Towards a Therapist-Centered Programming Environment for Creating Rehabilitation Games

Caitlin Kelleher, Simon Tam, Matthew May
Computer Science and Engineering
Washington University in St. Louis
St. Louis, MO

Rachel Profitt, Jack Engsberg
Occupational Therapy
Washington University School of Medicine
St Louis, MO

Abstract— **Stroke is the leading cause of disability in the developed world. Motion based video games show promise in helping people with hemiparesis (or partial paralysis) due to a stroke recover motor abilities. However, commercially available games are typically only playable by a minority of people with hemiparesis. Custom games can address the needs of a broader group of people with hemiparesis, but are expensive and time consuming to build. Environments that enable therapists to quickly create motion-based games tailored to individuals with hemiparesis may enable faster research exploration of the rehabilitation game design space and, ultimately, wider use of games in stroke recovery. This paper presents guidelines for and research challenges in the design of programming tools for therapists drawn from two studies. In the first study, we asked ten therapists to describe the relationship between players performing therapeutic motions and the motions of objects within the game world. Based on the language study results, we augmented an existing novice programming environment with support to detect and react to therapy motions. A second study, in which we asked pairs of therapists to design and build a therapeutic game, suggests guidelines for supporting therapists in programming games. These include including focusing on the player rather than input devices and using a mixture of events and constraints to capture player motion.**

Keywords- Programming Environments, Physical and Occupational Therapy, Video Games, Stroke.

I. Introduction

Stroke is the leading cause of serious, long term disability in the industrialized world [37]. In the United States alone, approximately 795,000 people have a new or recurrent stroke each year [22]. This number is expected to rise as the average age of the population increases [16]. Some data suggests that 45% of people who experience a stroke are younger than 65 and 27% are younger than 55 [38].

The effects of a stroke can have significant, lasting impacts on daily life. At least 50% of stroke survivors experience hemiparesis, a partial paralysis of one side of the body [16]. This paralysis is often more pronounced in the upper body and is characterized by deficits in range of motion, strength, and motor control [16]. These deficits frequently limit people's ability to perform everyday tasks such as bathing, dressing, and cooking [36], living independently or holding a job [35].

Recent research using animal models suggests that hundreds of daily repetitions of therapeutic motions can recover a significant amount of lost motor function [17,26,32]. Recent guidelines for human therapy recommend a similar high repetition approach [20]. Unfortunately, during typical therapy sessions, persons with hemiparesis complete only tens of repetitions[19]. While therapists often recommend home exercises to increase the number of repetitions, research suggests that only 31% of people with hemiparesis perform these exercises [33]. As a result, relatively few persons with hemiparesis achieve a full or nearly full recovery [23].

Early research into using video games for stroke rehabilitation suggests that games can motivate people with hemiparesis to complete more therapeutic motions [2,6,8,11,30]. However, a number of barriers currently prevent large-scale use of games in stroke recovery. Existing commercial games require players to have a normal or close to normal range of motion, rendering them unplayable for many people with stroke [6]. While some researchers have built games to address particular deficits [10,11], these games are often only usable by a narrow range of people with stroke.

In the relatively near term, tools that enable therapists to quickly create or customize games for individual persons with stroke can speed research into how to design games that maximize stroke rehabilitation gains. Ultimately, we hope that therapist-centered authoring environments will enable therapists to create or tailor games to meet the specific needs of individual people recovering from stroke.

This paper presents guidelines for and research challenges in the design of programming tools for therapists drawn from two studies. In the first study, we asked ten therapists to describe the relationship between players performing therapeutic motions and the motions of objects within a game world. Based on the results, we augmented a novice programming environment with support for therapy motions. In a second study, we asked pairs of therapists to design and build a therapeutic game. The results of these studies suggest a focus on the player rather than input devices and a mixture of events and constraints to capture player motion.

II. Related Work

Our related work falls into three areas: 1) therapeutic games, 2) game authoring tools for novices, and 3) authoring tools for therapists.

A. *Therapeutic Games*

Researchers have suggested that motion based video games that respond to players' physical movements may be valuable physical and occupational therapy tools [30]. Some researchers

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have explored using existing console games designed for use with motion input devices such as the PlayStation 2 EyeToy [8] and the Nintendo Wii remote [7] in a therapeutic context. Unfortunately, games designed for players without hemiparesis often require a full range of motion and precise control, making them unplayable by most people with hemiparesis [6,8].

