initializing the game, the caretaker then passes the tablet to the player so they may begin to play the game. This initialization includes choosing whether to play in Test Mode or Practice Mode. Practice Mode will not record any progress statistics, but Test Mode does.

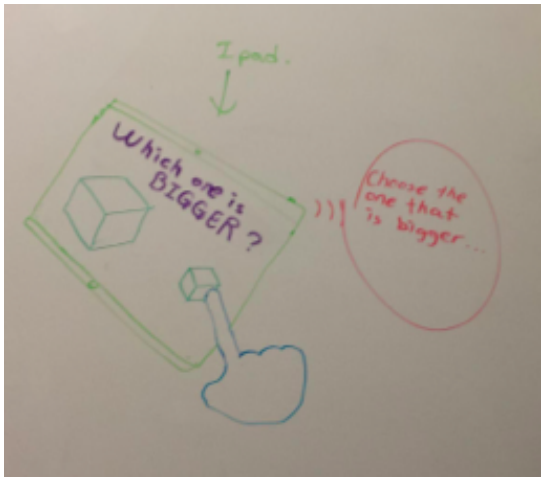


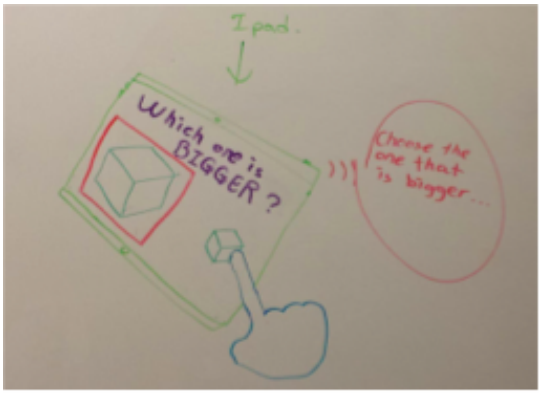
After initializing the game the caretaker passes the tablet to the player so they can begin to play the game. For the Concept Game, the player is presented with a question and a choice between two or three images.

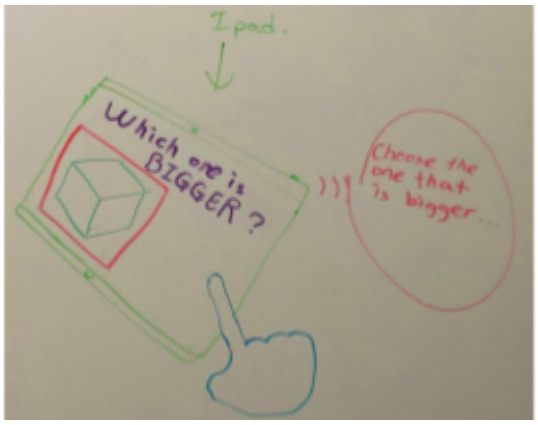


If the player chooses the correct image, a video will be played. This video is meant to be customizable based on each player's individual interests. This is meant to provide the user with positive feedback.

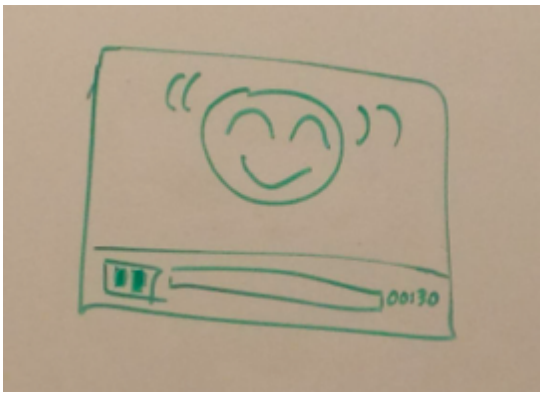
If the user selects an incorrect image, the correct image will be boxed to indicate to the player to select it. If they choose incorrectly again, the incorrect choices will be removed. This is to remove any negative feedback the player might receive from being incorrect in the game.







Once the user answers correctly, a video will play again, and the game will progress to the next question.



