Therapist-Centered Requirements:

A Multi-method Approach of Requirement Gathering to Support Rehabilitation Gaming

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Abstract—**Brain injuries (BI) are recognized as a major public health issue. Many therapists include commercial motion-based videogames in their therapy sessions to help make rehabilitation exercises fun and engaging. Our initial exploratory work exposed a need for tools to help therapists make evidence-based decisions when choosing commercial motion-games for their patients who have had a BI. Targeting this need, we are gathering requirements for a case-based recommender (CBR) system that will act as a decision tool for therapists. In this paper, we describe our ongoing work as a case study that illustrates our multi-method approach of requirement elicitation for the CBR system. Our approach is comprised of four overlapping steps: (1) interviews with therapists, (2) onsite observations of therapy game sessions, (3) diary studies in which therapists record detailed information about game sessions, and (4) a user study of a CBR prototype interface. Leveraging direct interaction with end users (i.e., therapists), this case study demonstrates requirements gathering techniques to address needs of a special population (i.e., therapists who work with patients who had BIs) in a specialized context (i.e., inpatient rehabilitation using motion-based video games).**

Index Terms—**Requirements elicitation, Multi-methods, Brain Injury, Rehabilitation, Therapy, Games, Case-based Recommender**

I. Introduction

The Center for Disease Control and Prevention (CDC) in the US recognizes that brain injuries are a major public health issue [1]. Approximately 6.4 million children and adults in the US live with a lifelong disability as a result of a traumatic brain injury (e.g. falls, car accidents) or a stroke [2]. People who have experienced a BI exhibit a wide range of physical and cognitive disabilities. Physical disabilities can affect both gross and fine motor coordination [3]. Full or partial paralysis is common especially with stroke, often affecting speech [4]. Patients often exhibit gait and balance impairments, which also increase the risk of falling and encountering further injury [5]. Cognitive disabilities (e.g., impaired memory, reasoning and problem solving abilities) are also common resulting in many day-to-day difficulties including problems in following directions (way-finding), completing procedural tasks (shortened attention spans), and understanding language [5]. Due to the wide-ranging causes, effects and recovery arcs associated with BIs, rehabilitation treatments vary widely and *need to be customized by therapists for each patient*.

Clinical experience and research has found that it is often challenging to motivate people with BIs to perform the repetitive exercises commonly prescribed for rehabilitation [6-8]. To address this challenge, many therapists include commercial motion-based videogames in their therapy sessions to help make repetitive actions fun and engaging. (Commercial motion-based videogames as those that use consoles; e.g., XBox Kinect, Nintendo Wii and Sony Move, which are played using gestures and/or sometimes-specialized controllers.) Commercial motion-games have been found as effective motivators for performing rehabilitation exercises [9]. Moreover, they have been found effective in helping people with BIs meet their therapeutic goals, including improvements in balance and range of upper extremity motion [10-11]. While this work is encouraging, it has focused on relatively small samples; as such, very little is understood about the mix of attributes (game, patient, therapy session) across the diversity of people with BIs that need to be considered for successful use of commercial motion-gaming in BI therapies. In other words, there is a paucity of information to help therapists consider customized treatments that include the use of commercial motion-games for the wide range of people with BIs that they treat.

In this paper, we describe our ongoing work as a case study to illustrate our four-step approach of requirement elicitation for a software system. The system will help therapists make evidence-based and customized decisions when choosing commercial motion-based videogames for their patients who have had a BI. Our goals of this study are to (1) explore the problem domain of therapeutic gaming in BI rehabilitation, (2) identify the therapists' requirements for choosing games for BI rehabilitation, and (3) identify specific requirements for attributes that contribute to good or bad game choices in the context of a specific patient and therapy session. This work contributes to discussions in requirements elicitation on methods that include users to elicit system requirements (e.g., [12-14]). Because of the challenge of selecting appropriate elicitation techniques, several researchers have proposed frameworks for deciding which methods to use (e.g., [15,16]). Additionally, researchers have also discussed traditional methods in requirement gathering; i.e. the use of interviews (e.g., [17]), observations (e.g., [18]), and ethnographic techniques (e.g., [19,20]). While leveraging traditional methods (i.e., interviews and observations), we also illustrate the use of

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a non-traditional method, i.e., diaries, for requirement elicitation within a multi-method framework. We anticipate that this case study will serve as a model of requirements elicitation in a specialized context.

Our envisioned system will also serve as a tool to support game developers and designers that want to design therapy-centered games; in other words, it will help further requirements gathering about games customized specifically for use in BI rehabilitation. This aspect of the project has overlap with research focused on requirements analysis to better address a wide range of user needs [21]. For example, Sutcliffe, Fickas and Sohlberg (2005) discussed the need for personal and contextual requirements to address diverse users, including people with disabilities. Specifically, in their framework, user *characteristics* and personal *goals* are considered as additive layers applied over functional specifications. This layering affords individual customization of systems to address diverse users' needs [22]. Our envisioned software system uses Sutcliffe et al.'s framework conceptually to consider patient *characteristics* and therapeutic *goals* to facilitate the understanding of personalized patients' needs when using motion-based video games.

