Supporting Therapists In Motion-Based Gaming For Brain Injury Rehabilitation

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Abstract

In this paper, we describe a work-in-progress that involves therapists who use commercial motion-based video games (e.g. Wii) in therapies involving patients who have had a brain injury (BI). We are collecting data to inform a case-based recommender (CBR) system that will help therapists stay current and choose appropriate motion-games for their patients. Data from the CBR system will (1) establish commercial motion-game efficacy among a larger and more diverse BI patient population than in previous work and (2) inform custom games that better meet needs for BI therapies.

Author Keywords

Brain injury; therapists; motion-based videogames; case-based recommender systems

ACM Classification Keywords

K.4.2. Computers and Society: Social Issues (Handicapped persons/special needs); K.8.0. Personal Computing: Games

Introduction

The Center for Disease Control and Prevention (CDC) in the US recognizes that brain injuries are a major public health issue; the CDC estimates that in the US 1.7 million people sustain a brain injury annually [1]. Therapists have told us that they often have difficulty

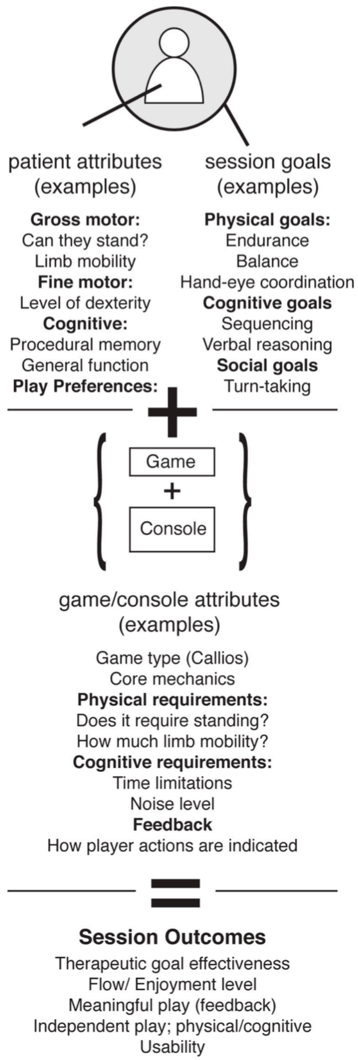

Figure 1: Illustration of a case

motivating their patients who have had a brain injury (BI) to perform the repetitive exercises needed for rehabilitation. As a result, many therapists include commercially available motion-based video games (referred to as motion-games in the remainder of this paper) in their therapy sessions to help make repetitive actions fun and engaging. Motion-based videogames use consoles, i.e. Microsoft Xbox Kinect, Nintendo Wii and Sony Move, which are played using gestures and/or sometimes-specialized controllers. Our goal in this project is to support therapists who want to engage their BI patients in therapy through motion gaming.

Previous research has supported commercial motion-games as effective motivators for performing rehabilitation exercises [2]. Moreover, research has supported motion-games as effective in meeting therapeutic goals for BI patients, including increasing balance and range of upper extremity motion [6]. While this work is encouraging, it has focused on small samples; as such, commercial motion-game efficacy across a wide range of BI patients has not been established. Our first goal in this project is to evaluate commercial motion-game efficacy across a wider range of BI patients than has been previously established.

Towards this goal, we have been working with therapists who already use commercially available motion-games as part of their therapies for BI patients; we are collaborating with therapists at the Schwab Rehabilitation Hospital (SRH) in Chicago. We will expand to more sites in 2013. We are collecting data on core game mechanics (i.e., the set of actions the player performs over and over) that meet therapeutic goals, levels of cognitive and physical help required to play a variety of games, and attributes that affect engagement/enjoyment. In other words, we are collecting data to understand patient, game and console attributes associated with motion-game success/failure across a diverse range of BI patients.

