Automating Game Progression to Empower Users with Disabilities

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Introduction

With roughly 67% of Americans playing video games [about 211 million people], gaming is an integral part of American culture (Crecente). In the United States, however, "perhaps 2 percent of the population [about 6.3 million people] cannot play computer games because of a disability, and 9 percent [about 28.4 million] can play only at a reduced level" (Garber). Games built for those with disabilities fail in two primary ways: many are designed with educational goals, despite research which shows disabled people want recreational games and they're designed for very young children, though gaming is most popular in the age range of 18 to 24 (Morris). This thesis stemmed from a desire to create an enjoyable game for this significantly underserved population.

The wide spectrum of abilities within this young adult population requires games to be adapted or modified based upon the unique challenges of each individual. One player might enjoy watching a game played automatically. For another, they might be able and eager to use input devices, but unable to see or interpret a standard screen. For yet another, using input devices might be difficult, but they may want a number of choices from which to make a decision. Many people with disabilities cannot play mainstream games as they require users to concurrently progress through a game and make decisions (e.g., using key strokes) within time constraints. The lack of customizable game progression is a major barrier to playability for many young adults with disabilities.

The objective of our project was to develop and test a new software-based game that appeals to young adults who want to play a game that is both enjoyable and adaptable to their physical, cognitive, and other abilities. To accomplish this, the game would need to overcome existing limitations with current games by focusing on being as adaptive and customizable as possible while not losing sight of what makes popular games so enjoyable and engaging to play.

Background Information

Adaptive switches are input devices that offer a simpler, more accessible alternative to traditional gaming devices, like joysticks, keyboards, and controllers, which typically have multiplicity of small, complex components. Different kinds of adaptive switches create a specific, unique interface for each person to best suit their abilities. For example, jumbo switches provide a broad stroke contact area for users with fine motor challenges, pictured in Figure 1 (Andre). Individuals with visual impairments can use a bright, vibrating, music playing switch. Flexible switches clamp to wheelchairs or other surfaces to allow for movement of specific body parts, like the head or knee for individuals with some mobility (Kanor). Light switches, triggered by eye movement, allow users to 'click' by blinking, requiring no movement of the body for those without mobility (Andre).

Adaptive switches plug in to switch interfaces, as seen in Figure 2, connected to computers (Andre). Standard mappings from the keyboard to switches include the left and right arrow, the up and down arrow, and the spacebar and enter keys. Eye gaze software enables users to control a mouse with their eyes, thus "clicking" buttons on the screen. Though switches enable users to provide input in a game, they inherently limit the level of choice a user has (Table 1).

Figure 1

Figure 2

Table 1

Mode	Degrees of freedom	Example of gameplay
Auto-play	0	Watch a game proceed, learning how it works
One-switch	1	Either click the button when you want the game to proceed (paused otherwise) or scan at some fixed rate and require the user to click at the correct moment
Two-switch	2	Press one button to advance through options and press the other button to choose one

Relevant Literature

"Very little research is being done on this topic" according to Dr. Folmer, a professor at the University of Nevada Reno and one of few researchers to have been awarded US National Science Foundation grants to evaluate the extent of video games accessibility (Garber). A key aspect to video game playability for the disabled is the use of game automation. This paper will examine multiple aspects of game automation and its application to enable and empower a previously underserved group of potential users. Table 2 describes the framework for the relevant topics and areas to be examined with that topic.

Table 2

Topic	Area To Be Examined
Automated game testing	How automation works and how it could be adapted to our target audience
Accessible switch gaming	Existing switch games and lessons learned
Assisted gaming and recent trends	Game assistance modes and their reception
Surveys of people with disabilities about what they want in a game	Target audience market research
Benefits of gaming for the broad population (psychological, social, behavioral, etc.)	Positive impact of games, how to design a game that makes a positive impact

Automated Game Testing

Understanding what motivates companies to develop automated game testing provides insight into the likelihood and prevalence of companies headed in this direction and potential arguments for leveraging this same approach to enable play by our target audience. To gauge the feasibility of adapting test software for the purpose of automated gaming, this paper will explore the design and functionality of the software, suggesting potential adaptations and uses for it.

A study from Nantes et al., focused on the automatic testing of video games stressed the importance of game testing since the functionality and playability of a product depend upon it. Though important and crucial for the quality of the software, "testing is also a time consuming and frustrating activity" and involves "making testers play the same game over and over again" which "could push them to overlook defects for the haste of getting their job done." Therefore, companies have strong incentives to develop automated testing to ensure product testing is as robust as possible both to decrease the time and investment associated with pre-launch testing/debugging and to ensure player satisfaction once the product is launched.

The Nantes study proposes a framework for how to accomplish game testing by combining Artificial Intelligence (AI) and Computer Vision (CV), to bring “important benefits to the game industry” such as “cost savings by decreasing the number of play testers required” and strengthening the product “by allowing the coverage of a far larger set of test cases currently performed only by human players.” CV provides techniques “that aim at making useful decisions about real and physical objects and scenes based on sensed images.”

In terms of our target audience, CV could augment and adapt to the disabled player’s input or lack thereof. For example, if a person with fine motor impairment is playing a game that involves pressing a series of buttons swiftly to defend a goal, it could sense their inability to succeed after X failures and adjust the difficulty level or time sensitivity. Another example is that the computer could extract pertinent information from what’s being displayed on the screen and announce it to a visually impaired player.

The research focused on the automation of bug detection via computer vision “processing the same image perceived by the human player but with the enormous advantage of working with noiseless data as it comes directly from the GPU pipeline and the drivers and not from real sensors.” By modifying graphic drivers such that they store the traffic that passes through them, “the pipeline can be read without either modifying the application output or requiring the programmer to make extensive modifications to the code for debug.”

