Modeling the Effect of Attention Deficit in Game-Based Motor Ability Assessment of Cerebral Palsy Patients

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ABSTRACT

Cerebral Palsy (CP) is a central nervous system disorder affecting 2 out of every 1000 births. CP limits a person's muscular function. Rehabilitative, touch-screen gaming promises to assist in developing muscle tone and dexterity for hemiparetic CP patients as well as help therapists keep track of a patient's performance over time. However, most systems fail to take into account other factors of the disorder that could affect the scoring of a patient differently on various assessment days - specifically attention deficit or distraction. Cerebral Palsy is frequently associated with diagnosed Attention Deficit (Hyperactive) Disorder (ADD/ADHD), but even if a child does not fall within that definition, pediatric CP patients are often easily distracted. In this work we perform attention deficit simulation experiments with able-bodied users playing three rehabilitative games as well as similar computer generated data and propose a methodology to model and eliminate the effects of attention deficit or distraction from the scoring scheme used to evaluate the patient's motor abilities and progress over time.

Categories and Subject Descriptors

K.4.2 [**Social Issues**]: Assistive technologies for persons with disabilities.

General Terms

Design, Human Factors.

Keywords

Cerebral Palsy, attention deficit, rehabilitative gaming.

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1. INTRODUCTION

The United States' Center for Disease Control and Prevention (CDC) [1] defines Cerebral Palsy (CP) as a non-progressive disorder in which a person has a limited ability to move or maintain balance or posture, and estimates of the prevalence of CP range from 1.7 [24] to 2.3 [12] cases per every 1000 persons. People who suffer with CP have incurred damage to their motor cortex – a region of the brain that controls muscle movement. This damage typically occurs before birth, but CP-inducing brain traumas can occur in the developing brain up until around age 5.

While CP remains incurable, rehabilitation is the main route of treatment. For the physical effects of CP, treatment usually consists of both physical therapy (to give maximum mobility) and occupational therapy (to increase function for daily skills – "occupation"). Because children can often become disinterested in the repetitive therapy, physical therapists (PTs) and occupational therapists (OTs) have noted that video games are a safe and healthy way to promote desired movement [8].

In the Heracleia lab at the University of Texas in Arlington, researchers are developing a touch screen gaming system called CPLAY [15]. With the integration of other data collecting sensors, CP patients will be able to play these games to increase dexterity and muscle tone. Simultaneously, the system will monitor events from multiple sensors to more accurately record and analyze the patient's development over time.

Currently, this system and other gaming systems intended for occupational therapy do not appropriately consider the effect distraction can have on the score of a patient. With the high prevalence rate of ADHD in CP patients, there should be an increased awareness and incorporation of distraction into the score of a patient. Without a system that appropriately accounts for distraction, a patient's development history could, for example, indicate periods of backsliding motor skills when, in reality, the patient was only more distracted one or more of the days he participated in the rehabilitative game therapy. However, if one could link the amount of distraction or attention (or combination of both) to the game performance, one could normalize the score of a patient and be able to more accurately determine a patient's development over time – perhaps even being able to justify continuing treatment that otherwise would have been hard to quantitatively substantiate.

Researchers have only recently begun to explore the role of distraction in video games intended for health. Scientists have noted a lack of data and exploration [8] and have suggested studies that examine factors of distraction and concentration - the type of study that this paper is based on. The goal of this study is to develop an algorithm that can normalize the game scores for patients participating in the CPLAY system. It is hypothesized that a trend can be discovered that relates the game score to distraction so that a score-normalization algorithm can be developed. Additionally, this paper begins to explore the type of rehabilitative games that are appropriate for CP patients, taking into account the high risk of distraction and making suggestions for the future of rehabilitative gaming for children with CP.

In section 2 of this paper we explore the related work around the problem of Cerebral Palsy and we present past and current trends in traditional rehabilitation therapy approaches and rehabilitative gaming. Section 3 introduces our methodology to measure gaming performance and incorporate the effect of attention/distraction in the final scoring system. Our experimental findings are presented in section 4. Section 5 continues with a discussion over the findings of our study, and finally, section 6 presents of our concluding remarks.

2. RELATED WORK

2.1 The Problem of Cerebral Palsy

Cerebral palsy is often categorized into four main types: spastic, athetoid, ataxic/hypotonic, and mixed [1]. About seventy to eighty percent of people with CP have spastic CP. The muscles of people with spastic CP are stiff. The muscle tone is increased, and the person struggles to move. Spastic CP includes spastic diplegia (affecting both legs), spastic hemiplegia (affecting one side of the body), and spastic quadriplegia (affecting the whole body). With athetoid (or dyskinetic) CP, a person's nervous/muscle control is uncoordinated, typically manifesting itself as slow movement. Ten to twenty percent of people with CP fall into this athetoid category. People with the third type of CP, ataxic CP, struggle in their depth perception and balance. This five to ten percent of the CP population can have either increased or decreased muscle tone. Lastly, a person with CP could struggle with a combination of these types – mixed – most commonly spasticity and athetoid movements.