II. Our Initial Exploratory Work

To explore the problem domain of therapeutic gaming in BI rehabilitation, we started this project by conducting exploratory interviews with therapists who used commercial games with their patients that had BIs. The exploratory interviews were conducted in June-October of 2012 with four physical therapists, two occupational therapists, and three recreational therapists, and two speech-language pathologists (N = 11). All therapists worked at the Schwab Rehabilitation Hospital in Chicago, Illinois, with people who have had BIs. As part of the interviews we asked therapists how they chose motion-games for their therapy sessions and what games they used. Therapists identified familiarity (i.e., games they already knew about) as their primary reason to choose a game. Moreover, despite the proliferating motion-game market, the therapists were using a very limited number of motion-game titles. In other words, there was a perceivable information deficit among therapists that we interviewed about options available in commercially available games.

Following the interviews we installed AV carts that housed the three major gaming consoles with games the therapists selected; we then observed sixteen motion-gaming therapy sessions. We observed that to maximize the limited 45-minute session times common at Schwab, it was critical to know if a selected game was going to be (a) a good match for the patient's play preferences and abilities, and (b) address the therapeutic goals for the session. We witnessed several sessions where the games were not a good match. In these sessions, patients were generally frustrated or bored and often verbalized negative feelings about themselves. Further, while therapists had specific goals in mind for the play sessions (e.g., weight shifting, balance), they had no ability to choose games based on evidence to support their efficacy at addressing those goals.

In sum, the exploratory work exposed a need for therapists to have access to information about games (e.g., those that best met their therapeutic goals and the abilities of their patients) that would help them make evidence-based decisions; *in other words, help in customizing the choice of commercial motion games* for *their patients with BIs*. To address this need, we are gathering user and system requirements for a case-based recommender (CBR) system that will act as a decision and information tool for therapists. CBR systems solve problems by referencing previous solutions or 'cases' [23]. They have been used in a wide range of fields, including many medical applications [24]. For example, Ahmed and Funk (2012) created a CBR system to help physicians choose a post-operative pain treatment plan for their patients [25].

III. Four Step Approach: Methods and Findings

Working with therapists at Schwab and Marianjoy Rehabilitation Hospitals (Wheaton, Illinois), we are using a multi-method approach of requirement elicitation for the CBR system. This approach has involved four overlapping steps: (1) interviews, (2) onsite observations, (3) diary studies, and (4) user studies of a prototype CBR interface. Each method has elicited different aspects of system and user requirements that are critical for the CBR system design:

- The interviews with therapists have helped to establish what they will need to input into the CBR system to help make evidence-based decisions including: (a) session goals, and (b) patient factors, e.g., patient abilities and personal preferences.
- The observations have established contextual factors the CBR system will need to consider when providing recommendations, including patient scaffolding issues and time limitations.
- Diary studies clarified the requirements by helping us define the attributes in a 'case' and have provided 'seed cases' that determine how well (from therapists; perspectives) the motion-games matched the session goals and patient factors.
- The user studies of the system interface have helped us understand required interface and content considerations, including (a) input controls and (b) output display.

In the following sections, we describe each method step in greater detail. We are only reporting here on findings that affect the CBR system design, i.e., many of the findings that had implications for game design are not included here.

A. Step One: Interviews

While the initial interviews with therapists at Schwab led to the need for a CBR system, the interviews (at Schwab and later at Marianjoy) also helped to establish general therapists' needs that are important to consider for a CBR system.

1) *Participants:* Among the 21 therapists we interviewed at the two rehabilitation hospitals, five were occupational therapists, nine were physical therapists, three were recreational therapists, and four were speech-language pathologists. At the time of the interviews, all therapists were

working in inpatient care with people who had BIs; therapists had between two and fourteen years of experience.

2) *Procedures:* Therapists were recruited through an email sent from their Quality and Research offices; as such, they represented a convenience sample. We conducted the interviews in June and September of 2012 at the Schwab and in September 2013 at Marianjoy. Interviews took 30-45 minutes; all were video recorded and later transcribed. Therapists were asked several questions about how they used motion-games. The questions we asked affecting CBR system design include: (1) major therapeutic goals they targeted; (2) major motivations for using motion-games; and (3) factors they considered when choosing games.

After the interviews were transcribed two researchers on our team independently analyzed the interviews and inductively coded for salient themes; they then co-wrote a codebook on how to identify the themes. (We are using 'code/coding' here as it is referred to in qualitative data analysis: "*A code in qualitative inquiry is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data*" [26].) A third researcher used the codebook to deductively analyze the interviews using the codebook. Pairwise inter-rater reliability between the third coder and the first two was calculated using Cohen's Kappa. For all findings described in the next section, average pairwise reliability was between .71 or and .88 (.61-.80 is considered 'good' and above .81 is considered 'very good' [27].)

3) *Summary Findings Affecting CBR System Design:* We focused on (a) goals, (b) motivations and (c) factors affecting game choice/use for the CBR system design.

a) Goals: While the speech-language pathologists only spoke of cognitive-related goals, all 21 therapists mentioned cognitive goals. The top three cognitive-related goals were (1) sequencing, (2) focusing attention, and (3) motor planning. However, the occupational, recreational and physical therapists were more concerned with physical goals. The top three mentioned were (1) balance, (2) weight shifting, and (3) standing endurance. For example, Interviewee 07 (occupational therapist), said, "***Traditionally the biggest thing that I used it for is when I'm working with patients with balance, especially when I want to work on the timing component of that***."