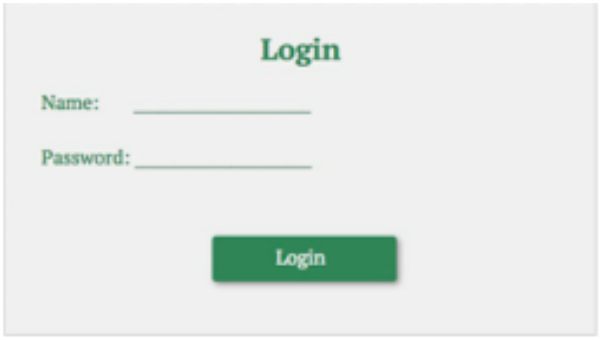
3.2 Wireframe

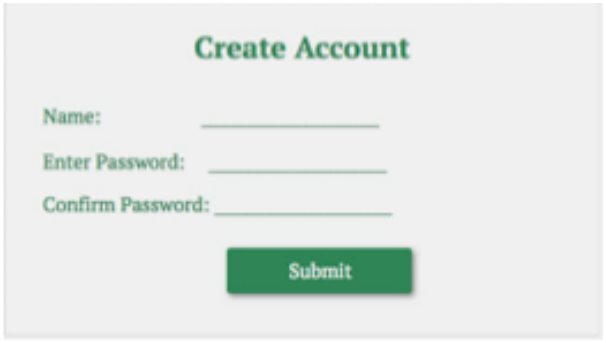
After establishing the basic mechanics of the game, wireframes were created for both games. This provides a more visually accurate representation of how the final product should look.

Concept Game

The main screen has three options for the caretaker: one for Practice Mode where statistics are not tracked, a Login option to log into an existing account, and a Create an Account option to create a new account if one does not previously exist. To create a minimalist system, plain solid colors were used for the main screens.

Caretakers can login with an existing account or create a new one if one does not already exist for them.

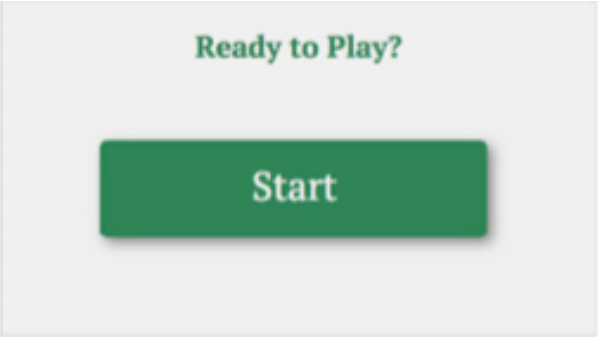




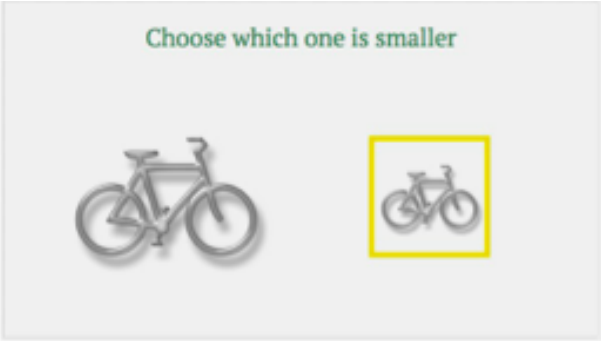
Caretakers must then select a player's profile from the players that they are accountable for, or they can create a profile for a new player.

A caretaker can choose to configure individual settings for the individual players. From this menu the caretaker can choose for the player to play the Concept Game, review their statistics, or can configure the positive reinforcers.

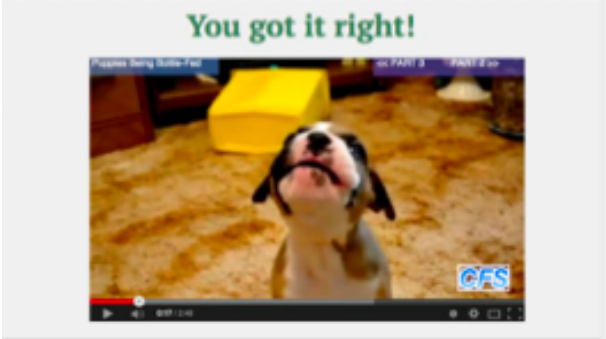
If the caretaker chose the Test Mode button, they would pass the tablet to the player, and they can begin to play the game. A large start button was necessary both to indicate to the player that they are about to play the game as well as to accommodate for any players with physical disabilities that restrict their range of motion or preciseness of screen taps.