Beyond muscle control, Cerebral Palsy is closely associated with a variety of cognitive impairments, including selective visual attention and attention deficit/hyperactivity disorder (ADHD) [5, 17, 11]. In fact, recent studies have reported an overall prevalence of ADHD of 19% in children with CP [20], and earlier population-based research suggested a 25% prevalence rate of hyperactive behaviors in children with CP [10]. Some studies propose an even higher 40% rate of severe difficulties with emotional regulation, behavior and concentration [16]. Prevalence estimates of ADHD in the CP population are difficult to assess because while children with CP exhibit significantly slower inspection time (IT) and more reported symptoms of inattention and hyperactivity than children without CP, there is a lack of statistical association between IT and the Connor's Parent Rating Scale-Revised (CPRS-R - a protocol for parents to assess the likelihood of ADHD in their child). Rather than an absence of a true relationship, this lack of association between IT and CPRS-R is likely due to the nature of the CPRS-R, which includes issues such as "children getting out of their seat and running around the table at mealtime" (something that is less likely for a child with motor disabilities) [21]. Therefore, it is possible that the prevalence rates of ADHD in children with CP could be higher.

2.2 Constraint Induced Movement Therapy

In cases of hemiplegia, constraint-induced movement therapy (CIMT) is one common method of rehabilitation. With the goal of improving extremity function in patients with central nervous system damage (a category into which CP falls), CIMT involves the restraint of the unaffected limb for various amounts of time (sometimes up to 90% of waking hours) [6]. In 2006, an online update of a 2004 Stroke Connection (American Heart Association) article, stated that CIMT was becoming increasingly common because of its proven effectiveness [2].

In 2005, the effectiveness off CIMT in young children with hemiplegic CP was investigated [7]. A control group of 20 children with hemiplegic CP who participated in conventional pediatric treatment was compared to a similar group of 21 hemiplegic CP patients who instead completed a CIMT routine (2 hours of constraint per day over 2 months). After the 2 months of treatment, the children who received the CIMT regimen had a significantly better ability to use their hemiplegic hand over the children in the control group.

Another research group applied CIMT to rehabilitative gaming [22]. In this case study, three adults with motor impairments in their hands and fingers (including one person with hemiplegic CP) participated in a treatment of 15 one-hour sessions consisting of computer gaming. The findings are consistent with other studies that assert the efficacy of CMIT. While the study utilized unconventional approaches to gaming control (a variety of therapeutic objects instrumented with motion sensors), the results suggest that touch-screen gaming is a viable option for rehabilitative gaming utilizing CMIT.

2.3 Rehabilitative Gaming

Television and video gaming are not only used for entertainment anymore. More and more, interactive media is being used for rehabilitation. In 2008, European researchers submitted that interactive computer play is a potentially promising tool for the motor rehabilitation of children [19]. In 2010, researchers utilized methods of interactional constructionism [4, 18] to address suggestions that motivation increases and training becomes more intensive with these rehabilitation methods. The study found that with careful game-to-player matching and bystanders who are both supportive and challenging, rehabilitative gaming is a productive method for therapy [23]. The children in the study were noted not to be responding to the games as a new treatment method but as a fun and motivating project.

A games accessibility special interest group in California outlines the need for accessible video games in a 1998 article [3]. While trends in gaming have slowly made room for more accessible games, the CPLAY system strives to create games that are both accessible and useful for therapy. Additionally, the CPLAY system is intended to be available for home therapy in addition to clinical use. As one study proposes, there is promising effectiveness in home programs for CP [14]. The CPLAY system combines these aspects of therapy and gaming, as well as other important features of

Figure 1: Screen-shots of the three rehabilitative games used in our experiments. Left: Bubble game. Middle: Baking game. Right: Maze game.

therapy (such as CMIT) to create a system that can effectively assist in and track over time the development of a CP patient. With the ability to correct for a distracted score – the goal of this study – the CPLAY system will be an effective regimen for CP therapy.

3. METHODS

3.1 Experiment Design

To examine the effect of attention time, distraction time and game level on game score across three touch-screen games (Figure 1), 3 different factorial experiments were developed with 3 replications each. Four people participated in this study by playing the games for three hours every week. At the time of the experiment, each person who participated did not have impaired hand or arm movement, nor were they diagnosed with ADHD. Each person participated in the study for a total of 8 hours, split into 1.5 hour segments, two times every week until completion. To simulate attention deficit, an artificial distraction protocol was designed.