b) Common motivations: The most common motivations for using motion games in therapies was to (1) add fun, (2) introduce something novel, followed by (3) a desire to distract patients. In an example of all three motivations, Interviewee 02 (physical therapist) told us, "***It gets kind of boring and we try to think outside the box and make things fun and exciting for patients so they have fun during therapy and it's not just the same old rote exercise or everyday things that they would not find motivating. I think that games are motivating. I've found that people forget how hard they are working while they are caught up in a game.***" Therapists who were involved with group gaming sessions also emphasized the power of games to encourage social interaction.

c) Patient factors that affected game use: The top factor mentioned were cognitive abilities; therapists felt that commercial games often had too many distractions (e.g., noise) and required too much sequencing to be tenable for many people with BIs. Patents' age and game experience were also considered very important inter-related factors; specifically, therapists were much more likely to use games with younger patients who had past gaming experience. For example, when asked about whom she used motion games with, Interviewee 01 (occupational therapist) responded, "***Typically it's the younger - adolescent to young adult that has used games before.***"

B. Step Two: Observations

To further understand contextually situated requirements for the CBR system, we conducted onsite observation of therapy sessions in which therapists use motion-games with their patients. After the interviews, we installed AV carts in both rehabilitation hospitals that housed the three major gaming consoles (Nintendo Wii, Xbox with Kinect, and Sony PlayStation with Move) with games the participating therapists selected, see Fig 1.

Fig 1. AV cart set-up at SRH

The games therapists selected fell into five categories: (1) sports, e.g. 'Kinect Sports', 'Wii Sports Resort', 'Sports Champions 2' for the Sony PlayStation; (2) fitness, e.g. 'Wii fit', 'Your Shape Fitness Evolved'; (3) dance, e.g., 'Just Dance 2', 'Michael Jackson The Experience'; (4) games with general physical activities, e.g., 'Kinect Adventures', 'Minute to Win-it'; and (5) games focused on cognitive skills but that required motion-based controls, e.g., 'Brain Body Connection'. While the initial observations at Schwab led, in part, to the need for a CBR system, the observations have also provided contextual factors the CBR system must consider. While similar, the structure of care was slightly different between the two hospitals:

- *Structure at Schwab* - Patients were scheduled for up to four 45-minute sessions per day. Therapists worked with up to eight patients a day' patients were scheduled with physical and occupational therapists and speech-language pathologist who in turn would work with recreational therapists if they felt that their patient would benefit from recreational therapy. Additionally, there were three social/gaming sessions a week.

- *Structure at Marianjoy* - Patients were under the supervision of physical therapists and were scheduled for at least four hours of therapy in 30 or 60 minute sessions. The supervising physical therapist would schedule sessions with occupational therapists and speech-language pathologists based on patient need. Marianjoy did not employ recreational therapists. Seven of our observations were 30-minute sessions; one was an hour-long session.

1) Participants: We observed sixteen game play therapy sessions in July through October of 2012 at Schwab, and eight in October 2013 at Marianjoy. Observations were video recorded from the front (for facial expressions) and back. Patients ranged in age from 34-69; all had survived their brain injuries within thirty days of our observations. Cause of brain injury was diverse, including stroke, falling accidents, and seizures associated with alcoholism.

2) Procedures: Prior to the observations, therapists completed a "Documentation of Capacity", that stated that the patient was capable of reading, understanding, and signing our consent forms. As such, we were limited to observations in which patient participants were not highly cognitively affected by their brain injuries.

Qualitative coding of video recordings has been established as an effective way of analyzing video data [28]. We coded the Marianjoy video recordings in 10-second increments to identify: (1) patient's activity (e.g., playing, resting, and seeking help); (2) therapist's activity (e.g., providing physical and cognitive support, setting up the game); and (3) patient affect (e.g., happy, focused, frustrated). (*We did not code the Schwab videos.)*

3) Summary Findings Affecting CBR System Design: Typically, patients played one to three games in a session. The most common game categories used in descending order were: (1) fitness, specifically the Nintendo Wii Fit mini-games in which the patient stood on a platform that sensed weight-shifting, balance, and foot movement; (2) sports, specifically Wii and Microsoft Kinect bowling; and (3) general gaming requiring physical action, specifically Kinect Adventures. Four findings from the observations have implications for the CBR system design: (a) therapists mobility, (b) patient scaffolding, (c) assistive devices and (d) timing.

a) Therapists mobility: Therapists in both locations spend most of their day in the therapy gym. Marianjoy had computers on mobile carts and at the sides of the gym; Schwab therapists had a cubicle space in offices off the gym. As a result, the CBR system needs to be accessible from both PCs and mobile devices (smart phones or tablets), which therapists can use while working with patients in the gym. The major implication for the CBR system design was consideration for a mobile first design [29].

b) Patient scaffolding: We found that even the high functioning patients we could observe needed a lot of cognitive and physical scaffolding; for example, during gameplay therapists often had one or more hands on the patient's waist or used a supportive belt. In the five of the eight Marianjoy sessions that we coded, therapists were providing physical support 100% of the time the patient was playing a game. For the remaining three session physical support ranged between 3% and 86% of the patient playtime. Therapists also spent an average of 42% of the recorded session time giving cognitive support (e.g., instructions). The major implication for the CBR system design was that because level of support widely varied, there is a need to describe level of expected patient scaffolding (cognitive and physical help) based on game type and patient abilities; this feedback should be included as part of the recommendation results.

c) Assistive devices: In most sessions that we observed, patients did not require any assistive devices; however, several people used walkers (17%) and canes (8%). Six patients (25%) were in wheelchairs but were able to stand using a walker to play the games. The major implication for the CBR system design was a need to filter games based on whether they could be played using assistive standing devices and whether the games can be played sitting down.

d) Timing: Setting up a game can take a lot of time, and it really varied from game to game. Therapists spent and average of 24% of the session time starting and setting up the games in the observations we coded; time spent on set-up varied between 7% and 38% of session time. The major implication for the CBR system design was a need to include expected start-up times for each game.