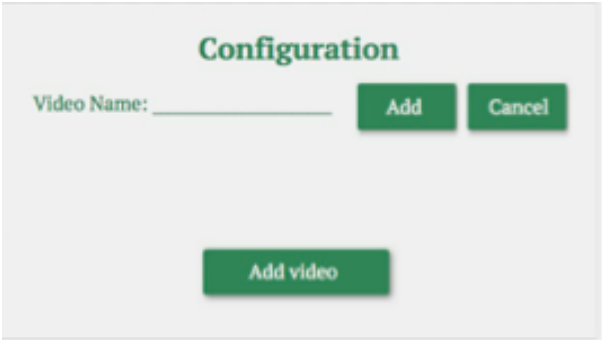
The player is presented with a question in text and over audio, and given either 2 or 3 choices. If they choose the incorrect answer, the game will guide them towards the correct answer. The game possesses no negative feedback. If the user chooses the incorrect answer the correct answer will be highlighted. This will help guide the player to the correct option. This removes any negative feedback from the game.

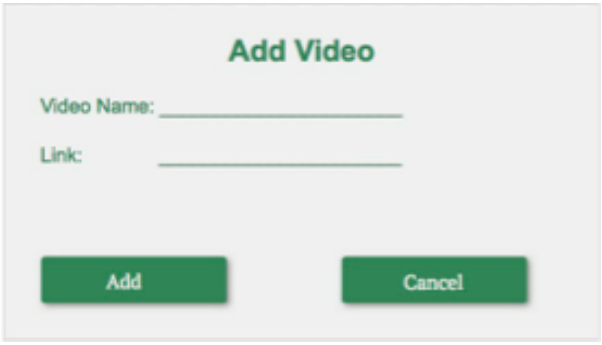


Once the player answers correctly, the game will display a video as positive feedback for the player. These videos are chosen from one of the caregiver's menus.

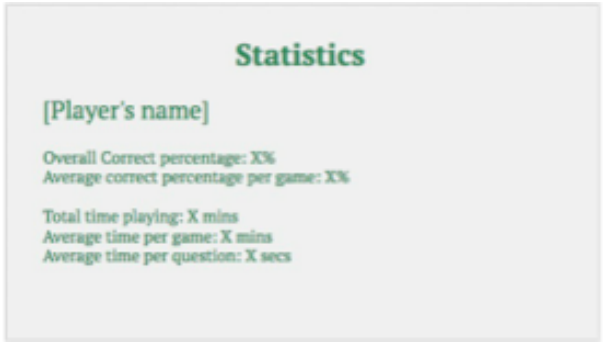


If from the menu before the player began the gameplay, the caretaker had chose the Configuration button, they would have been redirected to this screen. From these next two screens the caretakers can choose to add a video to the player's list of positive reinforcement videos that play when the user chooses the correct answer.





Then if the caretaker had chosen the Statistics button, it would lead them to this page where they are able to see the individual statistics for that particular player.

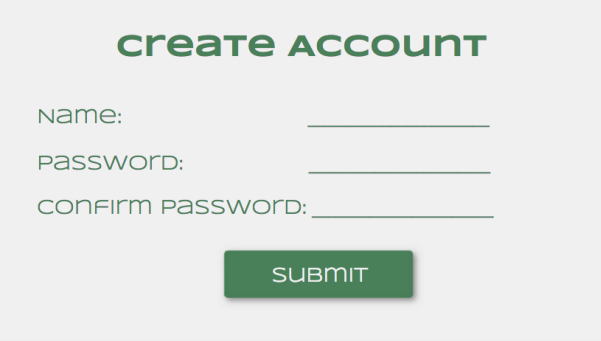


StarBlaster

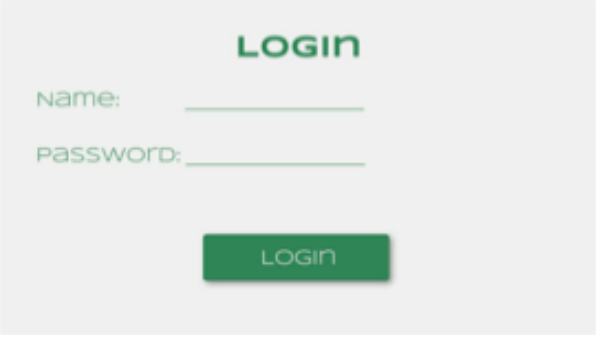
For StarBlaster, the menus that the caretaker navigate through are essentially the same as the ones for the Concept Game.

