'Choose a Game': Creation and Evaluation of a Prototype Tool to Support Therapists in Brain Injury Rehabilitation

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ABSTRACT
Brain injury (BI) is recognized as a major health issue. It is common for therapists to include commercial-off-the-shelf (COTS) games in their therapies to help motivate patients who have had a BI engage in rehabilitation tasks. In this paper, we present a prototype 'Choose a Game' tool that focuses on helping therapists select appropriate games that match their therapeutic goals and patient attributes. The tool leveraged a knowledge-base that we created about COTS games use in BI therapy. We evaluated the prototype through user studies with 29 therapists at two rehabilitation hospitals. While further improvements are needed, the tool enabled therapists to use games from a wider range of selections and therapists were generally satisfied with the game recommendations and the tool's user experience. This project is also a demonstration of a novel research model for investigating domains where technologies are rapidly proliferating for users with wide-ranging attributes such as the domain of therapeutic gaming for BI rehabilitation.

Author Keywords
Games; brain injury; rehabilitation; case-based reasoning

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

INTRODUCTION
Brain injury (BI) is recognized as a major health issue by the US Center for Disease Control and Prevention (CDC) [26]. Approximately 6.4 million children and adults in the US live with a lifelong disability as a result of a BI [7]. Causes are varied and include external traumatic events such as car accidents and firearms (i.e. traumatic brain injury), loss of oxygen to the brain (i.e. hypoxic brain injury), and cerebral vascular accidents (i.e. stroke) [7]. Individual impacts of a BI are also diverse and can involve a wide range of physical and cognitive disabilities [7]. A person who has had a BI might exhibit impaired gross and fine motor control [45]. Full or partial paralysis is common especially with stroke, sometimes affecting speech [44]. Gait and balance are also often affected, and worse, impose additional possible risks of falling and further injury. Cognitive impairments (e.g., impaired memory, problem solving abilities) are also common resulting in day-to-day difficulties including problems following directions, completing procedural tasks, and understanding language [44]. Because of the wide range of causes and potential impacts from a BI there are varied recovery paths; as such, therapists must customize rehabilitation treatments for each patient.

Clinical experience and cases cited in the literature have identified that it is often challenging to motivate people who have had a BI to engage in the repetitive exercises common for rehabilitation [6, 20]. As a result, it is common for therapists to include games[1] to help make repetitive tasks fun and engaging; i.e., to increase motivation to perform both physical and cognitive rehabilitation exercises [22, 29]. And because commercially available products are reasonably affordable and readily available it is also common for therapists to use commercial-off-the-shelf (COTS) games/systems such as the Nintendo Wii [22, 29]. However, in exploratory research, we found that therapists had difficulty finding pertinent information about COTS games and systems; i.e., information to guide selection of appropriate and therapeutically effective games in an environment of rapidly proliferating games/systems [39].

In this paper, we present the creation and evaluation of a prototype 'Choose a Game' tool aimed at helping therapists select appropriate games for their patients who have had a BI that match their therapeutic goals and individual patient attributes. This prototype leveraged a Web-centric knowledge-base that we designed and optimized in a larger project to support the use and creation of games for BI rehabilitation. We created and evaluated the prototype using a user-centered approach with 29 therapists who work with inpatients with BIs at two rehabilitation hospitals in Illinois: (1) Schwab Rehabilitation Hospital in Chicago and (2) Marianjoy Rehabilitation Hospital in Wheaton. This project

[1] Throughout this paper, we use the term 'games' to include both gamified activities and games.

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represents a novel research model for investigating domains where technologies are rapidly proliferating for user groups with wide-ranging attributes such as the domain of therapeutic gaming for BI rehabilitation.

Related work

There are two general approaches to including games in BI therapies: (1) **use** COTS games and systems either 'as-is' or with modifications and (2) **create** new games and/or systems. While in the larger project we embrace both approaches, the work presented in this paper (and therefore the more related literature) is focused on the former, i.e. 'use of COTS games and systems' approach. In the next sections, we present several studies that used COTS games for BI rehabilitation; we organized the related work by study type: (a) case studies; (b) experimental designed studies (including meta-analysis of experimental designed studies). We also include studies focused on (c) games for cognitive improvement in work related to BI therapy, and (d) work concerned with therapists' perspectives in the gaming-rehabilitation space in this literature review.

Case studies of COTS motion-based in BI rehabilitation.

Case studies have been conducted using: Nintendo Wii [8, 18], Sony Eye Toy [19], and Microsoft Kinect [36]. Deutsch et al. compared standard therapeutic practices to the use of the Wii in their effectiveness for helping with balance and mobility post-stroke (n = 2) [18]. While the authors found that the Wii training generated more initial enthusiasm, greater enthusiasm was not sustained in follow-up studies. Flynn et al. used a Sony Eye Toy and 15 different commercial games in the rehabilitation for one client post-stroke and evaluated efficacy through multiple physical therapy measures. The authors found that the games were effective at meeting therapeutic goals [19]. Paavola et al. reported on a case study using Microsoft's 'Kinect Adventures' for 10 sessions over a month with a single patient with a TBI. The participant showed improvements in physical clinical outcomes, including balance and gait [36].

Experimental designed studies of COTS videogames.

Experimental designed studies with larger samples (more than 10 participants), some using randomized assignments and control groups, have become more common in the literature in the last five years; all used either Nintendo Wii (e.g., [14, 17, 24, 28, 43]) or Sony Eye Toy [49]. For example, Cho et al. used the WiiFit, which comes with a balance board, with 11 participants (plus an 11-person control group receiving conventional therapy) for six weeks. The experimental group performed significantly better than the control group in dynamic balance and in the Time Up and Go test; however, there were no differences in static balance [14]. Researchers have reported on multiple challenges of controlled studies in this domain; many have stated that: (1) commercial games were too difficult for many people with BIs (e.g. [24]); and (2) there is a small pool of possible matched participants making randomized trials difficult to conduct [43].