To reach people with greater motor limitations, researchers have created therapeutic motion based games that target particular exercises. Huber et al [10] created games in which children with hemiplegia (a more severe form of hemiparesis) open and close their affected hand to scare away butterflies and mosquitoes. Jack et al created a ball catching and piano playing game to help adults with hemiparesis increase their finger strength [11]. Burke et al [3] created target touching games that track the motion of the player's hand using a webcam. Some therapeutic games require special purpose hardware such as virtual reality tracking and display devices [39] or robotic devices [4,31], which may prevent large scale home use. Unfortunately, most of the existing games are designed to address a specific motion and are only playable by a small subset of people with hemiparesis. Authoring tools that decrease the time and expense necessary to create therapeutic games could help broaden access to game-based rehabilitation.

B. Game Authoring Tools for Novices

There is a long history of research into how to make programming accessible to non-experts [15], some of which has focused on game creation. Many of these systems have focused on trying to address mechanical barriers associated with programming. Some systems prevent syntax errors through drag-and-drop based program construction [13,14,25]. Others provide alternative methods for expressing programs including authoring rules [24,29,34], programming by demonstration [12], and form filling [21]. One system, HANDS [28], includes a new programming language based on the way that children describe the solutions to game programming problems. We are not aware of any systems that enable novice programmers to create motion-based games like those described in Section 2.A, for any purpose.

C. Authoring Tools for Therapists

Recently, researchers have created tools designed for use by therapists in a variety of settings. Coyle et al [5] have created a novice programming tool called PlayWrite that is designed to enable mental health professionals to create social simulations for use in mental health settings. To improve the communication between therapists and clients, Dodge et al [7] have explored requirements for an authoring tool to enable therapists to create exercise animations for home viewing.

III. LANGUAGE STUDY METHODS

We conducted a study in which we showed therapists videos depicting functionality likely to be needed in therapeutic video games and asked them to describe that functionality. We presented game functionality using videos to minimize verbal cues that might influence therapists' descriptions.

Video Clips of Game Elements

Based on an analysis of the components that make up a set of games designed for stroke rehabilitation [1], we created seven video clips. Each video clip illustrates a player motion and a corresponding reaction to that motion within the game world. The motions in the video clips are a representative sample of the therapeutic motions that occupational therapists and computer scientists co-designed for use in stroke recovery games. The video clips show examples of both gross and fine motor control tasks. To illustrate the relationship between a player's motion and the effect of that motion in the game world, the videos in this category show synchronized video of the player moving and the game world (see Figure 1). The following video descriptions illustrate a range of potential relationships between a player's motions and the motions or behaviors of objects within the game world:

1. A player controls the position of a baseball mitt in a catching game by moving his hand in space.
2. A player raising her shoulder above a given height causes a frog to "jump" from a road lane to the next.
3. A player rotating his wrist causes a frog to move right and left along a horizontal road.
4. A player picks up a yellow beanbag (representing virtual dynamite) and places it on a virtual weed.
5. A player bending her elbow up and down controls the height of a helicopter flying through a city.
6. A player holding a Wii remote like a joystick points the Wii remote in different directions to control where a fish swims.
7. A player raises and lowers his shoulder to vertically position of a snail to defend against a predator fish.

To direct participants' attention, we used intentionally minimal text and red boxes around relevant objects.

Participants

We recruited ten licensed therapists (eight occupational and two physical therapists; nine female and one male) from the Washington University School of Medicine and The Rehabilitation Institute in St Louis. All had experience with stroke. None had prior programming experience.

Figure 1. A video clip showing a player's motion (above) and a snail moving vertically (below).

Session Procedure

During the sessions, an experimenter showed the game clips to each participant. To prevent ordering effects, we randomized the presentation order for each participant. Each game clip included intentionally minimal textual instructions directing participants to describe how a computer should perform the actions depicted in the clip. We gave participants paper on which to write or draw their answers, however most participants chose to give their answers verbally. If a participant did not fully describe a given clip, the experimenter used a standardized set of prompts to elicit necessary details.