3.1.1 *Bubble Game*

The first experiment was with the Bubble Game. The Bubble Game is a game in which bubbles fall from the top of the screen and the user is expected to touch them to "pop" the bubbles before they fall off of the screen. Among other things, the game records the number of hits, failed attempts (when the screen is touched where there is not bubble) and bubbles escaped. The score is a calculated by with the following formula:

$$score = 100\left[\frac{hits}{hits+bubbles\_escaped} - \frac{1}{2}\frac{failed\_attempts}{hits+bubbles\_escaped}\right]$$

In this experiment, distraction times and attention times of 3, 10, 18, 26, 34 and 42 seconds were fully crossed with one another. In a real-life application, the attention and distraction times would be automatically detected using eye and facial tracking tools to determine the user's focus of attention. However, since during this study such tools were not readily available, we artificially induced distraction. The participant would actively attend the game for the time specified by the "attention time" and then look away from the game for the specified "distraction time", repeating the combination until game completion. The attention/distraction patterns of the player were monitored by an independent *observer* to ensure correct execution of the protocol. Because each game only lasts 45 seconds, some of the attention time/distraction time pairings were not performed. For example, the attention time of 42 seconds was only paired with 3 seconds because the pairing of 42 seconds with anything over 3 seconds would not be different than the 3 second pairing. Additionally, depending on where in the sequence the attention

	Distraction Time (sec)					
Att. Time	3	10	18	26	34	42
3	50, 47, 52	27, 25, 22	20, 14, 14	13, 14, 14	13, 14, 14	7, 7, 7
10	79, 73, 73	55, 49, 45	45, 45, 45	42, 36, 31	24, 23, 23	
18	86, 81, 85	78, 71, 67	60, 54, 50	42, 40, 40		
26	93, 87, 87	78, 71, 67	60, 58, 58			
34	93, 87, 87	78, 76, 76				
42	93, 94, 93					

Table 1: Percent attention yielded from attention time and distraction time for the baking and bubble games. The three numbers in each cell represent three different replications.

time started, the percentage of time played would change slightly. Because of this, the start times were changed with each replication – 0, 3 and 5 seconds, yielding 3 percentages for each pairing. As Table 1 shows, 21 games were played with varying attention and distraction times. 2 games were played for controls – a positive control with 100% attention and a negative control with 0% attention – making 23 total games. We should note that, throughout this paper, *percent attention* is defined as the amount of time the user was fully focused on the game over the overall time duration of the game.

A third dimension with three levels was also fully crossed - game difficulty. Level one is a slow bubble falling rate (45 seconds iteration delay). Level two is a medium bubble falling rate (30 second iteration delay). Level three is a high bubble falling rate (15 second iteration delay). Each game level was played at all 23 points of percent attention.

3.1.2 *Baking Game*

The second experiment was with the baking game. The baking game is a game in which the player is expected to tap cakes or pancakes that have completed baking and are in the "delicious" stage. From the beginning of the game, each cake or pancake takes 5 seconds to bake and rests at the "delicious" stage for 3 seconds before turning "burnt" and immediately beginning the baking process over. If tapped before the cake is burnt, the baking process begins at zero. A bonus is received if the player taps three "delicious" cakes in a row, but if the cake is tapped before it is finished baking (in the "uncooked" stage), points are taken away. The score is calculated with the following formula:

$$\begin{aligned} score = (-15) \times burnt + (20) \times delicious \\ +(5) \times bonus - (10) \times uncooked \end{aligned}$$

The experiment design for this game is exactly the same as the bubble game, with multiple attention times and distraction times fully crossed with 3 game levels (Table 1).

3.1.3 *Maze Game*

The third and final experiment was with the maze game. In this game, players must navigate a ball through a maze using a finger on the touch screen. Metrics recorded include the user's path length, time needed to complete the maze and the number of wall collisions. Because of the nature of the maze game, a "user-paced" game (play until completion, usually less than 60 seconds, rather than for a set amount of time), the attention and distraction times used were slightly different (Table 2). Note that because the percent attention is dependent on the length of time needed to complete the

		Distraction Time (sec)		
		3	10	18
Att. Time	3	50	23	14
	10	77	50	36
	18	86	64	50
	26	89	72	59
	34	92	77	65
	42	93	81	70

Table 2: Estimated percent attention from attention time and distraction time for the maze game.

maze, percent attention is estimated in Table 2 as *(attention time)/(attention time + distraction time)*. Additionally, there are two scoring methods used for the maze game, referred to as "score 1" and "score 2". Score 1 is the score that is inherent in the game – a function of wall collisions and path length. Score 2 considers both of these factors as well as completion time to add another variable.

3.2 Computer Simulation

To explore the feasibility of simulating user attention deficit and distraction patterns with artificially generated data as well as to increase the amount of available experimental data, we generated similar game-playing data using a computer program we developed. The program used as input scores collected from real users while playing the games and generated data with similar distributions of performance and attention/distraction levels.

Each experiment was modeled in MATLAB to determine the expected scores. The bubble and baking games utilized input such as the amount of time needed for a person to respond to the introduction of a bubble or cake and the minimum amount of time between two consecutive taps. Each game model can output a matrix of score and percent attention data. It should also be noted that the models assume that when the player plays the game, they play with 100% accuracy. That is, the models do not account for mistakes that a human player might occasionally make. However, it is possible - and likely - that multiple starts (which is directly correlated to attention and distraction times according to the experiment design) can significantly affect the score of a player.