With the increase in number of experimental studies, some researchers have conducted meta-analysis studies [30, 42] For example, Laver et al. examined studies encompassing 19 trials that included 595 people who had a stroke; all studies were focused on using games to improve gross motor functioning. The combined studies supported improved upper limb function and improvements in activities of daily living [30].

Studies focused on games for cognitive improvement.

The availability of game-like activities for cognitive training, e.g. CogFit-Quest [15] and Lumosity [31], has led to researchers assessing the value of cognitive-based computer games [16, 50]. While generalization is limited to BI, previous research with older adults has demonstrated that cognitive-based training can combat decline due to aging [4]. Lumosity is especially attractive for research because Lumos Labs, creator of Lumosity, offers a research portal for investigators to capture frequency, duration, and outcome of participant use. In an example, Zickefoose et al. compared Attention Processing Training (APT3) to Lumosity training for cognitive improvement in four people with BI using a within-subjects design. While there were no significant differences between treatments, participants improved through both interventions [50].

Therapists' perspectives

While most research concerned with game-based rehabilitation focuses on patient outcomes, in this work, we are also considering therapist needs. In similar work, Annema et al. used structured observation to explore therapist roles in the use of games with children who have cerebral palsy and multiple sclerosis. One finding that we are also considering is a need for an easy game set-up [3]. Related, therapists themselves have written about how they use commercially available games and consoles. For example, Jonathan Halton, an occupational therapist, has written several articles that discussed how he used the Wii console/games in his work (e.g., [21, 22]). Rebecca Redmond, a physical therapist in the UK, created a now-defunct Website and blog called "Wii-habilitation", which offered news, reviews, and tips for using games with diverse audiences [41]. Halton and Redmond's works are examples of the need for therapists to share experiences using games in therapy. We argue that a systematic means to share information (e.g., through decision and information-sharing tools) will become more important as the number of games and systems expand and as the patient population becomes more familiar with playing games.

Summary: related literature

In summarizing literature focused on leveraging COTS games, there has been great support for the notion that games and game-like activities will ameliorate boredom/tedium associated with rehabilitation exercise. There is also support that playing COTS games can contribute to improved therapeutic outcomes. Additionally, previous work supports the advantages of commercially available games at increasing scalability and affordability.

In this paper we present work to help maximize the use of COTS games in BI rehabilitation through the creation of a decision tool for therapists that uses a Web-centric knowledge-base of COTs use in BI therapies.

PRELIMINARY WORK

We laid the foundation for the knowledge-base through a multi-method approach involving: interviews, observations, paper-based diary studies, and usability studies of a "Choose a Game" interface. Because we have discussed our previous work in other papers, sections presented here are to provide a brief background of our foundational work.

Interviews

We interviewed 21 therapists who worked with inpatients who had BIs: five occupational therapists (OTs), nine physical therapists (PTs), three recreational therapists (RTs), and four speech-language pathologists (SLPs) from Schwab and Marianjoy. Therapists had between 2-32 years of experience (mean = 9.5 years). All of the therapists used games as part of their therapies prior to our interviews and all had specific goals in mind when choosing games. One key finding motivated our focus on the 'Choose a Game' tool is that therapists desired a means to find relevant information about games and systems – which were rapidly proliferating – to address therapy goals; for more see [39].

Observations

To further understand contextually situated requirements for decision and information-sharing tools for therapists, we conducted onsite observations of therapy sessions of COTS game use. After the interviews, we installed AV carts at Schwab and Marianjoy; the carts housed the major COTS consoles and games that the therapists selected. We observed 24 therapy sessions at Schwab and Marianjoy in 2012-2013. Two findings had major implications for the design of information and decision tools about COTS games use: (1) therapists mobility – because therapists spend most of the time working with patients in therapy gym areas (i.e. not desks), tools for therapists need to be accessible from mobile devices; and (2) assistive devices – because several people used walkers, canes and wheelchairs there was a need to filter games based on whether they could be played using assistive standing devices and/or sitting down; for more see [12].

Ideation for Case Based Reasoning Methodology

From the early interviews and observations, we learned that the problem and the solution spaces for the 'Choose a Game' tool are both quite large. In the problem space, BIs have a wide-range of effects so that (a) patients are distributed in a large number of dimensions (physical, cognitive, and personality attributes) and (b) therapists have wide-ranging therapy goals. In the solution space, the number of COTS games/mini-games that can potentially be used for BI rehabilitation is also quite large. While therapists discussed the use of more than 30 games/mini-games in our initial interviews and observations, the available games are rapidly proliferating and therapists were keen to explore new games to maintain novelty in game therapies. Because of the complexity of the problem and solution spaces, we reasoned that traditional rule-based methods were not going to work for our decision tool. We structured the knowledge-base as 'cases' and adopted a case-based reasoning (CBR) methodology.

CBR systems solve problems by referencing previous solutions or 'cases' [48]. Rather than solving a problem by reasoning from first principles, a CBR system uses the problem situation to retrieve applicable knowledge in the form of cases. Cases are then adapted to fit the new situation. A working CBR system also has a natural learning mechanism; as new problem solutions become cases in its memory they can be applied to future problems.

One important application of CBR has been the creation of decision and recommendation tools. The key feature of a CBR system is that it has a structured representation for the problem and the solution, in addition to a similarity metric that can match new problems against known cases. CBR systems have been used in multiple domains to help people make decisions by leveraging the experience of the many collected as 'seed cases' (e.g. [32]). There are many CBR projects that have focused on the medical domain both in diagnosis and treatment, for example, in cancer diagnosis [37], radiotherapy planning [38], and diabetes management [33]. In one study, similar to the work presented in this paper, Ahmed and Funk created a CBR system to help physicians choose a post-operative pain treatment plan [1]. For a survey of medicine-specific work, see [25]. In our literature review, we were not able to find previous work related to the use of CBR for therapeutic gaming decisions.