We will make the results of our exploration available to therapists through a case-based reasoning system. Case-based reasoning systems solve problems by referencing previous solutions or 'cases' [8], and are built around the concept of a memory 'script'. By storing knowledge in scripts, we set up expectations and perform inferences when we encounter a similar situation/script. A case, then, can be conceived as an instance of a script; a script has attributes and relationships among those attributes. A case-based reasoning system understands relationships among attributes and is capable of adapting old cases to meet new situations. One important application of case-based reasoning has been in the creation of case-based recommender (CBR) systems. CBR systems have been used in a wide range of fields; for a survey of medicine-specific work, see [7].

A case in our system will describe a particular instance of a therapeutic BI session with motion games, including (a) patient attributes (e.g. physical and cognitive abilities), (b) game/console attributes (e.g. physical/cognitive requirements), (c) therapeutic goals (e.g. balance) and (d) previous therapeutic outcomes (e.g. effectiveness at meeting therapy goals). See Figure 1 for an illustration of how we are operationally defining attributes for a game session. These attributes are based on game design theory/practices and our current work with therapists at SRH.

Related work
Our work builds from several categories of research, including: (a) custom BI games designed for non-commercially available consoles and/or that use specialized controllers [2], (b) research focused on the therapist perspective in this problem space [3], and (c) games on commercially available consoles used to support therapy. Because the CBR system is focused on commercially available games, two studies focused on BI in the latter category are very relevant.

Deutsch et al. (2009) compared standard practices to the use of the Wii's effectiveness for helping with balance and mobility post-stroke [5]. While the sample was small (*N* =2), the authors found that the Wii training generated more enthusiasm; however, enthusiasm was not sustained in follow-up studies indicating a need for novelty when using games in therapy. The CBR system will address this by helping therapists learn about new games. Flynn et al. (2007) used a Sony Eye Toy and 15 different commercial games for one client post-stroke [6]. The authors found that the games were effective at meeting therapeutic goals, supporting motion game efficacy. As with many similar studies, only small samples were involved, indicating a need to establish commercial game efficacy across a wider range of BI patients.

Collecting data to build the cases

We are currently working to build cases to seed the CBR system. We began our collaboration with SRH by interviewing eight therapists; three additional therapists joined the research team later. After the initial eight interviews, we left two AV carts with commercial game consoles (Wii, Xbox Kinect, and Move) and multiple games requested by the therapists. We then observed therapists using games with patients. We were however limited to observations in which patients had the capacity to understand a consent form. To gather data about a wider range of patients, our third step involves a diary study in which therapists are/were asked to complete a short form about game sessions. In the next sections, we describe the three studies.

Study 1: Interview methods and summary findings
In the interviews, we explored how therapists choose games for their patients to meet therapeutic goals and how games succeeded/failed to meet those goals.
Participants. Among the eleven therapists we interviewed, three were occupational therapists (OT), three were physical therapists (PT), three were recreational therapists (RT), and two were speech-language pathologists (SLP); all but one RT are women. All therapists had between two and fourteen years experience working with BI patients. BI patients were scheduled for up to four 45-minute sessions per day; they were scheduled with PTs, OTs and SLPs who in turn would work with the RTs if they felt that their patient could benefit from recreational therapy. Three social-group gaming (co-treatment) sessions were also conducted each week.
Data collection and analysis. We conducted eight interviews in June and three interviews September-December of 2012 at SRH. We asked about therapists' experiences, opinions and expectations, including: (1) games they used; (2) to describe their experience using the games, e.g. their goals in using the games, the effectiveness of the games for meeting those goals, and problems they had with the games; and (3) features they would include in games if they could design games for their patients. After the interviews

	Common Wii games discussed	Objectives
OT	Bowling, Boxing, Michael Jackson's Dance	Fine movement, gross movement, static balance, strength
PT	Bowling, Soccer, Wii Fit balance games	Weight shifting, dynamic balance, gait, adjusting for neglected limb
SLP	Bowling, Family Feud, Wheel of fortune	Socialization, social language, focusing attention, turn-taking
RT	All above	All above

Table 1: Common discussed (Wii) games and objectives by therapist type

were transcribed, two researchers (PI and a PhD student) independently analyzed the interviews and inductively coded for major themes and patterns.