3.2.1 Bubble Game

The bubble game model creates a large matrix with time and two columns for each introduced bubble – one for the amount of time the bubble could be on the screen and one for the amount of time the bubble is actually on the screen. A smaller matrix is also created that takes input from the large matrix, showing time, when the player is attending the game, how many bubbles have been introduced, how many bubbles are on the screen at any time, when a bubble is popped and when a bubble escapes. With the model it is possible to run through an array of distraction and attention times and output a score. As previously alluded to, this model assumes the player plays the game with 100% accuracy and will not make any mistakes in popping the bubbles (e.g. "failed attempts").

3.2.2 Baking Game

The baking game model creates one matrix including columns for time, when the player is attending, each oven that shows when the oven contains a "delicious" cake, when a "delicious" cake is tapped, when a cake is burnt and when the bonus is achieved. Like the bubble game simulation, this model can output score for various distraction and attention times. As with the bubble game model, the baking game model assumes that the player will make no mistakes in game play (e.g. tapping "uncooked cakes").

3.2.3 Maze game

A model was developed to simulate the maze solving game experiment by creating a simple matrix that has time in one column and time played in another column (with a zero in the place of time not played). The matrix adds more data until the time necessary to complete the maze is reached. These numbers were determined by averaging the completion times of each level in preliminary data. As with the other models, this model assumes that the user makes no mistakes in gameplay (e.g. "wall collisions").

3.3 Statistical Analysis and Normalization Method

The simulated data was first compared to the actual data using a paired t-test [9]. A best subsets regression [13] was performed to determine the best combination of predictors to determine the score. The regression coefficients were determined and turned into a model for normalization.

4. RESULTS

The simulated data aligned with the actual data in most cases, the exception being the second level of the maze game. The maze game has consistently unusual data. This is shown in this section and explained in the discussion.

4.1 Bubble Game

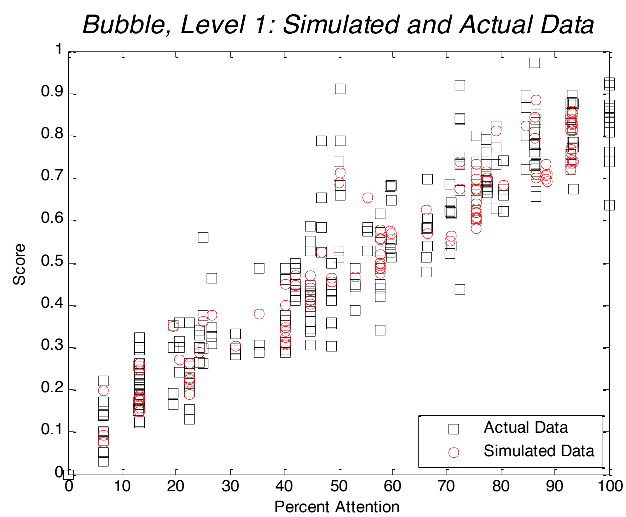

Figure 2: Bubble Game, level 1, simulated & actual data. The chart shows scores achieved as function of attention percentage.

The experiment simulation results are not statistically different than the actual data from the physical experiment on

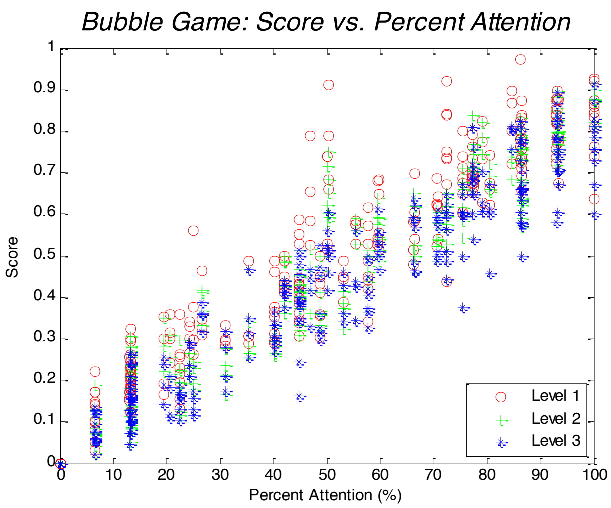

Figure 3: Bubble Game, score vs. percent attention for three different game difficulty levels.

all three levels ($\alpha = 0.05,\ p < 0.001$). The level 1 plot of simulated data is shown with actual data (Figure 2). Levels 2 and 3 have similar plots. As one would expect, the score rises linearly with percent attention – from the lowest possible score at 0% attention to the highest possible score at 100%. Additionally, there is a significant difference between the scores on levels 1, 2, and 3 ($\alpha = 0.05,\ p < 0.001$), (Figure 3).