The study suggests two approaches which can be taken: the representational approach and the sub-representational approach. The former requires a “symbolic translator” which converts low-level information, such as vertices and shapes, into high-level terms of abstract meaning, such as “kill the guard before he triggers the alarm,” but no such language exists and developing one would be costly. The latter digests the low-level output data and the user activity, utilizing CV and AI technology to “provide the agent with visual bug detection capabilities” (Nantes). The sub-representational approach could be adapted for automated gaming as the CV “needs to analyze the same images perceived by a human player” and the AI evaluates the virtual environment, measures the challenge level, and detects patterns in the data, environment, and user input.

In terms of adaptability of these concepts to our target audience, CV could be used to detect that a player hasn’t pressed a button in a while, since it's hard for them to do so, and rather than “time out,” the program could wait for the player to press a button without penalty.

Another study, from Southey et al, suggests a framework for automated gameplay analysis which collects and summarizes gameplay information, using machine learning to choose scenarios to examine. In the context of automated gaming, the chosen scenario could be the one at hand. The framework automatically and dynamically adjusts the game based on recent player performance, analyzes situations to make AI decisions, provides feedback on AI vs player performance, and provides commentary, feedback, or advice to the player during the game (Southey). Some developers have reservations about the use of AI and CV in augmenting a player’s input believing that a game is meant to meant to be challenging and ultimately rewarding.

Adding an optional “adaptive mode” would address these concerns and enable our target audience to play.

Switch Games

Absent CV and AI equipment, switch games attempt to meet the needs of some impaired players by lowering a game’s degree of freedom. A review of switch gaming allowed us to glean useful design principles and understand shortcomings. Switch games exist in an abundance, but they often require temporal finesse that some of the target audience lacks. In games that do not rely on temporal finesse, several issues emerged. Dr. Karen Erickson, the Director of the Center for Literacy and Disability Studies at the University of North Carolina, said existing switch games often prove to be unsuccessful for our target audience as a result of a combination of the following factors (Personal Communication, October 9, 2019):

1) Youthful appearance or game theme
2) Lack of freedom in game progression
3) Low replay-ability
4) One-dimensional appearance
5) Time constrained

Games currently on the market may address one or more of these limitations, but none address all limitations, leaving a large group of disabled potential game players with no reasonable game options. Figure 3 is an example of a youthful switch game that lacks replay-ability in its limited story line (Inclusive Technology Ltd). While Figure 4 appeals to a more mature audience, it relies on time constraints (Ellis). Through our consultation with Dr. Erickson, we concluded that a mature theme and graphics, high replay-ability, player freedom without temporal constraints, and multidimensional player movement constituted our design specifications.

Figure 3

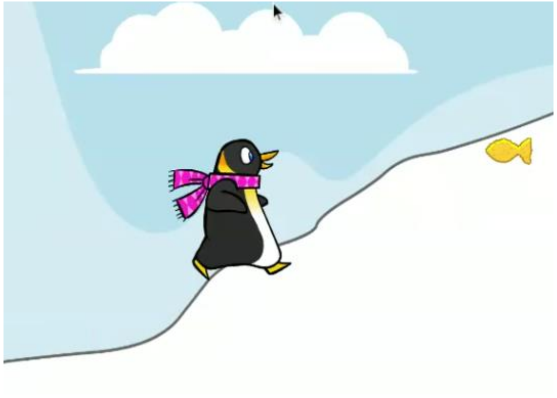


Figure 4

In switch gaming research, a study of one-switch video games for children with severe motor disabilities in 2015 proclaimed, “to our knowledge, we are the first to address the question of whether it is possible to develop dynamic video games playable by children with severe motor disabilities using only a single switch as input device” (Aced López et al). The research involved three games, the first two of which did not involve timing or scores. The third game required the selection of multiple elements (aliens) moving down the screen with a time constraint, before they touched the ground. We believe that our game will bridge the gap, allowing a measure of success without time constraints. This paper provided valuable design recommendations, as described in Table 3.

Table 3

Recommendation	Benefit
Simplify the number of decisions players need to make	Reduces the demands on visual-spatial reasoning
Reduce the consequences of errors	Keeps the game fun
Limit available actions	Reduces number of decisions player needs to make
Remove the need for precise positioning and aiming	Reduces motor skills and physical demand required to play

Assisted Gaming and Recent Trends

Building accessibility considerations early in the design process seems obvious given the market potential but hasn’t yet proliferated (Gadded). In recent times, the few companies retrofitting accessibility into their games have won awards and become newsworthy. For example, Microsoft created a way to play Minecraft using just your eyes (Gadded). Everyone benefits from the efforts being made to make games accessible, allowing each user to fine tune the game for the best possible experience (Gadded). For example, Allegra Frank, a gamer without disabilities, writes about how the platform game Celeste's assist mode makes it more enjoyable for him since he doesn't love to play games where all he does is "crash and burn" (Frank). He enjoys Celeste equipped with Assist Mode, dubbing it otherwise a "painful, frustrating" game. With numerous options, such as becoming invincible and decreasing the game speed by 10 percent intervals, Celeste is "granular enough to make the assistance feel like a learning tool" (Frank). Such features enable a wider audience to play, including those "with a limited amount of time or patience" that might otherwise be deterred (Frank). One of the developers who worked on the mode confessed that it only took a few days to add the accessibility options, indicating the relatively small price to pay as compared with the benefit (Frank).

Another example of assisted gaming is the Copilot feature on Xbox One, released in 2017 (Gadded). Much like driving school cars, which allow both the driver and passenger to steer, Copilot links two controllers so two players can access them in case one of them needs assistance ("Copilot on Xbox One").