In the first menu, again there are three options: one for Practice Mode where statistics are not tracked, a Login option to log into an existing account, and a Create an Account option to create a new account if one does not previously exist. The design of the menus are similar to maintain consistency.

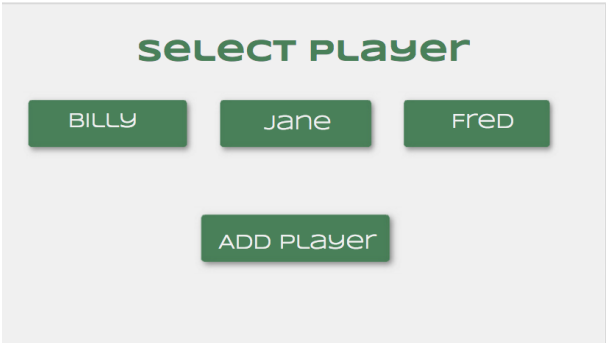
If the caretaker chooses the Practice Mode option, they will be redirected straight to the gameplay. If the caretaker chooses to create a new account, they will be redirected to the Create an Account page.



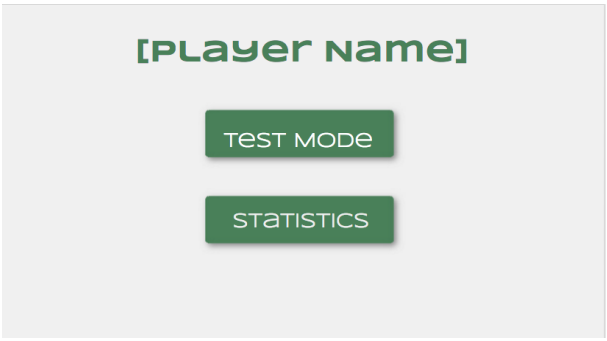
If the caretaker chooses the Login option, they will be asked for their credentials.



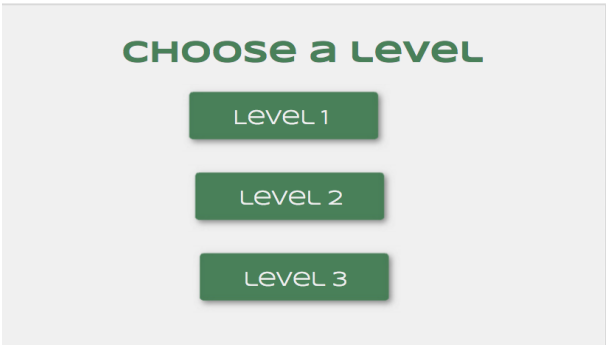
Once the caretaker has logged in, they will be redirected to a page to select the individual player who will be playing the game.



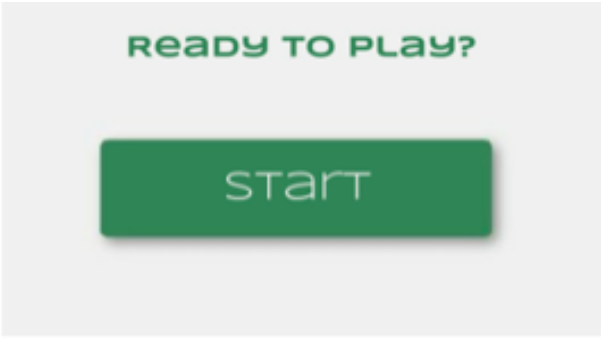
Once the caretaker has selected a particular player, they will then be asked whether they want to start the gameplay or view the statistics for that player.



If they choose to begin Test Mode, they will be redirected to a page where they need to select a particular level for the user to play.

