Gamification of Physical Therapy for the Treatment of Pediatric Cerebral Palsy: A Pilot Study Examining Player Preferences

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Abstract

Physical therapy of the upper extremities has been demonstrated to be a useful treatment for pediatric cerebral palsy. This paper describes a test of a custom-made Kinect-based health game called *Burnie* that gamifies upper arm physical therapy for pediatric cerebral palsy patients by placing the player in the role of a bird navigating a nature-themed obstacle course. Precise repetition of the games can be a difficult learning task as the player's feedback of correct learning is kinesthetic rather than visual. This study seeks to illuminate the affective element of learning specific physical poses within a video game learning paradigm. This pilot study evaluates the game for player satisfaction along the dimensions of graphics, controls, and overall enjoyment. In preparation for later testing with the target population of pediatric patients, an initial pilot study was conducted with undergraduate students as test subjects using a post-test only control group design. After subjects played the game for fifteen minutes, they evaluated the game along the aforementioned dimensions using a pen and paper survey. Average observed ratings (on a 10 point scale, higher being better) were: 7.65, 5.4, and 6.75, respectively. These results indicate that Burnie is an enjoyable game experience, but in order to maximize effectiveness more research needs to be done on the control scheme to determine why it was rated lower than the rest of the game. Identification of the specific factors that contribute to control enjoyment is recommended. This work contributes to HCI by presenting a new method for leveraging computers to improve the quality of life of pediatric sufferers of cerebral palsy, and contributes to education by providing a new means for teaching individuals how to perform specific therapeutic gestures within a game-based learning session.

Keywords: cerebral palsy; serious games; Kinect; behavior modification

Introduction

Cerebral palsy (CP) is a chronic movement and muscle disorder whose onset begins in childhood and persists for the duration of an individual's life [23, 25]. Though there is not a cure for the disease, physical therapy (PT), particularly when applied to the upper extremities, has been shown to ameliorate some CP symptoms [1, 18]. Despite the demonstrated effectiveness of PT, patient adherence to therapy is problematic, as patients tend only to maintain their regimen while actively enrolled in a therapy program [2]. The reasons for the lack of compliance are multi-factored and not completely understood [29]. This lack of adherence has been observed to be even worse in pediatric CP patients [4, 6, 20]. This results not only in diminished motor function related clinical outcomes, but also has negative mental health correlates [14].

Games have long been used as a means of health promotion [17]. New, inexpensive, motion-based game technologies such as the Wii and Kinect have enabled new ways of applying games to health. Several researchers have successfully used both the Wii balance board and the Kinect to aid in balance rehabilitation [5, 18, 19]. Chang et al [9] have used the Kinect to increase motivation for PT, and in so doing improved exercise performance. A consistent theme recurrent in the literature is that therapies accompanied by a gaming component are more likely to have

improved clinical outcomes due to increased patient motivation [15, 30]. The commercial games market has also responded and has produced a wide array of games categorized as "exergames" [16].

Despite these encouraging efforts, there seem to be few games, if any, specifically crafted for the clinical and preferential needs of pediatric cerebral palsy patients. The sometimes repetitive nature of video game play seems to present an excellent opportunity to reinforce to children the correct way to conduct their physical therapy pose regimen.

This project is an attempt to address this gap. We have created a Kinect-based game that is modeled after the upper body physical therapy routines typically prescribed to pediatric cerebral palsy patients. We have taken four pediatric PT upper arm poses and provided a behavior modification-oriented structure in order to motivate a child to perform these poses correctly and more frequently. Physicians at a prestigious children's hospital collaborated directly with the game designer of this project to ensure the validity of the game's specific approach. The game is whimsical and juvenile in tone with a focus on providing ample opportunities for positive reinforcement as opposed to a gameplay model in which the player can "lose" or be penalized in any way.