Gaming organizations have increasingly been embracing accessibility (Gadded). Many games "with the highest budgets and levels of promotion are being recognized for the work they are doing" (Gadded). For example, the game company Naughty Dog added accessibility options to the game Uncharted upon receiving feedback from Josh Straub, editor-in-chief of Disabled Accessibility for Gaming Entertainment Rating System, "a website that provides reviews of games based on their accessibility features" (Sarkar). One setting, for example, allows a player to hold as opposed to repeatedly press a button to stimulate an action. In turn, Straub “gave the game his highest recommendation” and said Uncharted “represents a standard of accessibility that should be more widespread within the gaming industry” (Sarkar).

Game organizations that embrace accessibility incorporate it at earlier stages in development since adding it later can be less effective and more resource intensive (Sarkar). Increasingly, inclusive design is an emerging topic for the industry, as is evident by the formation of new conferences dedicated to the matter like the Gaming Accessibility Conference scheduled for this year (Gadded).

Studies of People with Disabilities

Many games built for people with disabilities have therapeutic, educational, and/or rehabilitative goals. However, a demographic survey of people with disabilities showed that their interests align with those of the broader gaming community (Beeston). This suggests a discrepancy between the games created for people with disabilities, with set intentions to improve the individual in some way, and the fun, mainstream games desired by those with disabilities. This study concluded that “game designers and researchers can assume that people with disabilities want to play mainstream games with everyone else and will attempt to find a way to play” (Beeston). The study notes that players reported using adaptations like auditory alerts, key remapping, subtitles, alternative controllers, and screen readers with varying degrees of success. It suggests that designers and researchers should bear in mind how these adaptations impact the overall experience of the game and the resultant social experience of playing games with others. While our target audience may have access to a variety of these adaptive tools, their ability to play mainstream games isn’t that simple. Dr. Folmer said most games are not accessible to the majority of people with disabilities (Garber). For example, “people with motor impairments— like cerebral palsy, Parkinson's disease, paralysis, and multiple sclerosis—have trouble using parts of their body. This keeps many players from effectively utilizing consoles and manual-input devices" (Garber). Intellectual disabilities often leave "people completely or partially unable to understand how to play a game or manage complex situations" (Garber). These are just a few of the challenges people with disabilities can face in enumerable combinations. Bearing this in mind, we set out to create a game which would handle the basic game progression for the user to a customizable extent.

Benefits of Gaming for the Broad Population

Our target audience, those with severe disabilities barring them from mainstream games, has very few game options with a primary intent of enjoyment. Such games have been shown to enhance people's lives in many ways, even improving people's ability to learn as an unintended byproduct. A paper focused on the impacts of gaming in four categories – cognitive, motivational, emotional, and social found that "although playing games is often considered a frivolous pastime, gaming environments may actually cultivate a persistent, optimistic motivational style. This motivational style, in turn, may generalize to school and work contexts" (Granic). Having established the reasons for making the game fun, the next step was to identify what makes a game fun to play and how those attributes could be adapted for our target audience. Design principles which make a game fun include freedom, mystery, challenge, interaction, and sensation (Shi et al). Each of these principles is defined in Table 4, along with strategies for how to achieve each and their positive and negative impacts relative to our target audience.

Table 4

Design principle	Definition (Shi, Yen-Ru, and Ju-Ling Shih.)	How this is achieved	Positive impacts	Negative impacts
Freedom	Encompasses all of the game resources players can master	Increased clicks to get through a greater number of options	More intellectually stimulating, challenging and/ or fun	Less reward per click More physical effort required
Mystery	Provides a novel experience for players, including curiosity and exploration	Randomness in layout of game / game components	Increases replay-ability	More intellectually demanding, lessens likelihood of improvement through effort/repetition
Challenge	Player efforts toward the game or personal goals	Time limits, wrong vs right answers, reward, penalty	Keeps gamer engaged, eager to play again, fun, learning from failure, rewards	Frustration with poor results/penalties More intellectually and/or physically demanding (if time sensitive)
Interaction	All interactions and conflicts occurring between the game program and player	Communication to player based on game state and conditions such as hints	Gamer has more clarity/help so it's less intellectually demanding	Less challenging for those who want an intellectual challenge
Sensation	Multimedia presentation of the virtual world	Audio and visual components	More engaging and appealing	Could be overstimulating

The Approach Undertaken

With all of these aspects of fun in mind, we developed the beta version of our game with an emphasis on movement based on input from Dr. Erickson, who expressed the importance of this for players with limited mobility. We chose to use the Unity game engine because of its superior graphics that mirror mainstream games (Figure 5). Having completed the automated game, several issues emerged. In order to progress the player automatically through the course, values had to be hard coded. While other levels could be developed so that the scenery would change as a player progressed, this would still lack the replay-ability which proves vital for enjoyable games. Secondly, Unity games don't run in the browser. We wanted our game to be easily accessible, hosted by GitHub pages.

Figure 5

For revision two of our game, we switched from Unity to the JavaScript-based, Phaser game engine as it can be hosted via GitHub pages. Dr. Erickson provided input that most accessible games don't allow the user to customize the game. The goal for our game was to allow the player to select from a wide range of options for everything from cheerleading to sports. We decided that the player should get to customize their game – choosing the background color, their character, and target objects. For example, choosing a red background, the sports category, and a cheerleader character, as seen in Figure 6.