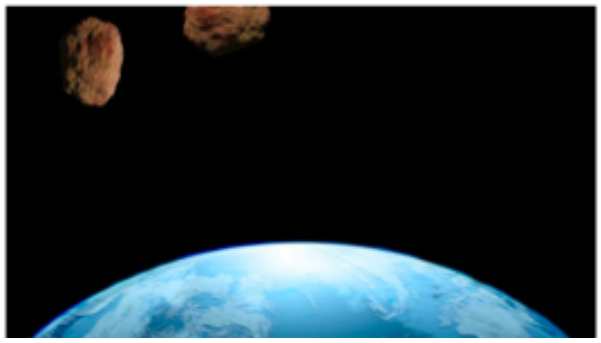


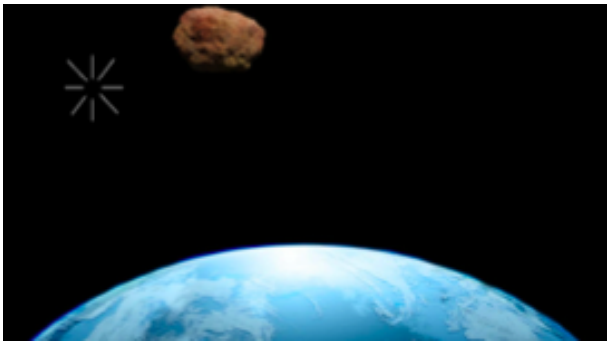
Once the caretaker has selected a level, a similar Start page as the Concept Game will appear. At this point the caretaker would transfer the tablet to the player.



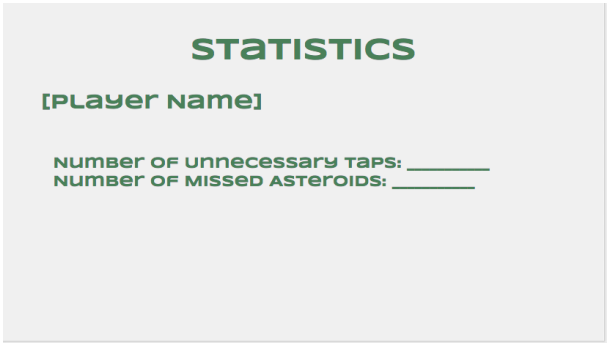
This game possesses three levels, but the objectives for each level is the same. The user must tap the screen whenever they see a rock. Whichever level the user is playing, different

objects fall from the top of the screen. The goal for the player is to tap anywhere on the screen when they see a rock. An audio prompt plays at the beginning of the game, and will repeat itself whenever a player taps the screen when there was no rock present. If the user succeeds in tapping the screen when a rock is present then there is both visual and audio positive reinforcement. The audio reinforcement is the sound of an explosion, and the second image below depicts the image reinforcement.





If the caregiver chose the Statistics option they would be redirected to this screen which would display the statistics regarding any unnecessary taps by the user or any rocks that fell past the bottom of the screen.



4. HIGH-FIDELITY PROTOTYPE

From the gathered system requirements, a high-fidelity prototype was created which outlined this system that would provide lessons to further develop basic skills and improve cognition for individuals with DD.

Concept Game: This game involves a set of questions that aim to help users learn object relations and asses their knowledge in a fun way. Users are asked to identify a particular relation, shown 2 to 3 images, and asked to chose the image that satisfies the specific relation (e.g. smaller, larger). An audio prompt dictates what relation each question assesses. If the user chooses correctly, applause audio plays and the game transitions to the next question. If the user chooses incorrectly once, the audio prompt repeats and the correct answer is highlighted. If the user chooses incorrectly multiple times, the audio prompt repeats each time and the incorrect answers fade and are made un-selectable.

StarBlaster: This game is designed to help those with DD learn about causality and improve their cognitive skills such as patience, focus, and memory. This game is set in space, and has three different levels of difficulty. When the game first begins, asteroids begin falling from the top of the screen. The user is supposed to tap anywhere on the screen to destroy the asteroids before they reach the bottom of the screen. An audio prompt plays at the beginning of each level and repeats whenever the user taps the screen when no asteroid is present. This acts as a reminder to the user of their goal. Each level of this game is progressively more difficult than the previous. In the first level only asteroids fall, in the second level asteroids and stars fall, and in the third level asteroids, stars, and alien ships fall from the top of the screen. However, throughout all of the levels, the objective remains the same. For this game the user needs to pay attention to when asteroids are on the screen, figure out how to destroy as many as possible, and to remember to destroy only asteroids when they appear on the screen before they reach the bottom of the screen.