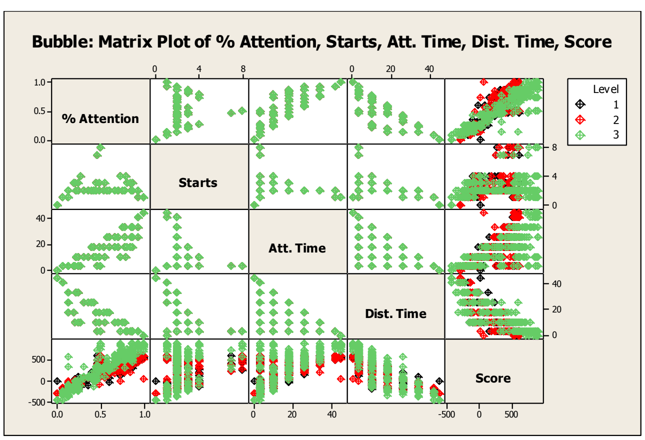

Figure 4: Scatter plot matrix of the bubble game with potential predictors (percent attention, number of starts, attention time and distraction time) and the response (score).

In addition to percent attention, a scatter plot matrix was created to visualize the effect of the amount of starts, attention time and distraction time as well on the player's score (Figure 4). The data shown in Figure 3 matches the northeast corner plot of every matrix in this paper. The matrix plot is included because there are observable trends between all of the predictors and the score.

4.2 Baking Game

As with the bubble game, the baking game experiment simulation results are not statistically different than the actual data from the physical experiment on all three levels ($\alpha = 0.05,\ p < 0.001$) (sample comparison in Figure 5). Again, the scores increase linearly with percent attention, from the lowest possible score at 0% attention to the highest possible score at 100%. For levels one and two of the baking game, scores range from -300 to 605 points. In level 3, two ovens are added to increase the difficulty; level 3 scores range from -450 to 910 points. There is no significant difference between the scores on levels 1 and 2 ($\alpha = 0.05,\ p = 0.707$). However, there is a significant difference between the scores of levels 1 and 3 and levels 2 and 3 ($\alpha = 0.05,\ p < 0.001$; $\alpha = 0.05,\ p < 0.001$), (Figure 6).

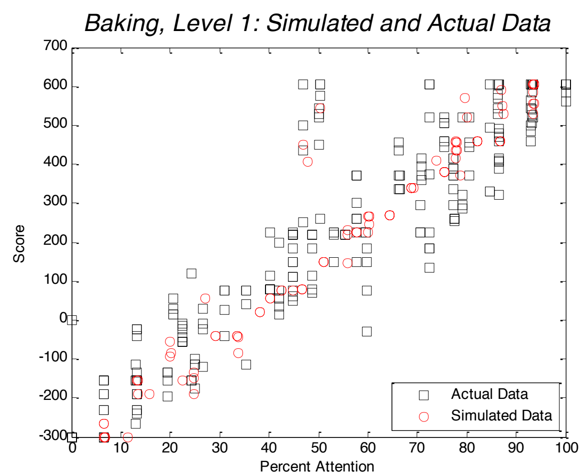

Figure 5: Baking Game, level 1, simulated & actual data. The chart shows scores achieved as function of attention percentage.

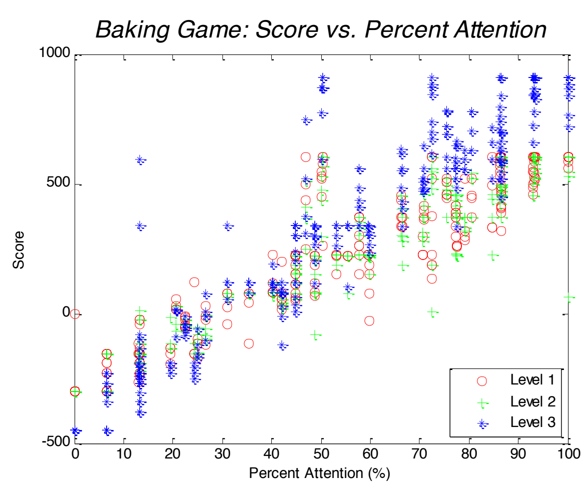

Figure 6: Baking Game, score vs. percent attention for three different game difficulty levels.

Again, a scatter plot matrix (Figure 7) was created to visualize the effect of percent attention, the amount of starts, attention time and distraction time on the player's score. There are observable trends between all of the predictors and the score.

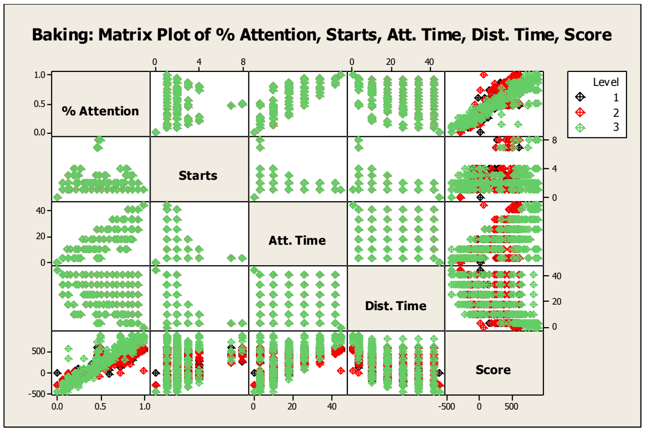

Figure 7: Scatter plot matrix of the baking game with potential predictors (percent attention, number of starts, attention time and distraction time) and the response (score).