C. Step three: Diary study

From the interviews and observations, the concept of a 'case' evolved. Findings from the diary studies have clarified the requirements by helping us define the attributes in a 'case' and have provided 'seed cases' that determine how well (from therapists' perspectives) the motion-games matched the session goals and patient factors. We are exploring relationships among the following categories of attributes: (1) patient variables, (2) therapy session goals, (3) game/console affordances, mechanics, and requirements, and (4) subjective measures of session outcome (e.g. effectiveness on therapeutic goals), see Fig. 2 for how we are envisioning a case.

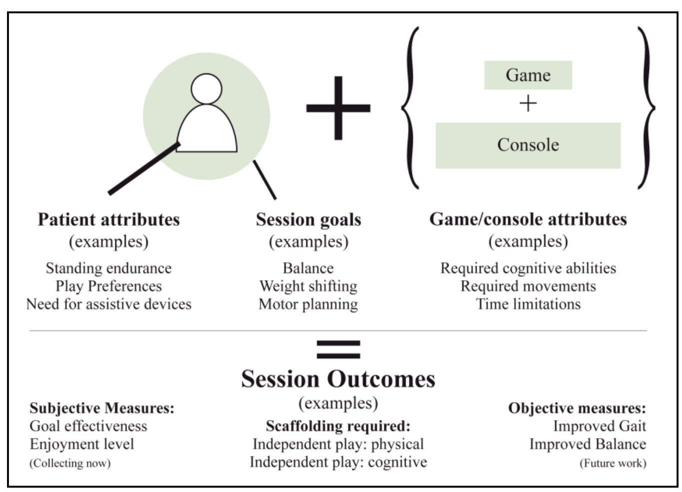

Fig 2. Summary attributes of a 'case'