The concept of our 'case' structure in the game therapy knowledge-base evolved throughout the preliminary studies to include the following categories of attributes: (1) patient attributes; (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 Figure 1 for the summary attributes of a case.

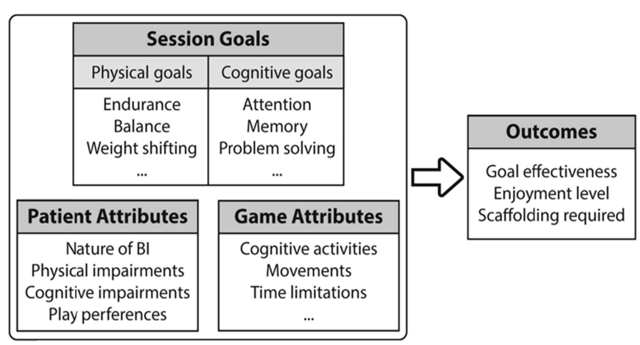


Figure 1. Summary attributes of a case

Paper-based diary studies

To collect 'seed cases' for the knowledge-base, we conducted paper-based diary studies with 16 therapists:

eight PTs, three OTs, two SLPs, and two RTs; 15 of the 16 had participated in the interviews. Therapists had between 2-32 years of experience (mean = 9.2 years)

In the study, therapists were given a notebook containing a 2-page diary form and were asked to record case details about play sessions over 2-week study periods. We collected game session information (i.e. cases) for a total of seven 2-week study periods: three at Schwab (2012-2013) and four at Marianjoy (2013-2014).

On the first diary page, therapists were asked to record: (1) session details; (2) non-identifiable patient information; and (3) their game selections (console, game/mini-game). We also assessed patients' play preferences using work from Stuart Brown [9]. While several researchers have developed/used existing personality tests to predict play preferences (e.g. [5]), we are looking to develop a reliable instrument that can be used quickly (to consume minimum therapy time) by people with cognitive impairments.

Brown has studied play personalities by conducting 'play histories', i.e., interviews focused on play. 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 for the diary, we created eight cards describing Brown's play personalities in a single sentence. After a play session, therapists shuffled the cards, laid them out and described the cards for the player-patient and asked them to identify the one that described them best.

On the second diary page, therapists: (1) identified the goals for playing each game (these were iterated with input from therapists throughout the diary studies); and (2) rated (subjective measure) the effectiveness of the game at meeting specified session goals, level of cognitive and physical help needed, patient enjoyment and the challenge level. Therapists were also invited to enter comments about the therapy play session. In the paper-based diary studies, therapists recorded data for 89 individual patients comprising 244 'seed cases' for the initial case knowledge-base; for more see [40].

Usability studies of the 'Choose a Game' interface

In the same timeframe as the diary studies we designed and evaluated interfaces for the 'Choose a Game' tool. We started with paper-based wireframes (line drawings) of the interface with three therapists at Schwab (one each OT, RT and PT) in July-August 2013. Based on the feedback we created a responsive, interactive Web-based mock-up and conducted usability studies with four therapists at Schwab who were involved in the original interviews (one SLP, one RT and two PTs). Participants were asked to complete three tasks using a think-aloud protocol. All participants were able to complete the three tasks and were 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.*" For more see [40].

METHODS: PROTOTYPE 'CHOOSE A GAME' TOOL

In the next sections we describe our methods for building the prototype. We also describe the evaluation we performed over three user study periods.

Building the prototype 'Choose a game' tool

Using the seed cases we collected from the paper-based diary studies, we developed an experimental CBR algorithm. The algorithm used nearest neighbors for case retrieval and weighted average to assess similarity [48]; the initial weights were set based on our assessment on the importance of the case attributes. A condensed version of the experimental algorithm is as follows:

1. For each case c_i in the case base C, calculate the **similarity s_i** between c_0 (the new case) and c_i ($0 \leq s_i \leq 1$, where $s_i = 1$ means c_0 and c_i are identical) based on the goals selection and the patient attributes:
$$s_i = w_{goals}s_i^{goals} + w_{patient}\big(w_{personality}s_i^{personality} + w_{age}s_i^{age} + w_{gender}s_i^{gender} + w_{ability}s_i^{ability}\big)$$
2. If $s_i \geq s_{threshold}$ (where $s_{threshold}$ is a predetermined similarity threshold) put c_i into the candidate list.
3. For each case c_j in the candidate list $C_{candidate}$, calculate its **outcome value o_j** ($0 \leq o_j \leq 1$) based on the goals effectiveness, the enjoyment ratings, and the help needed ratings from the diary data:
$$o_i = w_{goals}o_i^{goals} + w_{enjoyment}o_i^{enjoyment} + w_{help\_needed}o_i^{help\_needed}$$
4. For each game g_k mentioned in the candidate list $C_{candidate}$, find all cases that used g_k and put them into a set C_k. Calculate the average outcome value $\overline{o_k}$ and the average similarity $\overline{s_k}$ of all cases in C_k
5. Let the overall score for a candidate game g_k be $r_k = \overline{o_k} \times \overline{s_k}$.
6. In descending order, sort the candidate games according to their overall scores. Output this sorted list.

We coded the backend algorithm in Java and built a responsive interface using the Bootstrap framework. The interaction design followed three steps. Once logged in with an email address, therapists (1) chose goals for the session (goals were identified in the preliminary work), (2) entered information about their patient by clicking checkboxes that activated sliders for severity of possible patent impairments, and (3) filtered for game platforms; see Figure 2. To help save time, the system asked only for patient attributes found important for game decisions in the preliminary studies. The system was also capable of providing recommendations without any patient information, i.e., to goal matches; however the recommendations were more precise *with* patient information.