4.3 Maze Game

While the simulated maze game predicted the results of the score 1 of the maze game with certain accuracy, score 2 of the maze game was less predictable (see Figure 8). Score 2 is based significantly on the players' ability, accuracy and timing. The potential for score 2 to have a wide array of scores at a single percent attention is realized in the plot of the maze games' scores vs. percent attention (Figure 9).

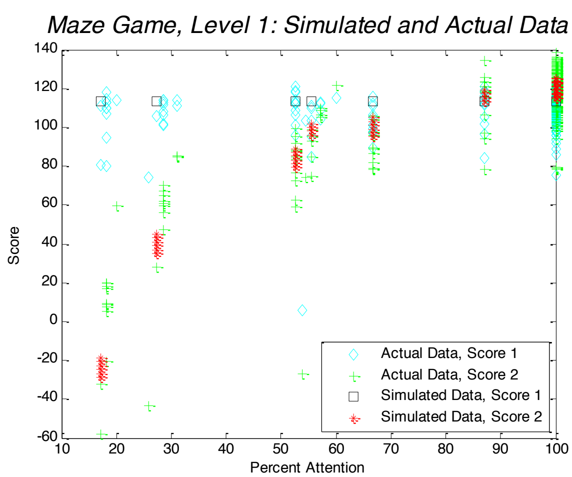

Figure 8: Maze Game, level 1, simulated & actual data. The chart shows scores achieved as function of attention percentage.

The trends between percent attention, starts, attention time and distraction time are less apparent in this matrix plot, especially in relation to score 1 (Figure 10). In score

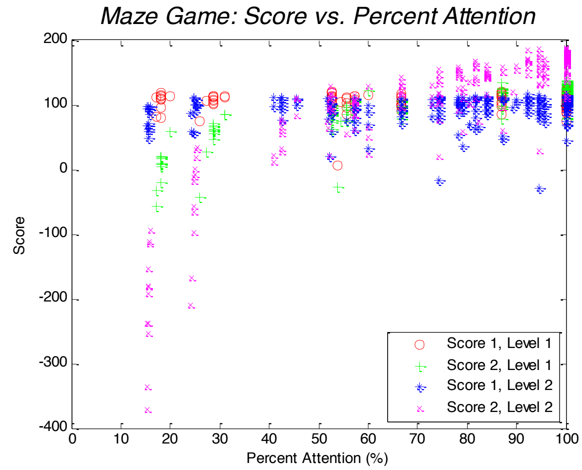

Figure 9: Maze Game, score vs. percent attention for two different game difficulty levels.

2, slight trends can be identified, but upon regression analysis, the four predictors are not accurate enough for proper prediction.

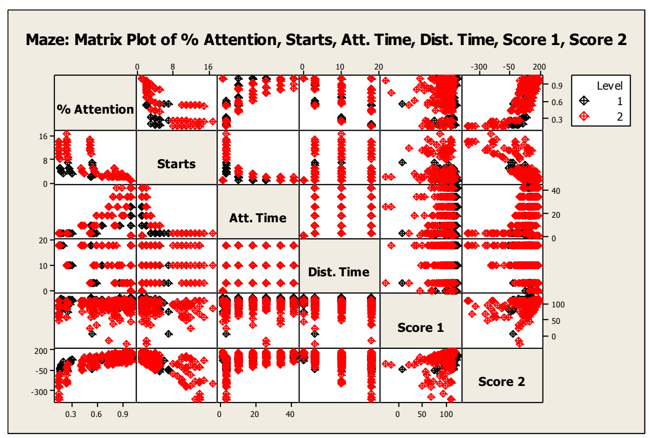

Figure 10: Scatter plot matrix of the maze game with potential predictors (percent attention, number of starts, attention time, distraction time, score 1 and score 2).

4.4 Score Normalization

To develop a base formula for the normalization method, a best subsets regression was performed for each game at each level. The 4-predictor model was chosen to be the basis for the normalization method because it consistently had the best C-p value and the highest R^2_{adj} value over all games and levels. As hypothesized, the maze game's scoring system does not lend itself to a normalization method; its R^2_{adj} values are not high enough for a superior method to be developed. This is discussed further in the discussion section.

Game, Level	β_0 (Constant)	β_1 (% Att.)	β_2 (Starts)	β_3 (Att. Time)	β_4 (Dist. Time)	R^2_{adj}
Bubble, 1	0.0102	0.783	0.0349	0.000219	0.000442	91.5%
Bubble, 2	-0.0073	0.816	0.0238	-0.000783	0.000398	93.3%
Bubble, 3	-0.0097	0.784	0.0126	0.000276	0.000779	91.1%
Baking, 1	-287	768	39.1	1.53	-1.51	90.0%
Baking, 2	-310	773	41.6	2.01	-0.744	90.5%
Baking, 3	-450	1185	65.4	1.23	-1.48	91.0%

Table 3: Regression Models for Bubble and Baking games. The table shows the optimal coefficients found for each predictor and the R^2_{adj} value for each model.