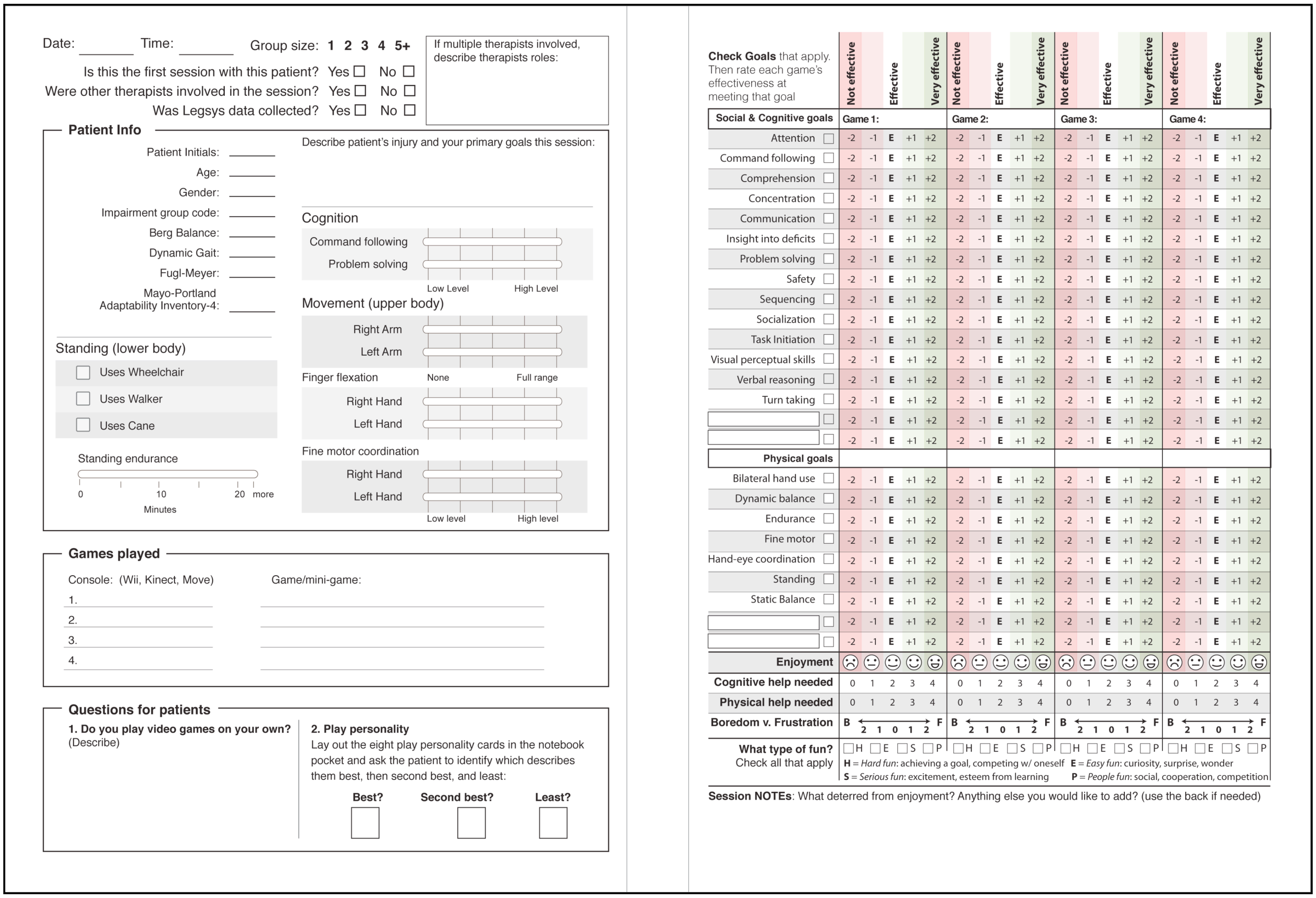

Fig 3. Current versions of the diary forms

The diary forms were based on how we defined a case. Therapists were given a notebook containing a two-page paper diary form and were asked to record details about play sessions over two-week periods. The first diary form designs were based on what we learned in the interviews and observations. The diary method has allowed non-identifiable patient data collection across a much wider range of patients than we are permitted to observe. We piloted the diary forms in October 8-19, 2012 at Schwab.

We continued to refine the diary forms (see Fig. 3 for the latest version) through the early studies at Schwab based on therapists' feedback. We collected game session information for three periods at Schwab (December 3-14, 2012, February 18-March 1, 2013 and June 12-29, 2013), and one period to date at Marianjoy (November 4-15, 2013). (As of this writing, three more diary collection periods are scheduled at Marianjoy in March, May and July 2014.)

1) *Participants:* Therapists have recorded data for 77 individual patients, ages ranging from 19-89 (M = 54.0); a little less than half (N = 34, 44%) were male. Through four studies, we have collected 184 cases; a case is a combination of (1) a patient, (2) a game/mini-game played on a console, and (3) its outcomes. The three most common causes of BI were: (1) stroke (N = 48, 62.5%), (2) TBIs (N = 10, 13%) due to car accidents, falls, gunshot wounds and other violently related causes, and (3) disease-related (N = 10, 13%) including encephalopathy and meningitis. Fifteen therapists who had participated in the interviews have recorded diary data. Broken down by occupation: eight physical therapists,, three occupational therapists, two speech-language pathologists, and two recreational therapists.

2) *Procedures:* On the first diary page, therapists were asked to record (1) date/time of the session; (2) session details (e.g., if a group session, the number of patients involved); (3) non-identifiable patient details (e.g., initials, age, gender, balance and gait measures, nature of the BI, assistive devices used, standing endurance, range of motion, fine motor control, command following and sequencing abilities; and (4) the game selections (console, game/mini-game). We also assessed patients' play preferences using work from Stuart Brown [30].

Brown has studied play personalities by conducting 'play histories' which are interviews focused on play [30]. From these studies he distilled eight play personality types (although most people are a combination): (1) Joker whose sense of play involves nonsense; (2) Kinesthete who enjoys movement; (3) Explorer who enjoys new experiences; (4) Competitor; (5) Director who enjoys organizing and planning events; (6) Collector; (7) Artist/Creator; and (8) Storyteller. To explore patients' play preferences, we created eight cards describing Brown's play personalities in a single sentence. We described each card (after shuffling), laid them out for the player-patients and asked them to identify the one that described them best. We also asked for their second and least identifiers.

On the second diary page, therapists: (1) identified the goals (check-mark) for playing each game (listed goals were based on the interviews, observations and the pilot diary study); (2) rated (subjective measure) the effectiveness (-2 to +2) of the game at meeting specified session goals (we set a rating of 0 as 'effective' after we found that therapists were likely to find the games at least somewhat effective because they chose them, i.e., confirmation bias); (3) rated the level (0-4) of cognitive and physical help needed to play the game; (4) rated patient enjoyment (0-4); (5) assessed appropriate challenge (range from boredom to frustration); and (6) were invited to enter additional comments about the session.

3) *Summary Findings and Proof of Concept for CBR system:* As a proof of concept, in this summary, we compared two games in which we had the most recorded cases, bowling (N = 47, 34 on the Wii, 13 on the Kinect) and soccer (N = 13, 1 on the Wii and 12 on Kinect). We are combining results from two soccer mini-games available in Kinect sports: target kick in which players kick into a goal and super saver in which players are the goalie.

TABLE I: SHARED GOALS: BOWLING V.SOCCER

	Bowling (N = 47)	Soccer (N = 13)
Weight shifting	100% of cases	100% of cases
Static balance	96% of cases	92% of cases
Standing	72% of cases	85% of cases
Endurance	70% of cases	85% of cases
Dynamic balance	74% of cases	92% of cases

Therapists had many common shared goals when using bowling and soccer; see Table 1 for goals that were selected for more than 50% of the cases.