This manuscript details a pre-clinical pilot study with primarily college students who tested our game *Burnie* in advance of formal deployment to pediatric populations. The primary factor of interest in this study was player satisfaction, which was measured along three dimensions: visual aesthetics, game controls, and overall enjoyment. These were measured using a post-game Likert-scale survey spanning from 1 to 10 with 10 being most preferable and 1 being least. On average, subjects rated *Burnie*'s visual aesthetics as 7.65, controls as 5.4, and overall as 6.75. These results indicate that *Burnie* is an enjoyable game experience, but in order to maximize effectiveness more research needs to be done on the control scheme to determine why it was rated lower than the rest of the game.

Related work

Physical therapy and cerebral palsy

Antilla et al conducted a major review of the literature to determine whether physical therapy was an effective treatment for pediatric cerebral palsy [1]. Only randomized controlled trials were reviewed yet the results revealed insufficient consistency across studies to make a definite claim of PT's effectiveness. However, the most methodologically rigorous studies revealed moderate evidence of the efficacy of physical therapy when used to treat upper extremities.

Serious games in education

Serious games refer, generally speaking, to video games whose goal is not only to entertain but to also fulfill some "serious" purpose. Marsh [21] has constructed a rigorous continuum-based classification scheme of serious games that includes games whose purpose is for "learning, training, education, health, well-being", among many other purposes. Several studies report that educational based games are generally as effective as traditional educational approaches but also benefit from increased learner satisfaction with and motivation toward their lessons [27, 28]. These findings are particularly relevant in the current study as maintaining the interest of the player is

crucial as increased player engagement and participation is what drives the effectiveness of the intervention.

Health games

Health games have a long history that dates back at least to the 1980's [17]. However, only until recently have gains in technology and manufacturing cost made it practical to consider game-based physical therapy beyond specialized settings. The Microsoft Kinect, initially released as a gaming peripheral for the Xbox 360 game system, has evolved far beyond its initial mandate and has been determined to be a valid means of assessing postural (kinematic) strategies [11]. Chang has used the Kinect to assist individuals with cognitive impairments to learn vocational skills, thus gaining greater levels of personal independence [10]. Freitas constructed a physical therapy game that combines biomechanical analysis and smart algorithms to provide instant corrective feedback to help patients conduct their physical therapy more effectively [13].

Though game technology has expanded the reach of games in health care, it has been the classic appeal of games – that people enjoy playing them – that seems to have brought about some of the more striking advances in health games. Betker et al developed a PT intervention using the Wii balance board to rehabilitate balance control in individuals. It was discovered that the effects of PT and levels of motivation were increased by the patient's increased motivation to play the game [5]. A similar effect has been observed in other studies as well. Sandlund reviewed sixteen studies that used motion interactive games for physical therapy and discovered that thirteen reported positive results [24]. In most of the evaluated studies, clinical gains were the result of increased patient motivation to participate in his/her prescribed therapy.

The findings of research with the Kinerehab system confirm the capacity for games to improve patient motivation. Chang et al observed increases in performance in motivation when their Kinerehab system was coupled with an operant conditioning approach [9].

Background and methodology

Theoretical underpinnings

Our game was modeled upon an operant conditioning model. As such, game play is characterized as a series of behaviors that are to be strengthened as a result of stimuli in the game world. All game actions were modeled using the Antecedent-Behavior-Consequence (ABC) behavioral analysis model [26].

The game

The game is Kinect-based and involves the player standing in front of the Kinect optical sensor and taking on the persona of a little bird named Burnie. The goal of the game is to fly Burnie through a nature-themed obstacle course in search of prizes while avoiding hazards. The player controls Burnie by flapping his/her arms and performing a sequence of static poses in response to changes in the environment (see Figure 1). By approximating the motions of a bird, *Burnie* provides a context and mental framework that results in what Burke et al describe as

"meaningful play" thus potentially improving the efficacy of the game's therapeutic benefits [8]. Further, Antilla has identified treatment of the upper extremities as the most amenable to clinical improvement [1].

Figure 1. A pre-pilot alpha test flaps her wings in Burnie.

Game prizes include fish, bugs, balloons, worms, and grasshoppers, which Burnie scoops up for points. Hazards include hot peppers and bees. To navigate Burnie through the game world, the player must perform one of four poses: flap, strafe right, strafe left, or dive. These four poses directly correspond to physical therapy actions defined by our medical partners. The goal is to reframe the meaning of the therapy poses. For instance, players are meant to think of arm lifts as "flaps", side-to-side balancing poses as "strafing", and the resting pose as a "dive."