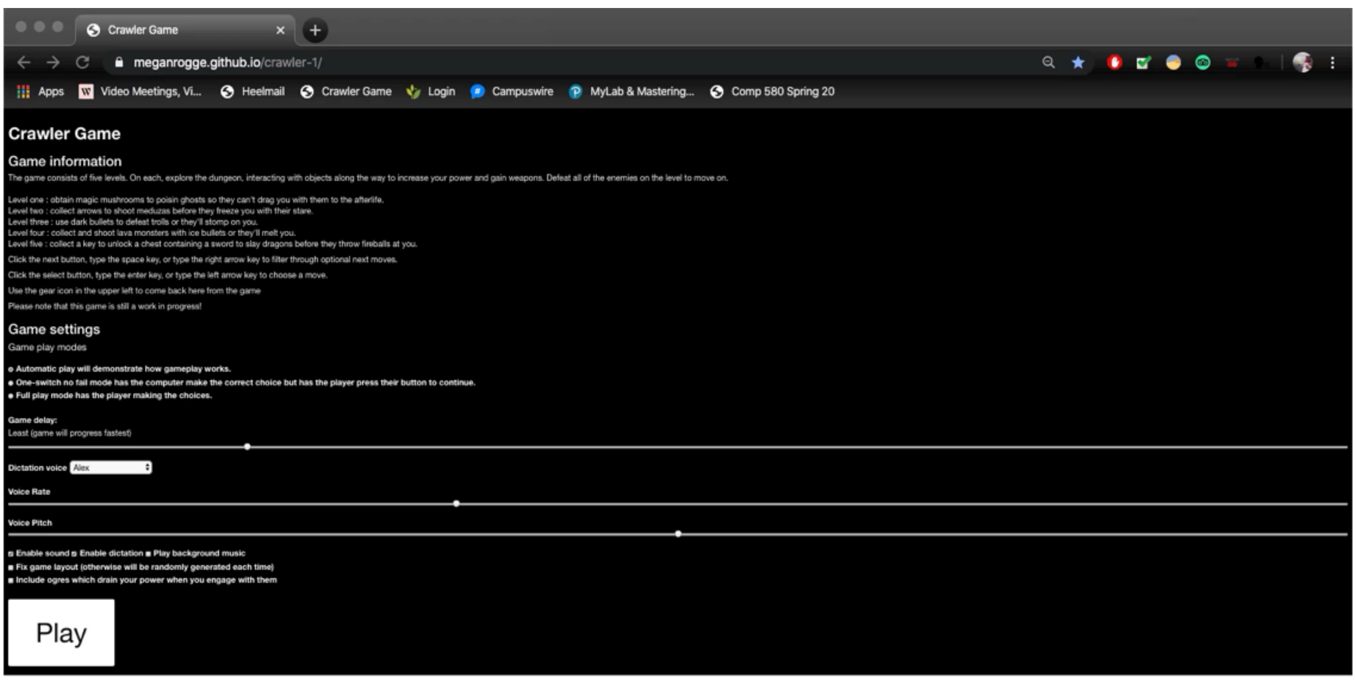
Figure 6

Next the player chooses the mode – no fail or regular. In both, objects appear in a random order as your character runs across the screen. When each object reaches you, you choose to either jump to obtain it or keep running, satisfying Dr. Erickson's goal of the player learning these actions via the game. In no fail mode, only objects of your chosen category appear, so you score whenever you obtain an item. In the regular mode, objects of all categories appear and you only score points when you jump for objects of your target category. We checked in with Dr. Erickson before progressing further and concluded that the 2D dimension of movement was too flat and didn't resemble mainstream games.

Seeking something a little more 3D, we next developed an isometric Phaser dungeon Crawler game. The game features landmark selection (exits, objects, enemies, etc.) which allows switch users to play games that have traditionally been played by moving one square at a time in any direction. For this reason, the Crawler is a building block upon which enumerable games could be developed. The game's settings allow the player many options. For example, the dictation setting allows the user to turn on and off the computer's audible description of the currently selected object, power goals reached, and other relevant information. Visually impaired players can use this setting to successfully navigate the game.

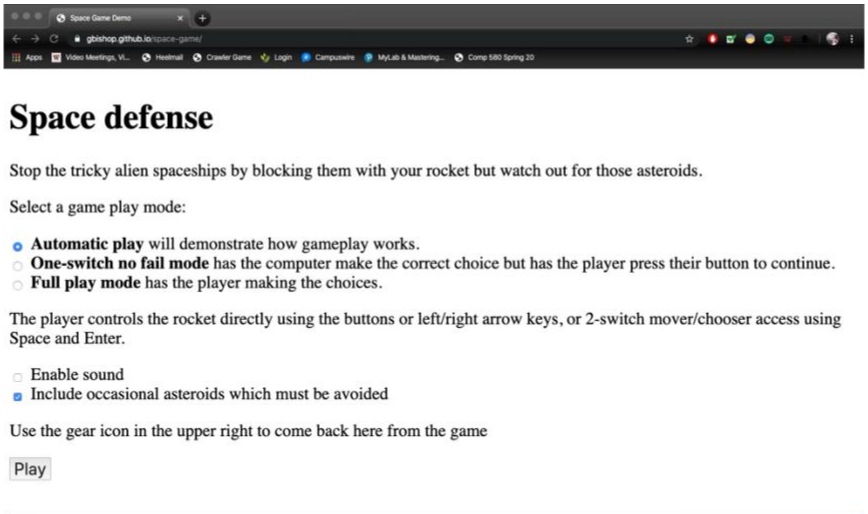
Simulated clicks within the auto-play, one-switch, and two-switch modes of our game teach the user what's driving the actions on the screen. For example, Figure 7 shows the game in auto-play mode, where next and select are being "clicked," causing the character to move and get various objects. This way, the player feels that they are the one playing the game, regardless of the mode. While watching the game played in auto-play might be enjoyable, the user is simultaneously learning how to play the game before potentially progressing to the one or two-switch modes. The code for this game can be found here.

Figure 7



We also developed a space game and a Tetris game. In the space game, the player chooses whether to move the rocket to the left or right to stop the enemy ships (Figure 8).

Figure 8



In Tetris, the player chooses which move to make given the worst and best moves (Figure 9).