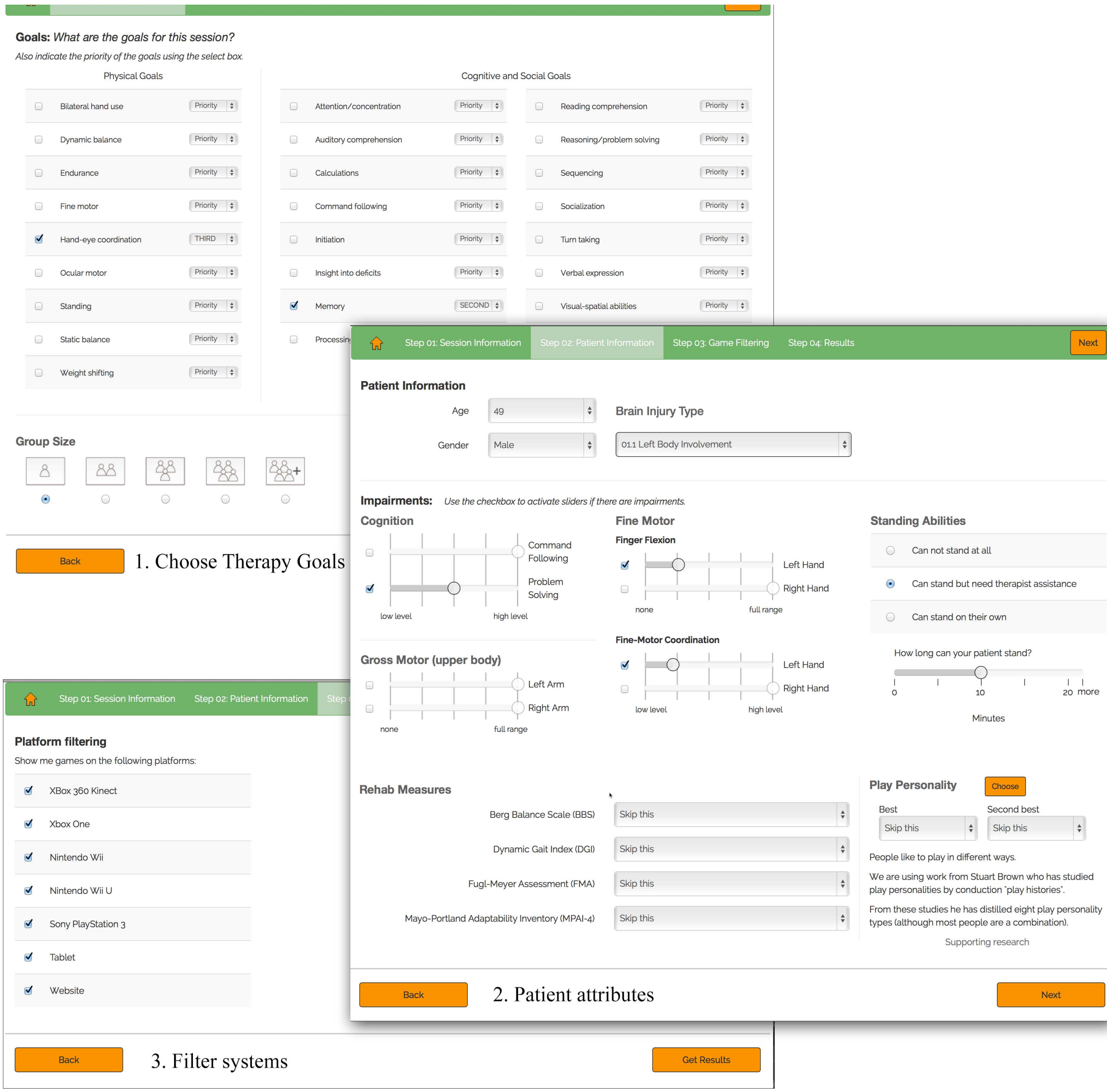
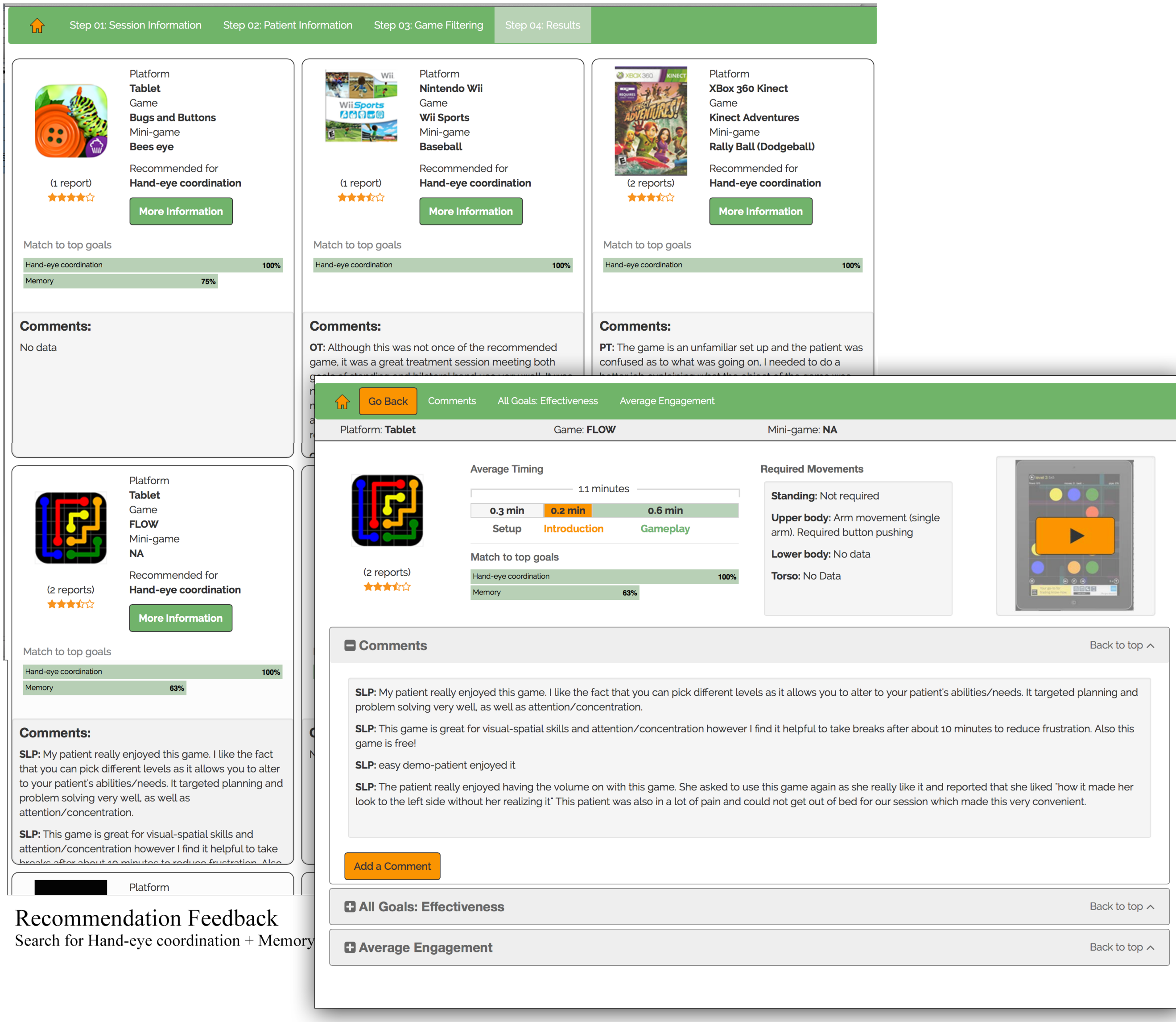


