Go Go Games: Therapeutic Video Games for Children with Autism Spectrum Disorders

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ABSTRACT
In this paper, we describe the design of a therapeutic video game suite for early elementary children with autism spectrum disorders (ASD). The purpose of this work is to present our hypothesis that games that are both fun and faithful to evidence-based therapies could serve as a mechanism to reduce the gap between the amount of therapy recommended for children with ASD and the amount they receive. We describe our process of creating a suite of games modeled on Pivotal Response Treatment (PRT), a technique known to be effective in educating children with ASD. We also describe early indicators of game engagement and outline planned future work to test the games' efficacy as therapeutic tools.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: *User Centered Design*
K.3.1 [**Computers and Education**]: *Computer Assisted Instruction*

General Terms
Design

Keywords
Autism, ASD, Behavioral Therapy, PRT, Pivotal Response Therapy, Multiple Cues, Video Games, Game Design, Education

1. INTRODUCTION
The Centers for Disease Control estimates that autism spectrum disorders (ASD) affect 1 in 50 children in the United States [2]. Collectively, ASD are the fastest growing disability in the country and can profoundly impact an affected individual's ability to engage with the world and lead a productive, independent life. Today, behavioral therapies are the gold standard of treatment for children with ASD, but they are time and resource intensive. For more than a decade, it has been recommended that children with ASD receive between 25 and 40 hours of behavioral therapy per week [11], yet in the United States, two-thirds of children on the autism spectrum under the age of 8 fail to meet even the lower bound of this recommendation [5].

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Go Go Games is a suite of video games that arose from our hypothesis that games could be an effective medium for shrinking the gap between the amount of behavioral therapy that is recommended for children with ASD and the amount they receive. A 2011 national survey showed that 41% of U.S. children with autism are "heavy use gamers" – meaning that they spend most of their free time playing video games [8]. This is more than twice the rate of heavy gaming in their typically developing peers. This same study also finds that the only predictors of video game play for children with ASD are access to technology and sufficient cognitive ability to navigate games – indicating that within this population, video games have equivalent (and deep) penetration across gender, race, and socioeconomic status.

Given these indications that children with ASD spend a large amount of time playing video games, and given the broad consensus that children with ASD can benefit greatly from extensive behavioral therapy, we seek to leverage gaming as a means of reducing the therapy gap. This paper describes our selection of a specific challenge for children with autism, identification of a corresponding therapy which improves this skill, and our process of translating this therapy into a set of games. We conclude with a discussion of our plans to assess the effectiveness of these games empirically.

2. SYSTEM DESIGN
2.1 Target Skill
The educational objective of *Go Go Games* is to teach a skill known as multiple cue responding. To understand this ability, imagine that you are driving toward a traffic light at an intersection where you plan to make a left turn. As you approach, the traffic light turns to a green left arrow and, noticing this change, you make your turn without pausing. This may seem like an obvious choice, but in order to make this decision you need to notice two different features, or "cues," of the traffic light. You must observe that the color of the light is green and that its shape is that of a left arrow. You then must hold these two pieces of information in your mind simultaneously and make a decision based on both of them. If either the arrow had been red or the green light had been in the shape of a circle, you would have made a different choice.

The ability to notice and respond to simultaneous multiple cues is known to be a common challenge in children with ASD. Children on the spectrum often hyper-attend to a particular cue, rather than considering all of the cues of a stimulus holistically [7]. Case studies cite examples of children who cannot tell the difference between the capital letters 'E' and 'F,' or between a fork and a spoon, due to this "tunnel vision" which blinds them to key elements of the stimuli they encounter [10]. The consequences of attempting to navigate the world with impaired multiple cue responding are profound and can affect virtually every area of functioning [10].

2.2 Therapeutic Approach

A guiding principle of this project was to create games grounded in existing, evidence-based therapies. *Pivotal Response Treatment* (PRT) is a behavioral intervention that targets key, or "pivotal," skills that are known to bring about incidental improvements in other "collateral" areas. PRT is one of the best-supported interventions for autism and has extensive scientific literature documenting its effectiveness [9]. Multiple cue responding is one such pivotal skill that improves with PRT and leads to improvements in general learning [3].