Figure 9

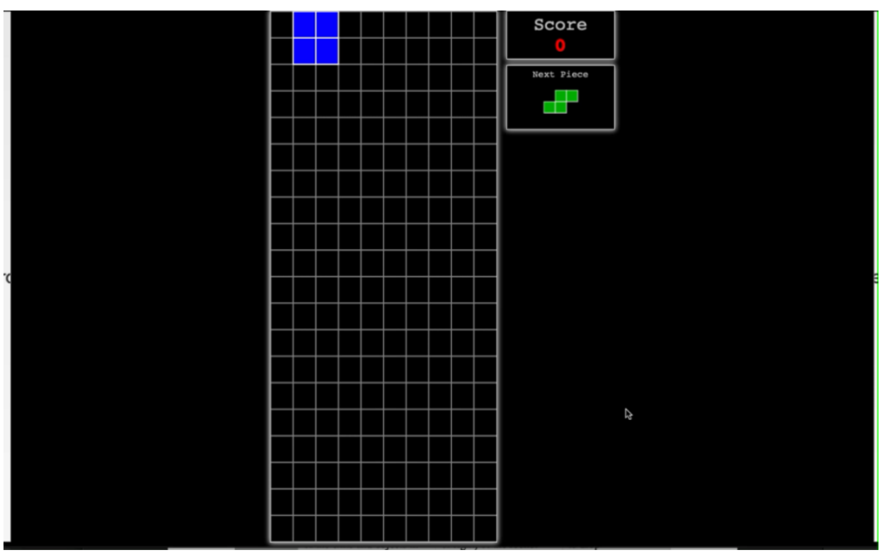


Table 5 shows how different aspects of fun were included in the games we developed.

Table 5

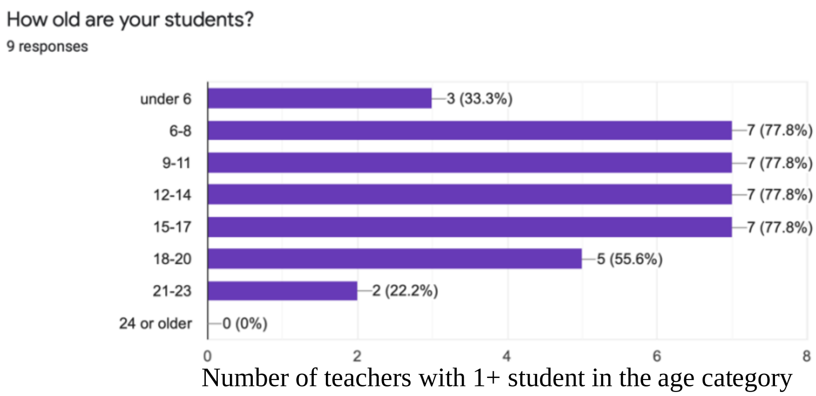
Design principle	Crawler	Space	Tetris
Freedom	Choose your target from all of the exits and objects in each room	Choose the direction (left or right) of the rocket	Choose which piece to drop
Mystery	New randomly generated board each time with randomly generated objects at random positions with setting to turn off all randomness (and fix the layout)	Randomly curved path of rocket makes it tough to judge which way you should move	The computer offers the best and worst move on each turn, not indicating which is which.
Challenge	Defeat enemies with setting to add ogres as obstacles	Optional addition of asteroids as obstacle	Learn to distinguish between the best and worst move to earn a high score, game over when the pieces reach the top
Interaction	Optional dictation, hint box, defeat enemies to reach the next level	Defeat the aliens	Indicates which piece will be given next for planning purposes
Sensation	Optional sound, animation	Optional sound, animation	Brightly colored, optional sound

User Testing Approach and Feedback

We reached out to more than 200 users of Tarheel gameplay, a website created by Dr. Gary Bishop to host a collection of free accessible games. Users of this site tend to be special education teachers. Using a Google survey, we collected feedback on game accessibility and encouraged the teachers to have their students try our newly developed games. Teacher surveys representing 215 students were analyzed as follows:

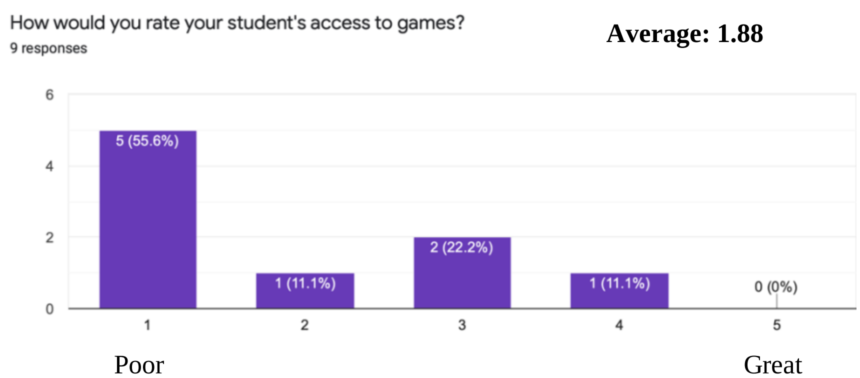
Student age varied widely (Figure 10).

Figure 10



Using a Likert Scale of 1=Poor and 5=Great, access to games for disabled students was reported as poor with an average of 1.88 (Figure 11).