Analysis

We transcribed all of the sessions verbatim, including disfluencies and space-fillers. Then, we performed a two-step analysis that included: 1) developing the rating form and 2) classifying participants' game functionality descriptions.

Developing the Rating Form

The rating form included three types of questions: 1) questions exploring the similarity between how therapists and other novice programming groups describe programming scenarios, 2) questions designed to help formalize interesting properties in therapists' descriptions, and 3) questions focusing on the relationships between player motions and game actions.

To capture the unique properties of how therapists describe programming solutions, three raters independently read participants' descriptions of each video and noted interesting patterns and themes. Based on a discussion of the properties raters noticed, we developed six questions that focused on the relationship between players' motions their corresponding changes within the game world.

Classifying Game Functionality Descriptions

To ensure rating consistency, we used a two-step rating process. First, two raters independently rated each question for two randomly selected participants (20% of responses). The two raters met and discussed the ratings for the two transcripts to ensure a consistent approach. Following this meeting, the two raters independently rated the remainder of the transcripts.

To rate a given game description, each rater first broke the description into individual programming statements (i.e. the shortest statement expressing a programming idea). Then, for a given question on the rating form, the rater classified each programming statement according to the categories suggested for that question. Each rater independently determined how to divide a given transcript into programming statements. We found a high level of agreement between the raters' programming statement divisions and the classifications of those programming statements.

IV. Language Study Results

We present the results of the language study organized by the six properties on which we focused during analysis.

A. *Question: Describing Motion*

Therapists' motion description statements were almost evenly divided into two groups: 1) statements that described motion using common language terms (e.g. move the shoulder up and down) and 2) statements that described motion using therapy-specific terms (e.g. flex and extend the shoulder). However, common language descriptions sometimes failed to disambiguate between two or more therapeutic motions. For example, the therapists used language like move the shoulder up and down to describe both shoulder flexion/extension and shoulder abduction /adduction, for example.

B. *Question: Relating Player and Object Motion*

When describing player motions, 39% of statements adopted a third person perspective, often focusing on the motion of a particular body part: "It's [the baseball glove is] moving the same exact way that his hand is moving." An additional 27% focused purely on the motion of the body parts: "So I guess the helicopter is governed by the height of, or the flexion and extension of the elbow." It is notable that fewer than 10% of statements explicitly referred to either the Wii remote or the webcam. Although the sensors were clearly depicted in the video, therapists focused on players' actions and rarely directly considered the motion sensing devices.

C. *Question: Assigning Sensors to Motions*

Several video clips depicted situations requiring the therapists to describe the relationship between a physical object or sensor (e.g. beanbag or Wii remote) and game objects. Most statements (73%) noted a relationship between a body part

From Player Motion to Game Action		
Describing Motion	***Relating Player and Object Motion***	***Assigning Sensors to Motions***
51% Common language 49% Therapy language	39% Third person - player 27% Body part 24% Second person - player 9% Controller	73% Implicit body part 23% Implicit 4% Explicit
Discrete 1-Dimensional Motion	***Continuous 1-Dimensional Motion***	***Continuous 2-Dimensional Motion***
43% Event-based 34% Constraint-based 21% Negative statement 3% Other	44% Event-based, two statements 24% Event-based, single statement 20% Constraint-based 7% Event-based, incomplete statement 5% Other	32% Event-based, incomplete statement 27% Constraint-based 19% Event-based, controller relationship 10% Explanatory 8% Cardinal directions example 3% Other

Table 1. Attributes of Therapists' Programming Descriptions

(73%) or a physical object (23%) implicitly. For example, "*The frog moves side to side with pronation and supination of the forearm.*" or "*The dynamite moves when the beanbag is picked up.*" Explicit assignment, e.g. "*The dynamite is the yellow beanbag,*" was rarely used.

D. Question: Discrete 1-Dimensional Motion

In the discrete 1-dimensional motion examples, a game action occurred when the player reached a motion threshold (e.g. their shoulder passed a certain angle). Forty-three percent of therapists described these situations using events. For example, "*If you raise your arm, the frog moves forward.*" Therapists also frequently used a constraint such as "*each time*" or "*every time.*" One example is "*Each time he completes full shoulder flexion, ... it's bouncing up into the next zone of traffic.*" Interestingly, some statements included a negative rule such as, "*...it's not moving when he comes back down.*"

While both event and constraint-based forms can be used, the constraint-based construction more frequently included a reference to a threshold such as "*full shoulder flexion*." Because the threshold is a key element in discrete 1-dimensional events, the constraint-based form may better communicate this concept.