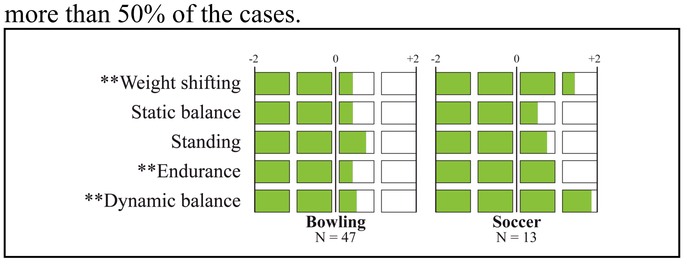

Fig 4. Bowling V. Soccer comparison by common goals

Using Mann-Whitney U tests we compared reported success for each common goal. There was a significant difference in effectiveness of the games to address three common goals: (1) 'weight shifting', U (60) = 133.0, Z = -3.99, p < .001, specifically, soccer was rated higher (average score on a scale of -2 to +2 = 1.23) than bowling (average score was -.23); (2) 'endurance', U (57) = 103.0, Z = -2.24, p < .05, specifically, soccer was rated higher (M= 1.00) than bowling (M = .74); and (3) 'dynamic balance' U (35) = 63.0, Z = -3.81, p < .00, specifically, soccer was rated higher (M= 1.92 – this was soccer's highest rated goal) than bowling (M = .69). No other common goals were rated as significantly different; however, the most successful reported goal (among goals with more than 10 reports) for bowling was for socialization (M = 1.06). See Fig. 4 for comparisons by common goals.

To explore the personality matching aspect of the seed cases, we examined differences among player types (as defined by the first choice card) and level of enjoyment when considering all gaming, the differences were significant, χ^2(1, N = 35) = 58.75, p < .05. Specifically, Jokers (N = 63) were rated as enjoying gaming more than other play personality types, (of a score from 0-4, M = 3.19). Kinesthetes (N = 19) enjoyed gaming overall the least (M = .92).

Together, these findings indicated that if therapists wanted to improve dynamic balance and had a patient who identified as a Joker-type, a soccer game would be a better choice than bowling. However, if socialization were also important, bowling might be a better choice. Similarly, if game developers wanted to design a game to improve dynamic balance for Joker-typed patients, they could benefit from game design elements from soccer; if they want to focus on socialization, game elements in bowling would be more beneficial. In other words, game developers can utilize the same data to gather personalized requirements of motion-games for BI therapy.

D. Step four: User Studies of a Prototype CBR User Interface

User studies of the system interface have helped us to understand interface and content requirements and further clarify the attributes of a case. We designed the initial CBR user interface based on the diary form and have evolved the interface based on therapists' feedback. We first evaluated paper-based wireframes (line drawings) of the interface with three therapists onsite at Schwab (one each occupational, recreational and physical therapist). Based on the feedback we created a responsive interactive web-based wireframe to usability test the interaction.

The interface's introduction page indicates that the system provides three major functions.

1. *Find game recommendations*, in which the system recommends suitable games for a user based on patient attributes and therapeutic goals.
2. *Explore games*, in which users can use filtering, and search tools to find information about games.
3. *Contribute to the system*, in which users can add information about a game-play session, add a comment to a game, or add a new game.

The process of finding game recommendations for patients involved two steps, which resulted in a summary recommendation. The steps were: (1) provide session information including physical and cognitive goals, and determine group size; and (2) provide patient information (that could be skipped) including initials, age, gender, balance and gait measures, nature of the BI, assistive devices used, standing endurance, range of motion, fine motor control, command following and sequencing abilities, and their play personalities using the Brown method (described above). Once the summary recommendation was displayed, more information was