Final System

- **Computer-based System:** Through Hope Services, the participants have access to both computers and tablets. At the moment, since the games are HTML5-based, it is most compatible with computers and Android tablets. The games still work on Apple products, however some features are incompatible.
- **PosItive Reinforcements:** These games were designed to be accessible for users with varying levels of cognitive disabilities that may or may not be coupled with physical disabilities. This is achieved by allowing users to provide input by tapping the tablet screen and avoiding complicated gestures.
- **Response to Incorrect Answers:** Both games use positive reinforcements. In the Concept Game, whenever the participant answers correctly, the sound of applause plays. In StarBlaster, whenever the participant taps the screen when an asteroid is present, an explosion sound plays and the asteroid image is replaced by an 8-bit explosion image for a few second before the explosion image disappears from the screen.
- **Response to Incorrect Answers:** When users answer incorrectly both games repeat the original prompt and users will be guided to the correct answer. For instance, in the Concept Game, the first time the user answers incorrectly a box is drawn around the correct image and the particular object relation prompt is repeated. If they answer incorrectly again, the incorrect image(s) are greyed out and become un-selectable. And in StarBlaster, whenever the user taps on the screen while no asteroids are present, the prompt repeats the game's objective.

5. EVALUATION

Before user testing began, the high-fidelity prototypes of both games were examined. To evaluate the systems, dif-

ferent inspection tests were performed either by the means of a heuristic evaluation or a cognitive walkthrough. Both tests were utilized to provide different points of view on the usability of the systems. The inspection was performed on the wireframe prototypes of the games. Once the prototypes were evaluated and polished, the user study was conducted to test the games. The user study was conducted with individuals with DD at a Hope Services facility in Santa Cruz.

5.1 Preliminary Evaluation

There were a few minor issues that needed to be addressed regarding the design of the Concept Game. One change that was made regarding gameplay was the method used to handle incorrect answer selections. Both the wireframe and the storyboard shows that if the user answers incorrectly twice, the Incorrect image(s) disappear. Since the Concept Game is all about object relations, it would not make sense to remove the incorrect options. The user would not be able to physically see how the right answer compares with the incorrect images if the incorrect images disappeared. So instead of removing the incorrect answers, the images are simply made un-selectable and fade. Another issue that arose was the fact that the positive reinforcement videos would not play on mobile browsers. So an alternative solution was created. This solution is the sound of applause ever time the user chooses correctly.

For StarBlaster, the main issue was the gameplay background. The fact that Earth is at the bottom of the screen and that is the direction that the rocks fall in, may be perceived as negative reinforcement. So the user might think that if they missed an asteroid then Earth would be destroyed. So instead, the background was replaced with a basic night sky background.

5.2 User Testing

The games will be demonstrated for the participant, and then the participant will play each game by themselves. At the end of the study, the participant will answer a short questionnaire assessing the level of difficulty of each game, engagement, identify areas of improvement, and if performance in game transfers to improved performance in target real-life tasks.

5.2.1 Users

Each game was tested by ten users from Hope Services. Hope Services provides services to individuals with DD of all ages within the Silicon Valley. Hope Services recruited all users using the following criteria: all participants must be over the age of 18, non being a pregnant female, and must have a DD. All participants had various ranges of cognitive function.

5.2.2 Testing Setup

The system was tested over a four-week period. The subjects played both games once a week for the first two weeks, followed by a one week break, concluding with a final week of testing. Subjects were shown a demonstration before they played each game. The demonstrations were not screen-captured. After the demonstrations, the subject played the Concept Game twice, and then played each level of StarBlaster once. All gameplay performed by the user was recorded through screen-capture to calculate statistics at a later time. At the end of the study, the participants answered a short questionnaire. The questionnaire consisted of nine questions assessing whether the user felt the games improved their performance in real-life tasks, how hard the Concept Game and StarBlaster were, whether the games were entertaining, and improvements they would recommend for the game. The questionnaire can be found in section 8 of this study.