Figure 2. Therapist input sequence. Sliders and drop-down lists were activated by clicking the checkboxes

After inputting session information, therapists were presented with a summary list of games. Information about games included: (1) cover art, (2) summary game information, (3) information about how well the game matches to the input case (five-star overall match and match to the top therapeutic goals), and (4) comments about the games from therapists. Therapists were also able to navigate to a detail page that provided additional game information. Additional information included information about the game's required movements, the game's rated effectiveness at all goals (i.e. including ones not selected in the query), and a gameplay demo video. See Figure 3 for output screens.

The prototype can be found at: http://gametherapy.cstcis.cti.depaul.edu:8080/TherapyGameRecommender/index.html



Recommendation Feedback
Search for Hand-eye coordination + Memory

Game Details ('More Information' button)

Figure 3. Feedback Screens

Evaluation studies

In the next sections we discuss our participants and methods for the evaluation studies.

Participants

Twenty-nine therapists participated in three evaluation study periods (25 completed all three sessions; all 16 therapists from the paper-based diary study participated). Participating therapists included eleven PTs, ten OTs, six SLPs, and two RTs. Therapists had between 2-32 years of experience (mean = 7.5 years).

Testing methods

The evaluation test protocol included a short training session, after which therapists were given iPad minis for their participation and asked to use the 'Choose a game' prototype for three testing periods between August 18, 2014 and June 30, 2015 (first period for four weeks, second for four weeks, and third for 16 weeks – total 24 weeks). Each study period was followed by a short interview or survey to explore user interface issues and usefulness of the feedback information and recommendations.

Therapists were asked to make at least three inquiries per four-week during the testing periods (6 four-week testing periods × 3 inquires = 18 inquiries total); inquiries were automatically logged to the system. Recall that each inquiry included information about session goals and patient attributes (see Figure 2); as such inquiries represented the first page of the paper diary form. After each therapist inquiry, we sent a questionnaire asking about: (1) their satisfaction about the recommendations (on a scale of 1 to 5) and reasons for their rating; (2) how well the recommended games they used matched the patient's profile and session goals; and (3) questions about the session and game use that paralleled the second page of the diary (i.e. rated the effectiveness of the games at meeting the specified session goals, the level of cognitive and physical help needed, patient enjoyment and the challenge level). **As a result, the inquiry and the corresponding questionnaire served as a digital diary form that resulted in new cases added to the case knowledge-base**. The questionnaire also allowed therapists to add new games to the system if they used a game or activity that was not on the recommended list; see Figure 4 for a graphic explaining the questionnaire design.

Analysis

In the analysis presented in this paper, we first evaluated the therapists' feedback from the post-testing interviews and surveys. Two authors independently analyzed the user feedback and then shared and discussed with all authors that resulted in several design iterations of the 'Choose a Game' tool between the three testing periods. We then examined the cases in the knowledge-base. Specifically, we examined (1) differences in games' effectiveness at addressing top therapy goals and (2) differences in perceived enjoyment in the therapy sessions among the eight patient play personality types. This analysis of the knowledge-base is intended to help validate the CBR methodology and provide more detailed information about factors associated with successful game use in BI therapy.

FINDINGS

The 29 participating therapists made 299 queries in which games were used in a therapy session (note that a single query could result in multiple cases if multiple games were used); therapists made an additional 36 queries in which they decided not to use games. (Not all therapists had appropriate patients for gaming during the user study windows.) The combination of the inquiry and survey returns (n = 472) were combined with the paper-based diary seed cases (n = 244) to create a total of 716 cases for the current knowledge-base that covers 413 unique therapy sessions and contains data about 157 games/mini-games from 51 games on five different platforms.

In the following sections, we first discuss details of user feedback and how that affected the iteration of prototype. We then provide an analysis of how games were used and how patients' play personality affected game enjoyment.