Figure 11

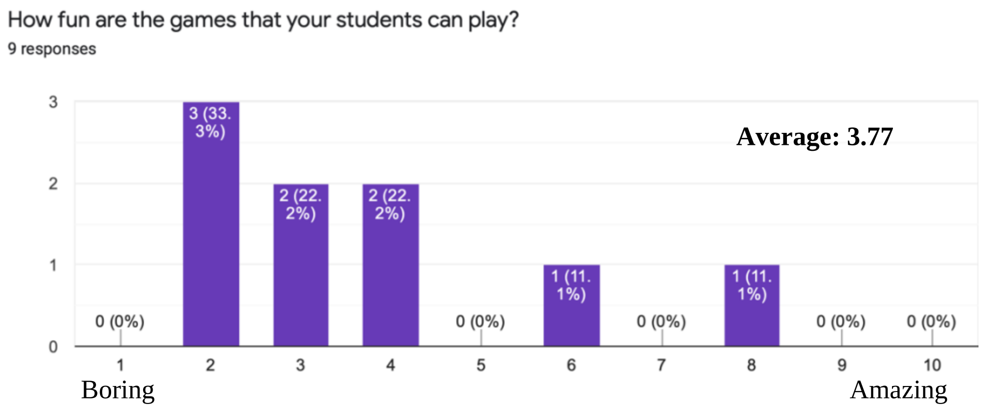


Current games played by students:

- Single switch apps on the iPad
- Helpkidzlearn.com switch games
- IanBean.co.uk
- Senswitcher
- Tarheel gameplay
- Gingertiger.net
- Purchased switch games from various sites like "pie in the face", "tic-tac-toe", super soaker, hi ho cherry-o, bingo, UNO attack, activities on specialbites.com, big bang, switch skills, Choose and Tell, and others by Inclusive TLC, boardmaker online

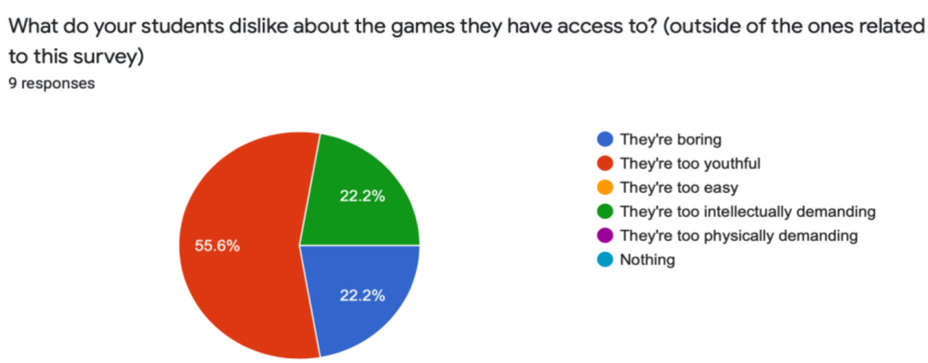
Using a Likert Scale of 1=Boring and 10=Amazing, teachers assigned games an average fun score of 3.77 (Figure 12).

Figure 12



Teachers reported their students disliked the games they currently have access to because they're too youthful (55.6%), boring (22.5%), and intellectually demanding (22.5%), provided options shown in Figure 13 and the ability to add others.

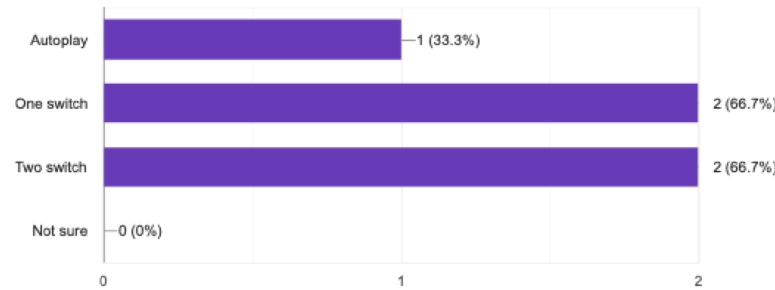
Figure 13



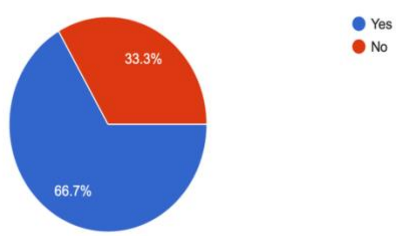
Feedback on the games developed as a part of this research varied widely based on the particular teacher's student ages and abilities. 3 teachers reported their students tried the Crawler and space games and 4 reported their students tried Tetris.

Crawler Survey Feedback

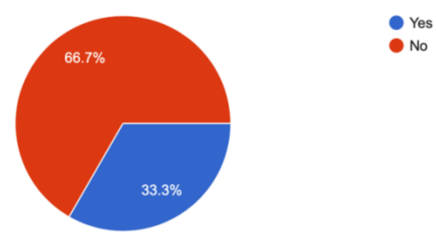
Which mode(s) did your student(s) use?
3 responses



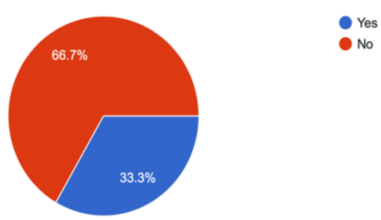
Did the game work for them?
3 responses



Do they want more choices?
3 responses

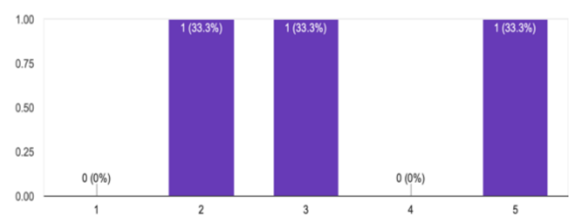


Do they want more control?
3 responses



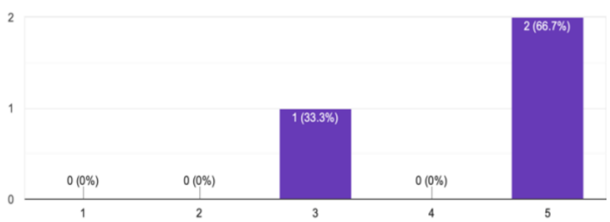
How challenging was the game physically?
3 responses