5.2.3 Statistics Gathering

Since the user's gameplay was screen-captured. The experimenter was able to come back at a later date to review the footage. When the experimenter reviewed the footage, they would keep track of how many attempts the user had per question. Any number more than one meant that there was at least one incorrect attempt. However, with StarBlaster, there is no current statistics gathering mechanism implemented. So while the users played the game, the experimenter would watch and keep track of the number of taps on the screen performed by the user when there were no asteroids present, as well as if any asteroids made it past the bottom of the screen.

5.2.4 Results

For sessions one and two, data for all ten participants was gathered. However for the third and final session one participant was absent. So data for only nine participants is available for the final trial and survey.

Concept Game

- Four out of the nine participants found the Concept Game to be really easy. Two out of the nine participants found the game easy. One participant chose between neutral and difficult regarding the difficulty level. And two others thought it was very difficult, rating the game's hardness level at a 5.

- The number of correct answers between both games were added together per trial. Each individual's score from trial 1 was then compared with their score from trial 3 (except for one participant who only participated in two trials, his results from trial 1 and trial 2 were compared) to find if there was a significant correlation between their scores at the beginning and end of the study. From observing this data, eight out of the ten participants had improved their score. A one-tailed t-test was also performed on the data. This study considers any p-value less than .05 to be significant. The computation of this t-test provided significant results with a p-value of .0203. This shows that there is a positive correlation between each participant's performance between the beginning and end of the trial.

- The number of incorrect responses per question type for all the trials were added together. Then the number of incorrect responses per question type across all trails were summed together. This was done to find which object relations had the highest error rate. The questions that assessed the relation less/more were the questions with the most errors with 26 total incorrect answers. The second object relation with the most error was closest/furthest with an error rate of 17. The third most missed object relation was shortest/longest followed by a tie between emptiest/fullest and smallest value/largest value. The object relationship with the least error was smallest/largest.

StarBlaster

- Six out of nine participants said StarBlaster was really easy. One participant said it was between really easy and easy. One participant said it was a 3 out of 5 difficult level, and lastly one participant said it was very difficult.
- No participant missed a single asteroid during any of the trials.
- The number of unnecessary taps for each trial were added together for each level.

Survey

- Both games were well-received by most participants. From the nine surveys, all nine participants said they had fun playing both games.
- Also eight out of nine of the participants said that playing these games improved their performance in real-world tasks. Some examples given by participants are as following: one participant claimed that these games helped with her problem solving and recognizing the relation between more and less, and a few other participant said that these games helped them play other games.

6. DISCUSSION

Both games were well-received by the participants. This means that this is a good and engaging media for people with varying levels of DD to learn through. Through the questionnaire that participants filled out at the end of the study showed that the app-lessons were well-received by participants as well as a few suggestions for game improvements. A few ideas of game improvements were discovered through the survey. These ideas include: (1) adding another level of difficulty to the Concept Game, (2) maybe including another mini-game like the game Memory, (3) more questions that focus on the object relations that most participants struggled with, (4) possibly adding themes to the Concept Game, (5) add more objects to the Concept Game, (6) adding more asteroids to StarBlaster.

7. CONCLUSION AND FUTURE WORK

The next steps for this project includes transforming these web-apps into smart-phone and tablet apps. It also includes improving the system based on the feedback from the surveys conducted at the end of the study. The caregiver interface must also be created, implemented, and tested.
Once the app has been developed for Apple products, another round of user testing will need to be completed to assess both the caregiver and player interface. But after this app has been developed, the system will have the potential to be an alternative learning mechanism for people with DD, give people with DD a sense of independence, and improve upon their life satisfaction.

8. QUESTIONNAIRE

1. Did you find playing these games improved you performance in any real world tasks?
2. If so, please list task(s)
3. How did you think you performed in the Concept Game
4. On a scale of 1-5 how hard was the Concept Game?
5. Was the Concept Game fun?
6. How would you improve the Concept Game?
7. On a scale of 1-5 how hard was StarBlaster?
8. Was StarBlaster fun?
9. How would you improve StarBlaster?

9. REFERENCES

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