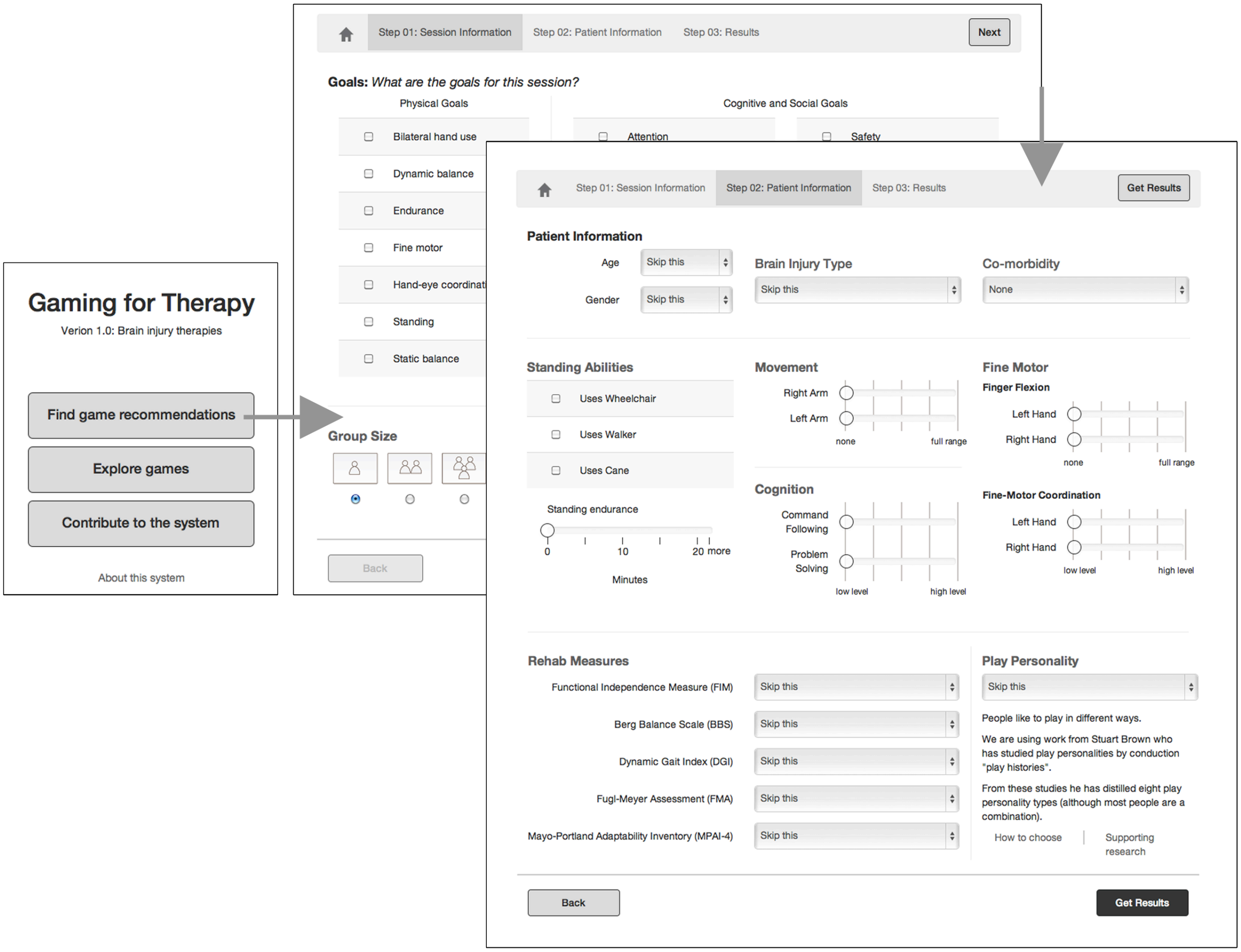

Fig 5. Selected Screenshots of Prototype UI (available at http://cyputnam.com/CBR_UI/)

available on demand, see Fig. 5 for selected screen captures of the interactive wireframes (wireframes also available at http://cyputnam.com/CBR_UI/)

1) Procedures: We conducted usability studies with four therapists who were involved in the original interviews (one speech-language pathologist, one recreational and two physical therapists). Usability studies were conducted onsite at Schwab. Participants were asked to complete three tasks using a think-aloud protocol [31]:

1. Think about a patient you worked with recently, who could potentially benefit from playing games. Use the system to choose two games that will work well for your patient.
2. You heard about a game called 'Space Pop' on Xbox 360 Kinect and think it might be appropriate for some of your patients. Use this system to answer the following questions about this game:
   a. Is Space Pop playable by a patient who uses a wheelchair?
   b. Is Space Pop recommended for improving fine-motor abilities?
   c. How long will you need to spend to set up Space Pop? How long will it take to play Space Pop?
3. Use the system to find games that satisfies the following three conditions:
   a. Possible to play with two players (your patient and you)
   b. Playable by a patient who uses a wheelchair
   c. Takes about three minutes to play.

After the usability studies, therapists were asked: (1) to give us open-ended feedback about the system; (2) which features they found most useful; (3) features they felt were missing; and (4) if they had other questions and comments.

2) *Summary findings:* All participants were able to complete the three tasks, and were generally positive about the concept. For example participant 3 told us, "***For being not very strong in this world, I love the idea of it – that I don't have to know***

stuff, that I don't have to have a background in any of it and I can still pull out what I could potentially use for a various of patients. I love that you can either be specific or not."

The most useful feature mentioned (beyond the recommendations themselves) was the inclusion of the expected cognitive help; however, one therapist (participant 4) wanted us to take this further and include sensory attribute of patients, "***Maybe it would be helpful to add some kind of sensory integration element, because we do have patients who are both hearing and visually impaired***."

Missing features included: (1) a way to filter out violent games, (2) better filtering by game genre, and (3) a desire to reorder the feedback so that the 'goal effectiveness' (how well the game was judged to effectively target a goal) and the level of expected independent play (both cognitive and physical) were at the top of the results page.

E. Summary of the four-step approach

With an emphasis on direct involvement of end users (i.e. therapists), each step in our multi-method approach has helped us understand different aspects of requirements for the CBR system. See Table 2 for a summary of the steps and the elements of requirements they afforded.

TABLE II: SUMMARY OF REQUIREMENT GATHERING STEPS

Steps	Elements of Requirements
Interviews	The CBR system needs to consider therapy session goals, patient physical abilities and cognitive abilities
Observations	The CBR system needs to incorporate patient scaffolding aspects and logistic issues in therapy
Diary Studies	Clarified the attributes in a 'case' (e.g. specific patient abilities needed to be considered) and generated 'seed cases'
Usability Tests	Clarified the user interface content requirements and elaborated the attributes in a case

Described here, we have presented four research steps as though they proceeded linearly. However, in reality the process has been very iterative. The interviews we conducted at Marianjoy were similar to those at Schwab, but were changed with what we had learned at Schwab. The observation coding method we used for the Marianjoy videos was first piloted with the Schwab videos. The first (pilot) diary forms we used at Schwab were comprised primarily of open-ended questions. Consequently the pilot diary data was only used inform later versions of the diary form; i.e., we modified the design to help minimize the time it took for therapists to complete the form. We continued to iterate the form throughout the first three diary studies at Schwab based on therapists' feedback.

There was also great overlap and interaction between the method steps. For example, both step three (diary studies) and step four (interface prototype studies) contributed to the evolvement of both the diary form and the interface design. We designed the first version of the interface based on the iterated diary form at Schwab. After the user studies at Schwab, we then turned around and made further modifications to the diary form that was presented in this paper to make it look and function more like the interface. We feel this interaction between requirements gathering and user studies was crucial for our project.