The regression models follow the form:

$$Score = \beta_0 + \beta_1(PercentAtt.) + \beta_2(Starts) + \beta_3(Att.Time) + \beta_4(Distr.Time)$$

Table 3 lists the coefficients for each game and level as well as the R^2_{adj} value for each model.

With these regression models, it is possible to create a scoring method that removes the element of distraction from the score, outputting a more reliable score to assess muscle development and control. Though the model has five dimensions, it is easier to visualize the normalization method in 2 dimensions. Figure 11 shows a model in which percent attention is the only predictor. If for example, a patient were playing at 75% attention, then his maximum score would be 75 (according to this hypothetical game's scoring system, the y-axis). If, however the patient's score was 37.5, it is assumed that the patient is playing at only 50% ability. That is, his score was at 50% of his maximum potential. By analogy, the 5-dimensional regression developed here has the ability to take percent attention, the amount of starts, average attention time and average distraction time into consideration when determining a maximum score. Upon calculating the maximum score and comparing the score to the patient's score, the model will output a percent ability at which the patient is performing, a number that can be recorded over time to better assess the development of a patient, eliminating distraction as a factor.

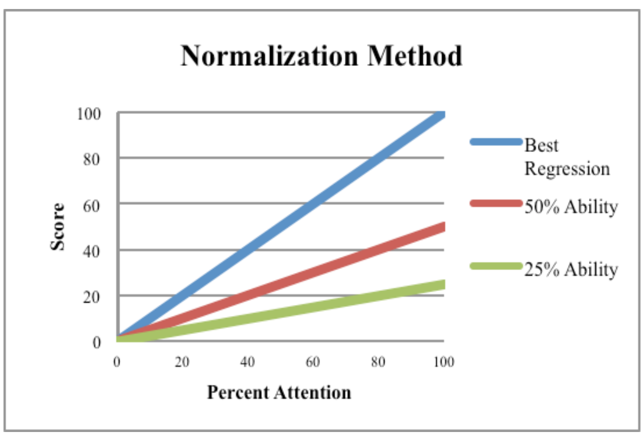

Figure 11: Normalization Method Visualization. The different lines show the scores that the player would get as function of their percent attention if they played at their full ability (blue line), 50% ability (brown line) and 25% ability (green line).

5. DISCUSSION

This study demonstrates the ability to take factors such as distraction out of the assessment of cerebral palsy patients in order to see the affect of rehabilitation on the physical ability of the patient. By using multiple linear regression, a model can be established that predicts the score of a patient on two sample games on multiple levels.

However, this model is limited by the scoring method of the game. In this study, the maze game is an example of a user-paced game. The scoring method of this game is based on the ability of the player to finish the game with the shortest path and without running into walls (control of the cursor). Upon analysis of the wall collision data in respect to percent attention, no pattern is apparent or statistically significant. Additionally, in testing a maze game without changing the maze, the path remains the same, and the player become accustomed to it after one attempt. Because of the constant nature of these variables with a change in percent attention, the inherent scoring system (referred to as "score 1" throughout this paper) is the most appropriate method of calculating a score that is not affected by how distracted or focused the player is. Because of this, the maze game and other user-paced games are a recommended system for rehabilitative gaming for cerebral palsy patients.

Concerning the system-paced games to which the distraction-eliminating algorithm may be applied, there are certain assumptions made. One large assumption is that distraction is the only factor that is keeping the game from collecting relevant information about the physical ability of the patient. There could be (and likely are) other factors similar to distraction that should be eliminated from the score to effectively single out the development of a patient's physical abilities.

6. CONCLUSIONS

This study examines the implications in the development of system-paced gaming intended for rehabilitation and suggest a methodology to tackle the problem. With the high prevalence of attention deficit disorder and other mental deficiencies that can negatively affect the ability of a cerebral palsy patient to actively attend an activity for extended lengths of time, it is important to have an effective system to eliminate the noise distraction creates in the assessment of a patient's physical ability and muscular control. The basis for such a system is described in this study and can be available immediately for the games described in this paper. However, with future research, this system can have broader implications for system-paced games beyond those described in this paper. A method for establishing a score normalization algorithm can easily be developed using the techniques described in this paper. Future work should include this attempt to generalize and categorize games effectively to normalize scoring error due to distraction and other factors obscuring the patient's development.

In addition, the rehabilitation system should include an eye-tracking function to analyze the attention of the player in real time, allowing for better measurement and assessment of cerebral palsy patients. As it is currently, the score normalization method described in this paper is dependent upon the estimation of the therapist of the patient's percent attention, amount of starts, average attention time and average distraction time. In the future, however, the eye-tracking function will be able to input this data directly into the games' scoring algorithm, allowing for a rehabilitation system that is most comprehensive and beneficial.

Acknowledgments

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7. REFERENCES

[1] CDC - cerebral palsy, home - NCBDDD. http://www.cdc.gov/ncbddd/cp/index.html.

[2] A rehab revolution - american stroke association. http://www.strokeassociation.org/idc/groups/stroke-public/@wcm/@hcm/@sta/documents/downloadable/ucm_310314.pdf.