User feedback and design iteration

Therapists were generally satisfied with the recommendations provided by the prototype tool; the average satisfaction rating was 4.2 (on a scale of 1 to 5, SD = 0.96). The top reasons stated for satisfaction included:

(1) The system enabled therapists to use a wide range of games. E.g., "*It provided me with some options for games that I would not have tried on my own.*"
(2) The recommendations were appropriate for the therapy goals and the patient. E.g., "*... this patient ... is much higher level and I felt that the game choices were higher level and were targeted at dynamic activities.*"
(3) The number of recommended games provided is abundant. E.g., "*There is a good variety of games to choose from*."

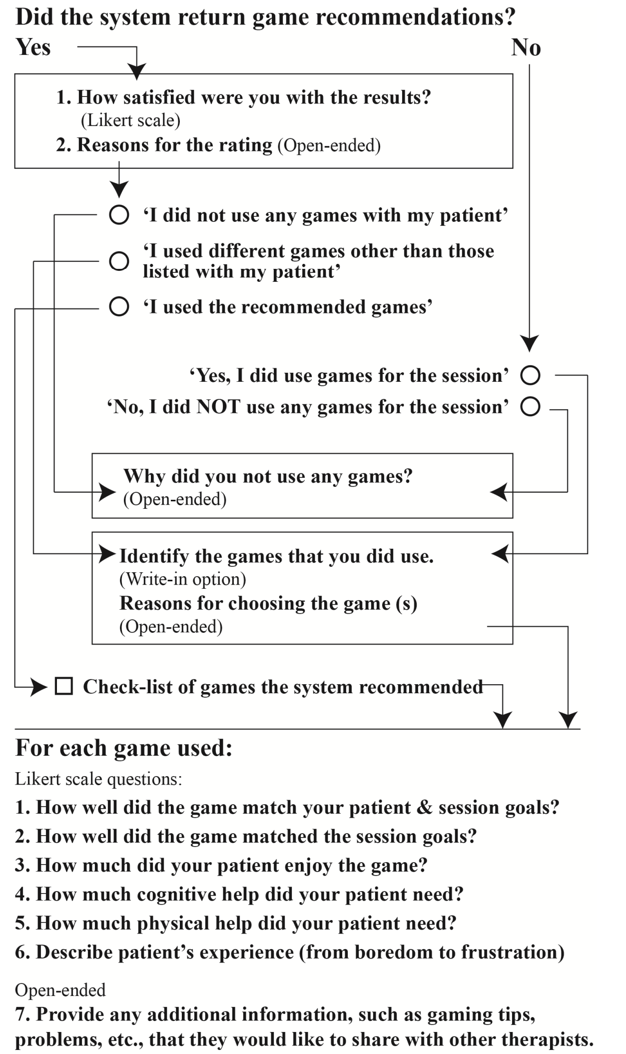


Figure 4. Questionnaire design

Through the user study periods, we made several functional and visual modifications based on the therapist input; the modifications included (1) adding goal priority settings, (2) modifying the information structure on the game list page, and (3) adding gameplay videos and timing graphs. With these improvements (and also due to a greater number of cases), therapists' overall satisfaction of the matches increased for each study period: 3.9 (SD = 1.15) for period one, 4.23 (SD = 0.9) for period two, and 4.32 (SD = 0.83) for period three using a Likert scale from 1 to 5; differences were significant using a Kruskal Wallis test ($H(2)$ = 10.64, p = .005). For the remaining of this section, we discuss these modifications and the corresponding user perceptions.

Adding goal priority settings

Based on therapist feedback, we added the priority drop-downs after the first testing period; see Figure 5 for a close-up of the interface. This addition also improved the CBR algorithm by adding weighting that used the goal priorities This addition was well received; for example in the second debriefing survey, a physical therapists reported "*I feel like weighting the goals for the session has helped to narrow the results to get more specific recommendations which makes it easier to decide which game to use*."

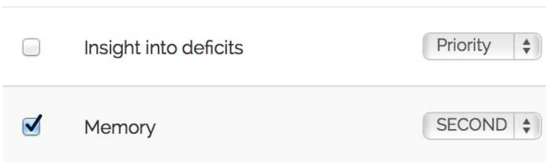


Figure 5. Close up of goal priority drop down

Modifying the information structure on the game list page

Changes to the recommended game list page included: (a) moving comments so they appeared on the first feedback page (rather than only on the game detail pages); and (b) modifying bar graphs to better visualize how well the game matches the therapeutic goals chosen by the therapist, see Figure 6. Moving the comments to the initial game list output was especially well received, for example one physical therapist told us "*I like the comments part as feedback from other therapist on these games can be very helpful in making your final decision*."

When asked to rate level of agreement to the statement "I found the 'Match to top goals' bar graphs on the results page to be helpful", therapists rated their agreement at 4.15 out of 5 (*SD* = 0.79). Comments included, '*There were often many results for the queries I did, so the bar graphs helped to make selections*". However, one therapist indicated that the graph is not quite clear by asking, "*What does the percent represent? How many respondents used this game to achieve this goal? Is it the percent that it will address this goal?*" This last comment indicates that we still have work to do in improving the feedback interface.