The core element of PRT that underlies our games is known as *conditional discrimination*. Through this technique, the PRT practitioner deliberately structures the natural environment such that a child must notice multiple cues simultaneously. In an interview with the authors, a behavioral therapist who practices PRT explained that she might work on multiple cues with a student who loves trains by asking him to build a train set using many different pieces of track. She might ask him to add a piece of "brown, curved track," forcing him to identify two aspects simultaneously [Personal interview with Dr. Kari Berquist]. Figure 1 shows a set of choices (including a "brown, curved track") where any one can only be distinguished from the group by noticing multiple cues.

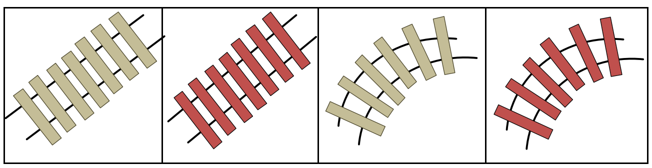

Figure 1: A student must notice both color and shape simultaneously in order to correctly select the "brown, curved track."

It is no coincidence that the therapist quoted above describes embedding this interaction in a play-based environment designed around her patient's interest in trains. In addition to specifying the conditional discrimination technique, PRT dictates that these artificial practice scenarios be carried out in naturalistic environments and reinforced using a child's existing interests [6].

2.3 Game Design

2.3.1 Design Process

We set out to build a suite of games that teach multiple cue responding by leveraging the tenets of PRT. Over four months, we worked with 30 children on the autism spectrum to test a series of prototypes. We found paper prototypes to be ineffective with our users and iteratively built and tested dozens of interactive versions of our games. We continually worked to balance between designing for usability, designing for engagement, and designing for therapy. We found that our users required player-controlled scenarios with forgiving gestures that demanded little fine-motor precision. When we added timers, moving items, or more challenging gestures (for example, a sharp corner turn) the games became unplayable, and testers quickly lost interest. The result of this work was a suite of three video games for the Apple iPad, released on the Apple App Store.

2.3.2 Core Mechanics and Game Features

In each game, players repeatedly select a correct choice from a pool of options. This is the core mechanic by which we create the continual discrimination scenarios of PRT (described further in section 2.4). Figure 2 shows a screenshot of the "Build-a-Train" game, where players must match a model train (at the top of the screen) by repeatedly selecting the correct next car from the options presented on the left side of the screen.

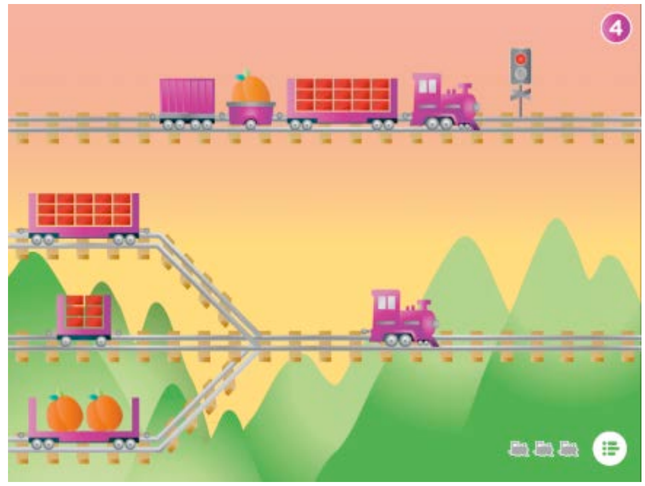

Figure 2: "Build-a-Train" ©Go Go Games Studios, LLC

The moveable train cars are "locked" on their tracks and make a "clink" sound when they meet the stationary locomotive in the center of the screen. When a player successful links up a new car smoke billows from the smokestack on the center train and the train animates forward. If a player moves a car without connecting it to the growing train in the center, the car slowly rolls back to its starting position. If a player makes an incorrect selection, all three choices are replaced with minimal visual feedback. We found that our user testers were equally excited by feedback in response to correct and to incorrect actions. To encourage players to follow the intended therapeutic progression of the game, we chose feedback that players found stimulating for correct actions and feedback that was visually uninteresting and involved no audio for incorrect actions.