Summary findings. The only console therapists were using at SRH prior to the June interviews was the Nintendo Wii. Relevant information about newer commercial games/consoles was not readily available to SRH therapists; therefore they used a limited set of games. We found patterns in their objectives for choosing games, see Table 1. The OTs, RTs, and SLPs described using motion-games for less than 25% of their patients; the RTs reported using video games in approximately 25-50% of their sessions. Common reasons therapists choose to use motion-games were to motivate patients to move and to support social interaction. Therapists expressed many desired changes and/or features they would like to see in commercial games so they could use with a larger percentage of patients. Most common desires were:

- Need to accommodate support, e.g., a wheelchair or therapist support. (*N* = 9 therapist mentioned)
- Means to modify/more control over game parameters, e.g. (slow) pacing, remove time limits, change scoring scales, and an ability to modify movement parameters. (*N* = 9)

Means to reduce sources of stimulation. (N = 6)

Study 2: Observation methods and preliminary findings

In the observation studies we explored how motion-games met session goals, problems therapists encountered using commercial games, and how patients felt about their game experience.

Participants. We observed sixteen play sessions with five of the therapists we had interviewed in June (two PTs, one RT and two OTs). Patients ranged in age from 43-64; all had experienced their brain injuries within the thirty days of our observations. Causes of brain injury were diverse, including stroke, falling accidents, and seizures associated with alcoholism.

Data collection and analysis. Observed sessions occurred in July thru October 2012; observations were video recorded from the front (for facial expression) and back. Typically, patients played one to three games a session. After each observation, patients were asked about the session, about what they did for fun and enjoyed for entertainment, and if they had played video games in the past. After each session, we asked therapists how the game(s) met the play session therapy goals, how much cognitive and physical help was needed to play the game(s), and about how they perceived the patient's engagement in the game(s). Coding observation sessions is work-in-process.

Preliminary findings. In further support of the CBR system, we repeatedly saw that it was important to minimize set-up and know ahead of time if the games were a good match for the patient and the patient's therapeutic goals to fully utilize the 45-minute session. We witnessed several sessions where the games were not a good match so the session was not productive. In these cases, patients were frustrated and often verbalized negative feelings about themselves. We also found that even with the high functioning patients we observed, they typically needed cognitive and physical scaffolding. For example, therapists would provide prompts for game sequencing, hold patients at the waist, and/or physically move the patient's arms. This need for close physical proximity made many commercial Xbox Kinect games not tenable.

Study 3: Diary study methods and preliminary findings

In the diary studies, we are collecting data across a wide range of cases to establish what attributes

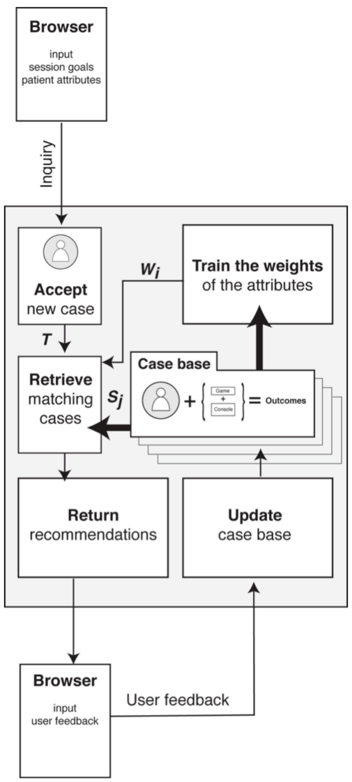

Figure 2: CBR system architecture

contribute to success; i.e. ideal game/console – therapy goals – patient matches.

Participants. We have collected data for 55 sessions that included eight different therapists and 34 different patients; 19 of the sessions were group sessions involving two or more patients.