E. Question: Continuous 1-Dimensional Motion

When asked to describe continuous 1-dimensional motion (e.g. up and down or left and right), therapists primarily used either two event-based statements or a single statement with two conditions and two responses to describe the motion. For example, "*If you raise up, the snail moves up and as you lower the snail moves down.*"Those who chose to describe the motion using a constraint incorporated language like "*following,*" "*in conjunction with,*" or "*corresponds with.*"

F. Question: Continuous 2-Dimensional Motion

Similar to the 1-dimensional motion cases, the therapists preferred an event-based description for continuous 2-dimensional motion. However, the motion in this case is not as easily broken into specific categories. Rather than giving complete event-based descriptions, 32% of therapists provided an example motion and 8% provided up, down, left, and right examples using an event-based structure. However, these example motions did not fully capture the target behavior. For example, "*Moving your hand up will cause the glove to go up*" specifies only upwards movement. Those who used a constraint-based description used terms like "*following*" and "*mirroring.*" One therapist described this motion as "*The claw is moving according to the motion that the person is doing with his hand.*" Nineteen percent of the time therapists used the controller to describe motion: "*The fish turns as the Wiimote turns.*" Ten percent used an explanatory style such as "*The baseball glove is going in a circular motion because the person is moving his hand in a circular motion.*"

V. Supporting Therapy Games

Based on the results of the language study, we integrated support for therapeutic motions into Looking Glass, a novice programming environment [9]. Looking Glass users construct programs by dragging and dropping graphical tiles that represent method calls and control flow statements. We summarize guidelines for the design of therapeutic programming environments and describe modifications we made to Looking Glass to support each guideline.

A. Guideline: Players and game objects should be actors.

Therapists tended to use both game objects (such as avatars) and players as subjects in programming statements, which is consistent with prior research on how non-programmers describe programming behavior [27]. However, participants in our study primarily used the player as the subject of programming statements, including events, constraints, and situations in which an action earns points. While several novice programming environments support user input [13], these environments focus on the input device rather than the player (e.g. **`when the mouse is clicked on <object>`** or **`when a key is pressed`**)

To support therapists in building games that react to therapeutic motions, we added a player object to the Looking Glass game template worlds. By selecting the player object, the user can see player motions to which the game can respond.

B. Guideline: The sensors should disappear.

In describing the relationships between player motions and game motions, therapists focused almost exclusively on the movement of the player's individual body parts. In essence, the motion sensors (i.e. Wii remotes and webcams) disappeared. While it may seem natural to create a game by adding graphical objects and motion sensors and then programming the game's behavior, this result suggests that the programming tool should enable therapists to focus on body parts rather than sensors.

Accordingly, the player events in Looking Glass focus exclusively on the motions of the player. When authoring a game, a therapist can concentrate exclusively on the player's target motions and the game's responses to those motions. Then, when the game author runs the game for the first time, Looking Glass guides the author through calibrating the necessary input devices for that game's motions.

C. Guideline: Use therapy-centric motion terms.

Therapists' descriptions of player motions and corresponding game actions were roughly equally divided between common language and therapy-specific language. Therapists often target specific muscles or muscle groups during therapy. Because the common language descriptions often lacked the precision necessary to uniquely identify these motions, we elected to use therapy-centric terminology.

D. Guideline: Use a mixture of event-based language and carefully chosen constraints.

Therapists demonstrated a strong tendency to express the relationships between player motions and game responses using event-based language. For discrete motions such as a frog moving up a lane of traffic each time the player raises their arm to a certain angle, event language captures the desired behavior. However, therapists captured continuous responses more accurately using constraint language such as "when the player's hand moves, the claw (a game object) follows."

To support continuous responses, we provided simple constraints that make a selected game object mirror the motions of the player. For example, to enable a player to control the height of a helicopter, a user might add the event **`As Player's Shoulder flexes and extends, helicopter moves up and down.`** Our initial therapy game programming environment included events for each of the joints in the arm: shoulder, elbow, forearm, and wrist.