From a behavioral perspective, in the clinic there is no immediate payoff to the patient for performing a therapy pose other than to avoid being reprimanded by the therapist. This is an example of negative reinforcement and is ineffective when not in the presence of the reprimanding individual. Thus compliance in the home is low. To induce a behavior, punishment is an ineffective tool; only positive reinforcement can increase the probability of a behavior's occurrence [22]. Participation in the game is rewarded by the player getting to experience funny sounds and animations, a sense of flying through a beautiful world, and the accumulation of points. Even the hazards in the environment have humorous, rewarding results (e.g., eating a hot pepper launches Burnie forcefully forward on a jet of burning hot gas). This dynamic of targeted

positive reinforcement and reframing of the therapy experience is the essence of *Burnie's* gamification.

An additional critical aspect of our implementation is the focus upon individualization of the game poses. Cerebral palsy affects patients idiosyncratically with a great deal of heterogeneity in terms of strength and movement capability. To accommodate this diverse symptomology, each player's game poses are calibrated against that individual's capabilities prior to beginning a game session. This pose calibration function serves a number of critical functions. First, by being infinitely configurable it allows a wider range of patients to play the game. Second, a physician can observe a player and coach the initial calibration in order to ensure that a player's version of a pose is medically validated. Third, this allows a level of individualization that is critical to effective behavior therapy [3, 7, 12].

Experiment

Participants

This study was composed of 21 subjects, including 15 males and 6 females ages from 6 to 34. Sampling was non-random and composed of a population of convenience. This study was conducted in accordance with all Institutional Review Board rules and regulations.

Procedure

Testing occurred in a 10x x 12d x 8h office with audio/visual components consisting of an LG 60" HDTV and sound-bar/subwoofer combination. The testing protocol was as follows: 1) acquire informed consent, 2) subject fills out pre-game survey, 3) subject calibrates poses to his/her specific body dimensions and capabilities, 4) subject plays game for a twenty minute session, 5) and subject fills out post-game survey.

Results

Subjects were asked the following three questions during the post-game questionnaire. All questions were presented as a Likert scale from one to ten with ten being the most favorable and one being the least favorable. Average responses are presented in bold text after each question below.

1. How would you rank your overall enjoyment while playing the game? **6.75**
2. How aesthetically pleasing did you find the graphics within the game? **7.65**
3. How pleasing did you find the game controls? **5.4**

Subjects enjoyed the game experience and were particularly pleased with the visual aesthetics of the game. The experience of using the game controls was the least favorite part of subjects' assessment of the game but was still positive overall.

Conclusions

The essence of our game's therapeutic benefit is predicated upon its ability to provide positive reinforcement and the reframing of the therapy experience. Players found the game enjoyable on all three observed dimensions: graphics, input, and overall enjoyment.

More research must be conducted to clarify our findings. It is unclear why players found the input mechanism less enjoyable than other aspects of the game. As the required poses had some potential to fatigue a player's muscles, it is possible that exercise-related discomfort was the source of the lower ratings. This, however, is a net positive as a player's physical therapy session is *expected* to cause some amount of discomfort in order to challenge the muscles. On the other hand, if the lower player ratings are due to mechanical issues or a perceived lack of responsiveness, than that situation is much more serious. As the goal of the project is to reframe therapy actions as game play actions, if these actions are frustrating then the therapy behavior is unlikely to sustain itself and will soon extinguish [22].

The strongly positive ratings of the game's visual aesthetics are especially encouraging. The game world should be as enjoyable as possible to play in in order to provide reasons for the player to return there. Further, whatever deficiencies may have existed in the control scheme, it seems they were not sufficiently distracting to detract from player enjoyment of the game world.

In summary, this pilot study represents an encouraging milestone toward providing a behaviorally oriented physical therapy game experience. A follow up study with pediatric cerebral palsy patients is recommended in order to confirm the target population's preferences regarding the game.

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