Data collection. The current diary study will be/was conducted in four two-week sessions. We have collected data from two sessions to date (October 8-19, and December 3-14, 2012). (Two additional sessions with SRH are scheduled for early 2013). Participating therapists were each given a notebook containing two-page paper diary forms that asked about session details that paralleled observation sessions. We have iterated the diary form design based on therapists feedback.

Preliminary findings: Common therapists' goals for using games were attention, sequencing, balance, endurance, use of a partially paralyzed limb, reaction time, verbal reasoning, and turn taking. Things that deterred from session success included: games were too fast paced, boredom (games were not novel), and patient inability to use a controller or perform an action (e.g. jump, release a trigger). We will use data from all our studies to seed a CBR system described next.

Building the CBR system

To use the CBR system, therapists will input session goals and patient abilities/preferences to find best-case game/console matches. The system will return information and tips about best practices associated with recommended games/consoles. The system will also ask therapists to evaluate the suggested matches, encourage therapists to share information about queried game sessions (e.g., suggested modifications for the games), and allow therapists to add new tips/suggestions and new games. Initially, we will incentivize therapists' system use through gratuities; ultimately, we hope the information provided by the tool will encourage participation. We will continue to work with therapists through user–centered design (UCD) iterative processes to build the system interfaces for input, results display, and feedback solicitation. Because of the nature of the work of therapists, we plan to implement a web-based CBR system so it can be accessed from various mobile/desktop devices.

To ensure the effectiveness and efficiency of the CBR system, we plan to adopt a hybrid algorithm using a machine learning method to optimize the weights for the attributes that we identified for the CBR system. See Figure 4 for an illustration of system architecture; the operational process for the system is as follows.

Step 1. Train the weights of the attributes. A fraction of the case base will be used to train weights of the attributes. We will explore the most appropriate machine learning method; candidates include genetic algorithm and neural network. Trained weights ($w_i,\ i = 1, 2, \ldots, N$) will be imposed in Step 3

Step 2. Accept input of new case from browser. New case input will include patient attributes and session goals; attributes are then organized as vectors.

Step 3. Retrieve top matching cases. The system determines top matching cases using the k-nearest neighbor algorithm. The nearest neighbor S_j^* is calculated through the following optimization problem:

$$\max_j \left\{ \sum_{i=1}^{N} \left[f\left(a_T^{(i)}, a_{S_j}^{(i)}\right) \cdot w_i \right] \right\}.$$

Where N is the total number of attributes, T represents the new target case, S_j represents the case j in the case base, $a_C^{(i)}$ is the attribute i of case C, w_i is the weight of attribute i, $f(a_1, a_2)$ is the similarity function of two attributes a_1 and a_2 .

Step 4. Return the recommendations. The system outputs suggested games to the user based on the top nearest neighbors. We envision the results will include a ranked list of games, metrics about previous outcomes, and user generated tips and suggestions.

Step 5. Update the case base. The system will ask users to evaluate suggested matches; this information will be used to modify the weights of the attributes.

Future work and conclusion

Despite their obvious potential, commercial motion-games have limitations for use in BI therapies. We and other researchers have found that commercially available motion-games are often too fast, too physically/cognitively challenging, and are designed for a learning curve that is inappropriate for many who have had a BI [2,4]. Researchers have addressed these limitations by creating custom games for non-commercial consoles (e.g., [4]), including games with adjustable parameters [2]. We plan to use (and share) the CBR system data (e.g., effective core game mechanics) to inform the design of adjustable mini motion-games to support BI therapies; we plan to target commercial consoles to address scalability.

In conclusion, this work contributes to research concerned with therapeutic motion-games. The CBR system will (1) establish commercial motion-game efficacy among a larger and more diverse BI patient population than in previous work and (2) inform custom games that better meet BI therapy needs. The system will also help therapists choose/share information about games and stay up to date with the rapid proliferation of new games. This approach acknowledges that because of their availability (despite limitations) commercial games will continue to play an important role in BI therapies. Ultimately, we hope this work helps people recover faster/better from BI.

Acknowledgements

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