Average: 3.33



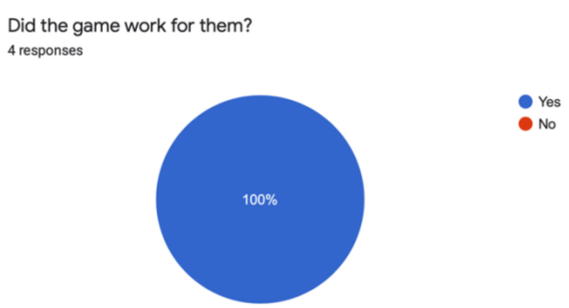
How challenging was the game intellectually?
3 responses

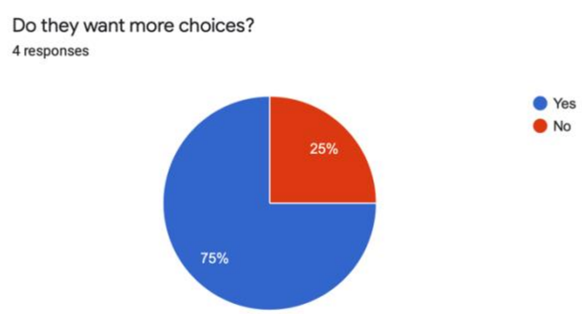
Average: 4.33

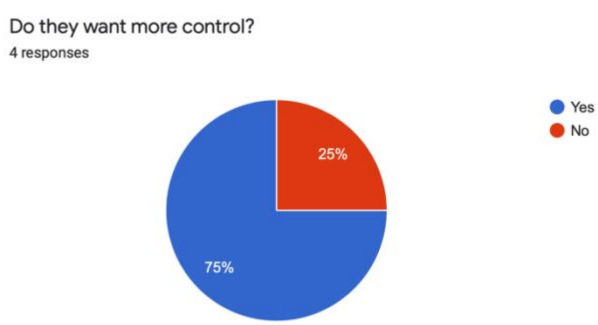


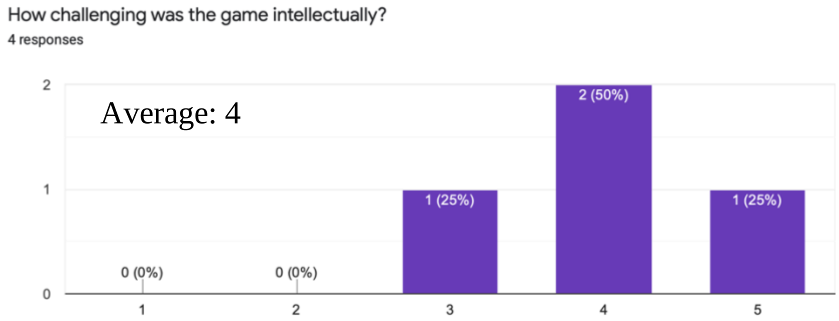
In summary, the majority of teachers said the Crawler game worked for their students and they had enough choices and control. The game was challenging for their students intellectually and physically. The teachers provided suggestions about how to make the game more accessible. Some of their ideas were implemented, including an option to turn off the random regeneration of the board and to provide clearer user instructions. When asked what settings they would like to add, one teacher said, “it would be nice if the choices popped up in their own window so you could better see all the choices and had different scanning options.” A dictation setting on the Crawler’s menu, when checked, dictates information about the object to the user in order to make the choices clear. Certainly, a pop out window could be added as an optional alternative to the dictation option for sighted players. Another teacher suggested increasing the contrast of the colors, which has since been adopted.