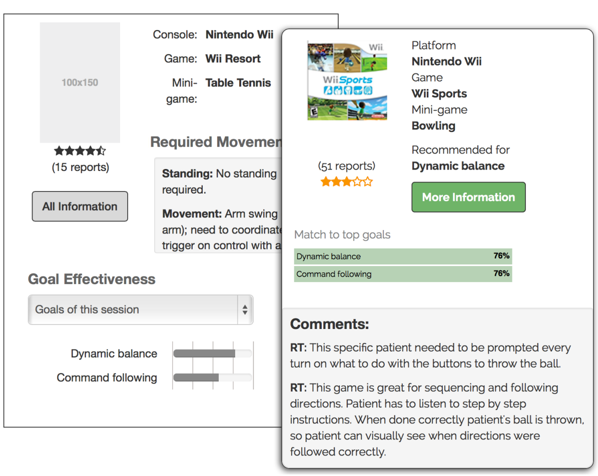


Figure 6. Revised initial game output (original on left)

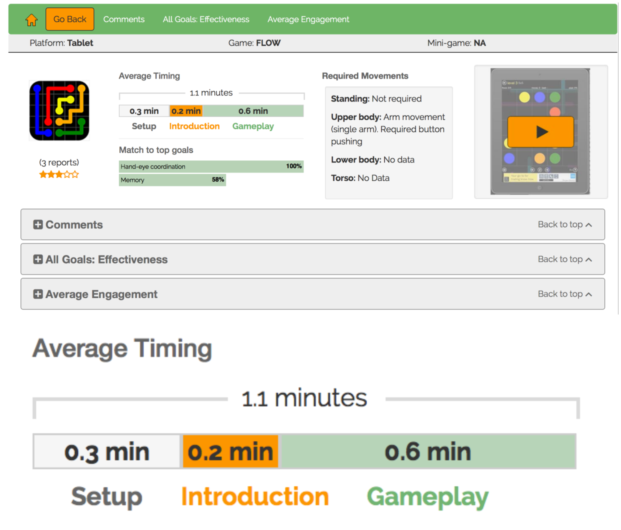


Figure 7. Updated detail page and close-up on timing graph

Adding gameplay videos and timing graphs

Based on therapist feedback, we added videos of gameplay and timing graphs to the detailed game information pages; see Figure 7. When asked to rate level of agreement to the statement "I found the timing graphs on the results page to be helpful", therapists rated their agreement at 4.07 out of 5 (*SD* = 0.92). While therapists found them helpful, there was also some mixed feedback about the timing graphs because we based timing on our own research (not the amount of time in actual sessions). For example, one physical therapists told us "*Really liked the timing bar graphs-however, I found with my patients- could be because of the level of cognitive or physical impairments that they possessed, it took much longer to set up.*"

While the videos were added because of therapists' requests in interviews, we had a mixed response to their addition; therapists loved the idea, but many felt it had limited use. For example, one recreational therapist told us "*I think videos are a great tool for a therapist that does not know how to play the game, as well as, for a patient that may need to see how the game is played. I did not use these videos, but as a recreational therapist I know how the games are played, so I would not need this.*"

Additional user feedback

We also asked for suggestions moving forward on refinement of the 'Choose a Game' tool. The most common input (mentioned by five therapists) was for a way to save results for later and an ability to refine recommendations from the initial list. For example, one occupational therapist wrote: "*The other thing I would like to see done is to make the recommendations available to e-mail to keep a copy. Also maybe there could be a link that once you receive the recommended games, if you see that they are not the right challenge you could click to increase challenge or decrease challenge and get a new set of games.*"

How therapists used the COTS games

Therapists had diverse goals based on their roles; see Table 1 for the top goals by therapist type. We did not include RTs in this analysis because their primary job responsibilities were to support the other therapists. In this section, we therefore examine the most frequently used games for the top goal for PTs, OTs, and SLPs.

Table 1: Top goals (in order) by therapist type

Physical Therapists	Occupational Therapists	Speech-Language Pathologists
1. Dynamic balance	1. Standing	1. Concentration
2. Standing	2. Hand-eye coord.	2. Memory
3. Weight shifting	3. Dynamic balance	3. Visual-spatial
4. Endurance	4. Concentration	4. Processing speed
5. Static balance	5. Endurance	5. Problem solving

Physical Therapists (PT) most used games

The five most popular games used to address the top PT goal (dynamic balance) were:

- Wii Bowling, which requires players to swing a controller and press a button on the controller to release the virtual ball; this requires accurate timing.
- Wii Fit Table Tilt, which requires players lean side-to-side and front-to-back on a raised balance board to steer balls into target holes.
- Kinect Sports Bowling, which does not require a controller, thus has advantages for people who have difficulty with fine motor control.
- Wii Fit Penguin Slide, which requires players to lean side-to-side to guide a penguin on an iceberg
- Kinect Sports Target Kick, which requires players to kick a virtual ball at targets to get past a goalie.

Isolating the top PT goal of **dynamic balance,** therapists rated the effectiveness significantly different using a Kruskal Wallis test, H (4) = 17.32, $p < .05$. Specifically, Table Tilt was rated the most effective (4.67/5) and Kinect bowling the least effective (3.90/5); see Figure 8.

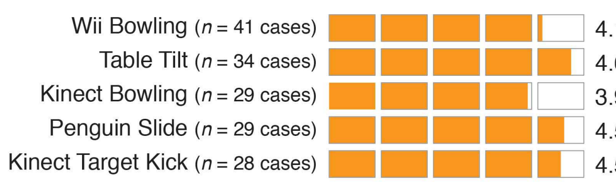


Figure 8. Game comparison for goal of Dynamic Balance

Occupational Therapists (OT) most used games

The most common games used by OTs were sports games that required some upper body movement, sometimes also focused on standing and balancing. The same five games above were also used the most for the goal of **standing**; however, OTs did not rate the games as addressing the goal of **standing** significantly different. Table Tilt was still rated as the most effective among the five games (4.69/5); see Figure 9.

Figure 9. Game comparison for goal of Standing

Speech Language Pathologist (SLP) most used games

SLPs primarily used tablet and Web-based games to address their top goals. While there were a smaller number of cases gathered for cognitive goals, the most common games SLPs used to address **concentration** were all iPad games that focused on cognitive training:

- Stroop Effect based on the well-known psychology test [42], which has players identify colors based on text rather than the color of the text (e.g., click a red button for the word 'Red' displayed in blue text).
- FLOW free, which is a puzzle game where players are tasked with linking similar colored dots with lines that follow a grid.
- Brain Baseline – The Trails Task, which requires players connect dots sequentially (labeled by letters and numbers) by dragging their finger from dot to dot without lifting their finger from the tablet screen.
- Count25lite – Attention Trainer, an app where players are presented with 25 buttons labeled with numbers and are required to pick the buttons sequentially.