Figure 3: "Wheels and Roads" ©Go Go Games Studios, LLC

Similarly, in the "Wheels and Roads" game (shown is Figure 3), a player must decide in which direction to send his vehicle given a choice of several roads, each marked with a sign. Players drive the vehicles along the road with a dragging gesture and can reverse the vehicle as needed. If a player makes a correct choice, a trail of stars follows the vehicle from the exhaust pipe as it drives off the screen, and auditory feedback is played (one of three honking sounds, a dog yip, or a cat meow). If a player makes an incorrect selection, the vehicle simply drives off without additional reward feedback.

In "Out of this World" (not pictured), players select body parts from an assembly line to construct a robot on the right side of the screen that matches the robot on the left. If a player chooses a matching body part, it snaps into place with accompanying auditory feedback. Once both robots are complete, spaceships descend, and the robots blast off into space. If a player makes an incorrect selection, the body part floats slowly back to its original position.

All games include animated rewards between levels, praise for level completion, simple introductory instructions that last only a few seconds, level locks to scaffold game progression, and music. Each of these elements was refined through repeated testing.

2.4 Algorithmic Design

For game design in general, a key element of creating an enjoyable experience is managing player stress such that game difficulty is balanced between too much and too little, ideally enabling players to maintain a sense of "pleasant frustration" as they play [4]. At the same time, gradually increasing demands on a child's multiple cue responding is central to achieving the goals of PRT.

Thus a key component in the development of *Go Go Games* was determining how to map the therapeutic progression of PRT into a difficulty curve that would hold players' interest. We operationalized game "difficulty" as a function of the distance between the correct choice and each incorrect one, where distance is measured by the number of differing features between items. For example, Figure 4 shows two items with a distance of 3: differing color, differing vehicle shape, and differing cargo. In contrast, Figure 5 shows two items with a distance of 1: only the presence or absence of a flag distinguishes them.

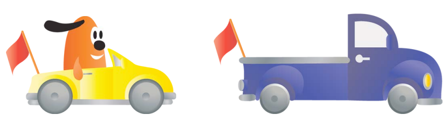

Figure 4: Two items with a distance of 3
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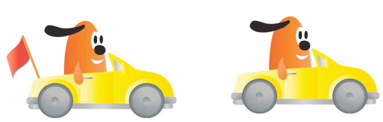

Figure 5: Two items with a distance of 1
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A pair of items with a smaller distance is more similar than a pair of items with a larger distance, and thus more difficult to distinguish. This means that decreases in distance result in increased difficulty. In the easiest puzzles, players select from a small number of diverse items separated by large distances, and as the games become progressively harder, players select from a greater number of items separated by smaller distances (and therefore more similar to the correct answer and to one another).

These coordinated increases in number of items and decreases in distance are only means to an end: together they enable us to force players to attend to multiple cues. For example, Figure 6 shows a set of three total choices, with the correct choice circled in red. Each incorrect choice differs from the correct selection by a distance of 1. Players can only identify the correct selection by simultaneously noticing both the color of the car and the type of animal riding in it – two different cues.

Figure 6: A player must notice two cues in order to pick out the correct selection (assuming it is the one circled)
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Compare this to the more difficult task in Figure 7, where incorrect choices still differ from the correct selection (again circled in red) by a distance of 1, but four choices are now presented. In this case, the player is forced to notice three different cues simultaneously in order to make a correct selection: shape of car, type of passenger, and presence/absence of a flag. As items cluster together in their features and additional items are added to the selection pool, the number of cues a player must simultaneously detect increases and the game becomes harder. In general terms, with n choices one can create a situation where a player must notice $n - 1$ cues.