IV. Discussion and Conclusions

We recognize that choosing methods for requirement elicitation is dependent on characteristics of a project domain. While some researchers have proposed frameworks that can be used for choosing elicitation methods (e.g. [15]); others (similar to this work) have reported their success in combining elicitation methods in various domains [13, 32]. For example, Sabahat et al. analyzed the strength and weakness of elicitation techniques for gathering different requirement aspects in the domain of Global Software Development [32]. While focusing on a different domain, we highlighted similar problems of requirements gathering for a special population.

We initially chose more exploratory methods (i.e. interviews and observations) because of our limited knowledge and lack of context on the problem domain (i.e. therapeutic gaming in BI rehabilitation) at the outset of this project. As the project proceeded and shifted focus towards a potential solution (CBR system), we adapted and refined the interviews and observations to focus on elicitation of the requirements for the CBR system. In other words, the lens for the data collection shifted from problem to solution exploration. However, we found we needed a different type of method to better understand the patients' attributes in the system because it is not possible for us as researchers to directly interact with many patients; i.e., those who are not capable of signing consent forms. The diaries then became a proxy means to gather patient attributes for the CBR system. The diaries were not just helpful to leverage therapists' expertise, but the diary design evolution, which was based on therapist feedback, directly led to the initial designs of the CBR prototype interface.

While it is obvious that direct interaction with end users is a critical key to success of technologies, it is even more important when considering requirements elicitation for projects that involve populations that are less represented in software engineering studies. In our case, the end users are the therapists who use games with their patients who have had BIs. In each step of our multi-method approach, therapists have been and will be deeply involved; their opinions and domain knowledge is fully acknowledged:

- In the interviews, user requirements that consider therapeutic goals and patient factors (e.g. patient abilities and personal preferences) are directly derived from therapists' responses.
- In the observations, both therapists and patients are involved. We gathered details about the interaction between therapists and patients in situ (e.g. physical scaffolding).
- In the diary studies, the diary form itself (which is later used as a framework for the interface design) has evolved based on therapists' feedback.

- In the user study of the interface prototype, usability issues and missing elements have been identified with the support of users.

Moving forward, this project also will consider the needs and domain expertise of game developers. There are two major approaches in the domain of therapy-centered motion gaming: (1) using existing commercial games with no modifications; and (2) creating new games specifically for rehabilitation [9, 33-35]. Both approaches have merit. While acknowledging the limitations of commercial motion-games (e.g. learning curve is too steep and sometimes physically and/or cognitively too challenging [36,37]), we recognize that commercial games, when carefully chosen for patient characteristic and therapeutic goals, can benefit a very wide range of people with BIs because they are readily available. As such, in the current work we are focusing on the first approach (i.e. direct use of commercially available motion-games for BI rehabilitation) and aim to support therapists in choosing commercial games.

However, we envision that our work will also benefit the second approach (i.e. creating games for BI rehabilitation). In particular, our work supports a personalized requirement gathering of therapy-centered motion games that will aid game developers interested in designing therapy-centered games. As our proof of concept analysis of the diary data has demonstrated, play personalities can significantly influence gaming preference and gaming experience. In addition, patients' physical and cognitive abilities affect the accessibility of a game and different therapeutic goals lead to different levels of effectiveness in therapy outcomes. Game developers need to consider all these factors in order to produce therapy-centered games that are both (1) enjoyable for this diverse population and (2) effective for the aimed therapeutic goals. We view the CBR system as part of the ecology of approaches to therapy-centered gaming.

V. Limitations and Future Work

As with all research, this work has several limitations; some we will continue to address moving forward. Limitations of this work include: (a) a specialized domain; (b) small sample size; (c) reliance on subjective measures and (d) as a work in progress, this project is still evolving.

A. Specialized Domain

In this paper, we focused on a case study addressing requirements elicitation problems of one project that leverages user-centered approaches and concentrates on a specialized domain. While our approach might be beneficial to similar projects that focus on requirements gathering for an unfamiliar and less represented population, the external validity is limited.

B. Sample size

Our sample size for most games (other than bowling and soccer) was too small to infer how well the games met any particular goal; i.e. there was no power to see statistical differences in many cases. Additionally, the requirements we gathered from Schwab and Marianjoy may not generalize to other rehabilitation hospitals or to other facilities (for example, outpatient clinics). We plan on addressing this limitation by expanding to additional rehabilitation hospitals and including outpatient care.

C. Reliance on subjective measures

Diary study data relied completely on subjective measures; i.e., on therapists' opinions about game success and patient enjoyment. While subjective opinions are very important (and in fact drive most recommendation systems), in future work objective measures of game efficacy are needed to credibly discuss motion-game efficacy. We are currently partnering with biomedical scientists at Rosalind Franklin University to pilot the collection of gait and balance measures during the diary studies at Marianjoy. The addition of objective measures through experimental design in outpatient care is also part of our future plans.

D. Work in progress

We acknowledge that because this is work in progress, our approach and definition of 'a case' will probably need to evolve given the diversity of brain injuries, patient characteristics, and game features. This will be addressed through evaluation studies and iterative design of the CBR system with users (therapists and game developers). We plan to launch an early beta of the system (revised based on therapists' feedback) in winter 2015.

Additionally, to further support personalized requirement gathering, we plan to create an interface to the CBR database specifically for game developers. The game designer interface will afford an understanding of common game design requirements (e.g., common goals, effective movements) for therapy-centered motion games.

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