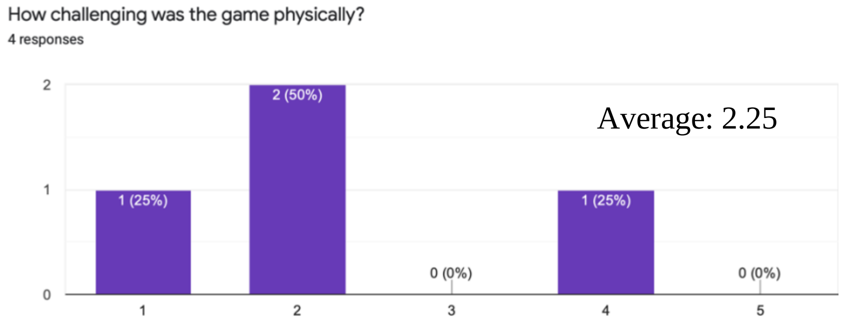
Tetris Survey Feedback





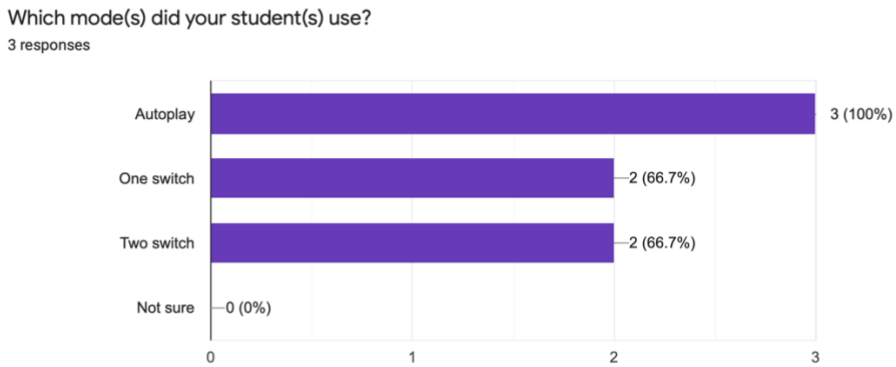


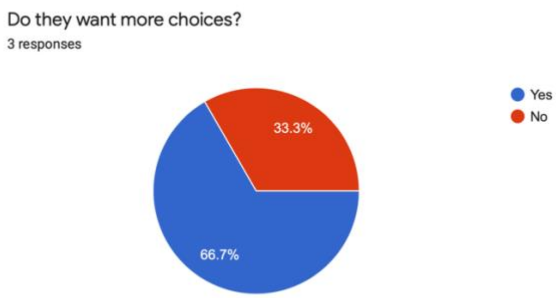


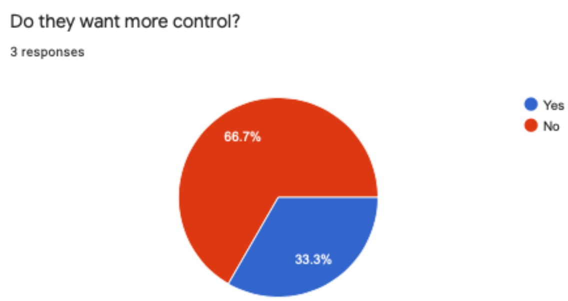


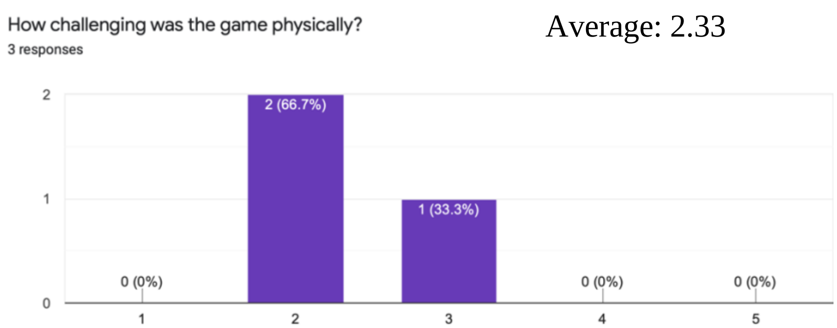
Overall, Tetris worked for the students, who found the game intellectually challenging, yet wanted more choices and control. Teachers reported that Tetris would be more accessible to them if they could scan from a field of choices and have additional settings. One teacher suggested to "add a setting with full control – left, right, rotate object." Though that would require 3 switch control, "it could be set up with either 3 switch option or could work with 2 switches, moving the shape across the screen then coming back on the other side." Teachers would like to add settings for speed control, high contrast colors, to program the auto-scan settings/timing, and the ability to pick their piece from a field of 4. These results raise an interesting question. Given the students already found it intellectually challenging, how could more choices and control be given to the player without making the game frustrating?

Space Game Survey Feedback

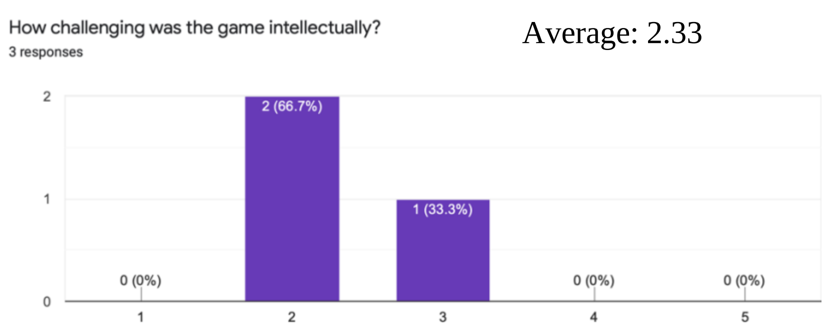








Average: 2.33



Average: 2.33

Students felt they had enough control, yet wanted more choices in the Space game. They didn't find the game challenging physically or intellectually. When asked what we could do to make the game more accessible, teachers suggested "have different speed settings to make it more/less challenging and help the students develop timing skills." They also suggested adding rewards for accuracy and high contrast colors for students with visual impairments.

Limitations of this Research

The difficulty of daily life for our target audience makes garnering feedback from them very challenging. Using a Google form survey, several teachers provided feedback on their students' access to games, enjoyment of those they have access to, and thoughts about the games we developed. Developing a more detailed plan for gathering additional feedback from a larger group of special education teachers through the use of incentives or engaging the support of a key opinion leader would provide better sights into the success of the game design. Secondly, getting feedback directly from users using novels techniques that would not require them to fill out a survey would lead to better insights about their experiences playing the game. For example, using web-based tools to understand how long each user played the game, how often they returned to play the game, and how their scores progressed over time, would help determine how enjoyable the game was.

Suggestions for Future Work

Adrian McPherson, a teacher of students with disabilities, described most switch-adapted games as "too simple, boring and not stimulating enough for students. Almost all the games I've seen and worked with seem to be set up for students with a cognitive age of 3-6 years. I am sure many of the stock-standard, cliched, but popular and stimulating games could be easily switch adapted. That would include things like Space Invaders, Pac-Man, Connect 4, Noughts &

Crosses, 2-person racing games, adventure and exploring games. That's why I like the concept you have started like Tetris and the Crawler Game. Please start with similar, timeless, and ageless classics. Another very important consideration is multi-player function. It would be great if our students could play the games against mainstream peers" (Adrian McPherson).

Other teachers also shared games they wish their students had access to: mainstream games like Sims, Minecraft, Mario Kart, and sports games.

As discussed in this paper and demonstrated by the development of the Crawler game, making games accessible to the disabled population requires developers to consider accessibility early in the development phase. Existing tools like AI and CV, used presently for automated game testing, have great potential in their application to automated gaming. Making games accessible benefits all users of a game, widens the user base, and importantly provides a source of enjoyment and inclusion to a worthy, overlooked group of society.

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