Figure 7: A player must notice three cues in order to pick the correct one (assuming it is the one circled)
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It is worth noting that we do not differentiate features by their salience. For example, a difference in color and a difference in size are both treated equally, despite the fact that this may not reflect the players' perceptual experience. Similarly, the distance between green and blue is considered equivalent to the distance between green and red. In-person PRT sessions are effective despite facing this same limitation; thus, we hypothesize that our games will achieve their learning objectives and believe this claim is worth assessing. However, we also see the current lack of salience information as an opportunity for software to make a contribution that would be very difficult for human practitioners to achieve on their own, which we plan to explore.

Using this framework, we designed an algorithm to modulate game difficulty over time. Selecting from a pool of 560 possible combinations of 20 different categories of features, the game dynamically chooses a correct item and constructs an accompanying pool of incorrect alternatives. The algorithm gradually shrinks distance between items as the game progresses. As a result, the number of cues a player must notice as he makes forward progress in the game steadily increases.

Figure 8 shows the average number of cues players must simultaneously detect as they progress through each level, based on 10,000 simulated runs of each game. As shown in the graph, we designed our algorithm to increase task difficulty along a sawtooth curve in order to balance between increasing and relieving player stress. This approach is a common game design technique used successfully to maintain engagement [12]. It is also aligned with the principles of PRT where a key component is balancing between maintenance of existing abilities (e.g. the number of cues a player can already detect) and acquisition of new abilities (e.g. detecting more) [6].

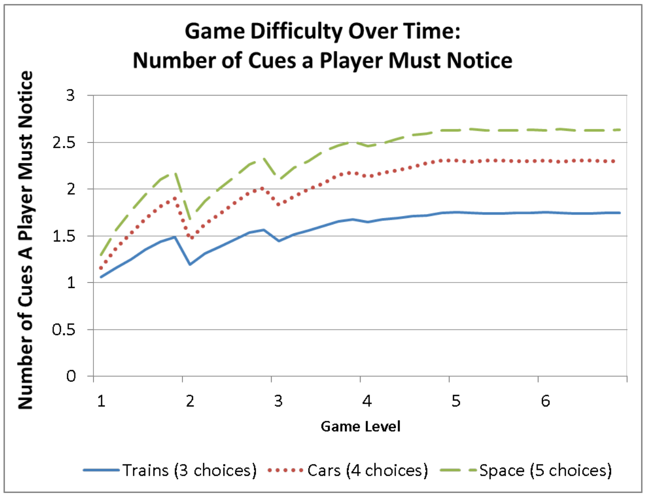

Figure 8: Game difficulty over time based on 10,000 simulations of each game

3. INITIAL EVALUATIONS

We have been encouraged by both our user testing sessions and responses from a commercial deployment of *Go Go Games*. In our in-person sessions, user testers have all been able to play independently (some requiring initial support from parents) and played for 10 minutes or more without prompts to stay on task.

A large number of internet users in 80 countries have downloaded the games. We know very little about who is playing as user information is fully anonymized by the Apple App Store, but we can see that the average session lasts approximately 12 minutes. Given that the average mobile game session lasts only 114 seconds, we are encouraged by this rough indicator of engagement [1]. We can also see how frequently users come back to play. In the most recent calendar month, just over 47% of all app owners played *Go Go Games*. On average, returning players had owned the app for 3.7 months.

4. CONCLUSION & FUTURE WORK

In this paper we describe the design of a game suite that combines the steps of an evidence-based therapy with common game design techniques and the feedback of 30 children with ASD. We describe how we intentionally increase demands on multiple cue responding and tailor reward structure around successfully meeting those demands.

We are in the process of conducting an efficacy study with children on the autism spectrum to assess both engagement and learning gains associated with playing our games. We plan to measure multiple cue responding and nonverbal IQ before, during and after several weeks of game exposure. We are interested in looking at learning gains, raw engagement, and changes in engagement as players master the games.

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