[3] K. Bierre, J. Chetwynd, B. Ellis, D. M. Hinn, S. Ludi, and T. Westin. Game not over: Accessibility issues in video games. In *Proc. of the 3rd International Conference on Universal Access in Human-Computer Interaction*, pages 22–27, 2005.

[4] R. Collins. *Interaction ritual chains*. Princeton University Press, 2004.

[5] S. Craft, D. A. White, T. S. Park, and G. Figiel. Visual attention in children with perinatal brain injury: Asymmetric effects of bilateral lesions. *Journal of Cognitive Neuroscience*, 6(2):165–173, 1994.

[6] S. C. Deluca, K. Echols, C. R. Law, and S. L. Ramey. Intensive pediatric constraint-induced therapy for children with cerebral palsy: randomized, controlled, crossover trial. *Journal of child neurology*, 21(11):931–938, 2006.

[7] A.-C. Eliasson, L. Krumlinde-Sundholm, K. Shaw, and C. Wang. Effects of constraint-induced movement therapy in young children with hemiplegic cerebral palsy: an adapted model. *Developmental Medicine & Child Neurology*, 47(04):266–275, 2005.

[8] M. Griffiths. Video games and health: Video gaming is safe for most players and can be useful in health care. *BMJ: British Medical Journal*, 331(7509):122, 2005.

[9] H. Hsu and P. A. Lachenbruch. Paired t test. *Wiley Encyclopedia of Clinical Trials*, 2008.

[10] S. McDermott, A. L. Coker, S. Mani, S. Krishnaswami, R. J. Nagle, L. L. Barnett-Queen, and D. F. Wuori. A population-based analysis of behavior problems in children with cerebral palsy. *Journal of pediatric psychology*, 21(3):447–463, 1996.

[11] F. Miller, S. J. Bachrach, and S. J. Bachrach. *Cerebral palsy: A complete guide for caregiving*. Johns Hopkins University Press, 1995.

[12] C. C. Murphy, M. Yeargin-Allsopp, P. Decoufle, and C. D. Drews. Prevalence of cerebral palsy among ten-year-old children in metropolitan atlanta, 1985 through 1987. *The Journal of pediatrics*, 123(5):S13–S20, 1993.

[13] R. H. Myers. *Classical and modern regression with applications*, volume 2. Duxbury Press Belmont, CA, 1990.

[14] I. Novak, A. Cusick, and K. Lowe. A pilot study on the impact of occupational therapy home programming for young children with cerebral palsy. *The American journal of occupational therapy*, 61(4):463–468, 2007.

[15] A. Papangelis, G. Mouchakis, A. Boisselle, D. Kosmopoulos, V. Karkaletsis, and F. Makedon. A game system for remote rehabilitation of cerebral palsy patients. In *Proceedings of the 5th International Conference on PErvasive Technologies Related to Assistive Environments*, page 19. ACM, 2012.

[16] J. Parkes, M. White-Koning, H. O. Dickinson, U. Thyen, C. Arnaud, E. Beckung, J. Fauconnier, M. Marcelli, V. McManus, and S. I. Michelsen. Psychological problems in children with cerebral palsy: a cross-sectional european study. *Journal of Child Psychology and Psychiatry*, 49(4):405–413, 2008.

[17] S. Pirila, J. van der Meere, P. Korhonen, P. Ruusu-Niemi, M. Kyntaja, P. Nieminen, and R. Korpela. A retrospective neurocognitive study in children with spastic diplegia. *Developmental neuropsychology*, 26(3):679–690, 2004.

[18] M. Pollner. *The Self We Live By: Narrative Identity in a Postmodern World, by James A. Holstein and Jaber F. Gubrium. New York: Oxford University Press, 2000. 268 pp. 49.95(cloth); 21.95 (paper).*, volume 23. JSTOR, 2000.

[19] M. Sandlund, S. McDonough, and C. Hager-Ross. Interactive computer play in rehabilitation of children with sensorimotor disorders: a systematic review. *Developmental Medicine & Child Neurology*, 51(3).

[20] R. Scehenker, W. J. Coster, and S. Parush. Neuroimpairments, activity performance, and participation in children with cerebral palsy mainstreamed in elementary schools. *Developmental Medicine & Child Neurology*, 47(12):808–814, 2005.

[21] L. K. Shank, J. Kaufman, S. Leffard, and S. Warschausky. Inspection time and ADHD symptoms in children with cerebral palsy. *Rehabilitation psychology*, 55(2):188, 2010.

[22] T. Szturm, J. F. Peters, C. Otto, N. Kapadia, and A. Desai. Task-specific rehabilitation of finger-hand function using interactive computer gaming. *Archives of physical medicine and rehabilitation*, 89(11):2213–2217, 2008.

[23] D. Wasterfors. Stretching capabilities: children with disabilities playing TV and computer games. *Disability & Society*, 26(3):337–349, 2011.

[24] S. Winter, A. Autry, C. Boyle, and M. Yeargin-Allsopp. Trends in the prevalence of cerebral palsy in a population-based study. *Pediatrics*, 110(6):1220–1225, 2002.