SLPs rated the effectiveness of these games to address **concentration** significantly different using a Kruskal Wallis test, H (3) = 16.53, $p < .05$. Specifically, Stroop Effect was rated the most effective (4.83/5) and Count25lite – Attention Trainer was rated the least effective (3.80/5), see Figure 10.

Figure 10. Game comparison for goal of Concentration

Play personality analysis

To explore the play personality data in the knowledge-base cases, we examined differences among player types (defined by the first choice personality card) for the perceived level of enjoyment (i.e., how therapists rated patient level of enjoyment). Differences were significant, H (7) = 19.54, $p < .05$; specifically, cases with Jokers (n = 101) and Kinesthetes (n = 18) were rated as having the highest level of enjoyment (scores for both were 4.11/5). Conversely, Directors (n = 15) and Collectors (n = 7) were rated as having the lowest level of enjoyment (3.30/5), see Figure 11 for enjoyment averages for all play types.

These findings indicated that if therapists wanted to use games as part of therapy, Jokers, Kinesthetes and Explorers were the most receptive. And while our data is somewhat limited (i.e. we did not have large enough samples for most games to examine how player types compared on their enjoyment of specific games) these early findings indicate much promise for the personality matching aspects of the 'Choose a Game' tool.

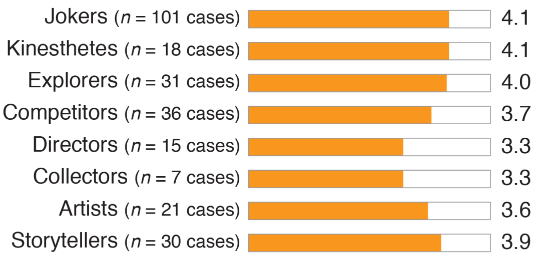


Figure 11. Enjoyment averages for player types

DISCUSSION

In this paper, we demonstrated how, using a user-driven approach, domain experts' knowledge (therapists in this case) can be collected and then (a) structuralized into a case-based knowledge-base and (b) used to support a tool that helps the domain's larger community. We argue that this research model has the capacity to generalize to other important domains where technologies are rapidly proliferating for user groups with wide-ranging attributes; e.g. supporting parents who have children with autism to choose educational software aimed at specific goals.

To summarize, our user-centered approach employed multiple overlapping phases: (1) the "Choose a Game' tool originated from user-expressed needs in interviews; (2) the underlying structure of the system (i.e. the case structure) was directly distilled from the interviews/observations and then refined through paper-based diary studies; (3) the knowledge-base was collected based on our end users' expertise via diary studies; (4) the system was evaluated and iterated with end users; and (5) the evaluation studies provided continued means for users (therapists) to contribute and add to the system which in turn strengthened the recommendations and added to the shared information.

Beyond the generalizable research model, our work also revealed several factors that are important to consider when designing systems to support non-technical audiences (e.g., therapists) who work with a group who has a wide range of abilities (e.g., patients with BIs). First, to support the range of abilities, it is important to afford a high level of customization for input parameters for decision tools such as this one. Second, therapists paid special attention to the comments that their peer therapists made about game use. Because therapists have many reasons to choose games beyond a therapeutic goal match, they valued this easy access to peer's opinion and used it as an important supplement the recommendations. Moreover, the case-based method we used also supports ranking and 'fuzziness' in decision-making. Instead of providing one "optimal" solution, the case-based method allowed our system to return a list of "working" recommendations in accompany with relevant information, especially comments from other therapists, so that the users can make further judgments and decisions with the support of the tool.

We also found it important to consider that therapists (as a non-technical audience) are not typically experts in games. As such, providing opportunities for therapists to learn how to play the games and providing information that is relevant to their therapy sessions (e.g. timing information) was also important to the therapists. While further improvements are necessary, the gameplay videos and the timing graph in the detailed game information pages of our 'Choose a Game' tool were perceived as useful additions that helped therapists use games with more confidence.

Limitations and Future work

In our work at Schwab and Marianjoy, we have found that many games therapist use – some designed to address specific goals aligned with therapy (e.g. reading comprehension) – are designed for children and therefore are often perceived by adult patients as degrading. Previous research has also established that COTS games are often too challenging for many who have had a BI [10]. Some research projects have addressed these limitations by creating digital games specifically targeted for adults who have had a BI (e.g., [2, 11, 23]). Additionally, several commercial products have become available recently aimed at addressing both physical therapy (e.g. Mira [34] and Jintronix [27]) and speech therapy (e.g., Tactus Therapy [47]). These efforts support the idea that therapy-centered game design is an important focus for the future of BI therapies; to address this perceived need, we are currently experimenting with leveraging the case knowledge-base to support the design of games for BI rehabilitation. Specifically, we are exploring methods to generate data-driven therapy-centered design patterns from our case knowledge-base to aid game design [13].

This research also had several limitations that we plan to address in future work. First, the sample size for most games is too small to infer how well the games met any particular goal. Expansion to additional sites will provide more cases, and will also address limitations of generalization; i.e., these findings may not generalize to other rehabilitation hospitals or to other facilities. Second, our CBR algorithm is still immature; a larger sample size will also help us improve the algorithm to make better use of input data. Third, our case knowledge-base relies completely on subjective measures; i.e., on therapists' opinions. While subjective opinions are very important and in fact drive most recommendation systems, in future work objective measures of game efficacy is also needed to help determine how games rank at meeting therapeutic goals and to help us continue to improve the system.

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