We also added two constraints for to 2D motions. One enables users to move an object as they might using a joystick (i.e. wrist circumduction): **`As Player's Wrist Circumducts, Melly turns left and right.`** The second constraint enables a game object to mirror the motions of a colored, physical object using a web camera: **`As Player Moves Hand, helicopter follows.`**

Therapists often described the interactions between objects within the game world using events. We added events for collision (**`When Melly collides with Fred do`**) and proximity (**`When Melly gets close to Fred do`**).

E. Guideline: Provide high-level behaviors where possible.

Pane et al [28] noted that non-programmer children and adults tended to leave out necessary details in their natural language solutions to programming problems. We observed the same tendency among non-programmer physical and occupational therapists. However, the deletions within descriptions may suggest opportunities for supplying high-level functionality within the programming interface.

One opportunity to provide high level behaviors arose when therapists described a player earning points. Each game contained a text object to display the player's score. However, when therapists described obtaining points, "*If you catch a baseball, your team gets points,*" they did not explicitly update the text object with the new score. To support this model, we added three actions to the player object: "Player gets points", "Player loses points" and "Player loses all points."

VI. THERAPY GAME DESIGN STUDY METHODS

To further develop the requirements for therapist centered programming environments, we conducted an exploratory user study in which we asked pairs of occupational therapists to design and then build a rehabilitation game for a fictional stroke patient. We took an iterative approach to this study; when we identified usability problems with one pair, we attempted to address those problems the next session. We focused on the following questions:

1. We extracted the example videos in our language study from a set of games built in collaboration with therapists. However, these games may not represent the full design space that therapists envision using. Do the designs therapists create suggest additional functionality needed for therapeutic games?
2. Few therapists have prior experience with computer programming. How can we introduce game creation in a way that enables them to get started quickly?
3. Like most medical professionals, therapists are busy people. To make a custom game based approach viable in a clinical setting requires that therapists are able to quickly and efficiently create games for their patients. Do therapists' designs or programming practices suggest opportunities to decrease programming time?

A. Participants

We recruited 8 graduate students, 7 women and 1 man, working towards Clinical Doctorate degrees in Occupational Therapy. Seven participants rated their skill with computers as "good" and one participant selected "very good." In the week prior to the study, participants spent 7.5 to 40 hours (with an average of 19) using computers. Four participants reported taking computer related classes: introductory computer skills classes and/or statistics classes that used statistical analysis tools. None had prior programming experience.

B. Session Procedures

We conducted our user tests during three hour sessions in which participants: 1) designed a game for a fictional stroke patient and 2) implemented that game using our prototype programming environment. We conducted all user tests in pairs to encourage conversation.

1) The Design Phase

At the beginning of the design phase, we presented users with the following description of a fictional person with stroke:

Heather had a stroke 10 years ago. She can reliably move her shoulder and elbow, but without a lot of precision. When standing she has a wide range of motion, although she cannot fully raise her arm over her head. She has some movement in her hand, but her fingers will often close tightly, sometimes painfully, and involuntarily around objects that she is holding. In response, she prefers not to hold objects in her hand. While Heather does not have full use of her affected arm, she does use it in daily tasks such as carrying or holding an object by pressing it against her side.

Heather is 65 years old. She lives with her husband, but is home alone during the day while he works. They see their daughter's family weekly (daughter, husband, an 8 year old boy and a 10 year old girl). Heather used to really enjoy cooking, but now struggles with food preparation tasks.

We asked our participant pairs to design a game for Heather with two constraints: 1) avoid direct simulations of real world tasks and 2) focus on a single, specific motion.

Occupational therapists are trained to focus on real world tasks that are related to their clients' goals. In a clinical setting, an occupational therapist might ask Heather to practice stirring with a big spoon using her affected arm, for example. In our early pilot sessions, we found that therapists often began by creating a virtual simulation of a real world task. For example, one pair envisioned creating a virtual pot and spoon. Because patients commonly cite the tedium of performing exercises as one of the reasons for failure to complete their recommended home therapy [33], one to one translations of physical exercises into a game-world simulation seem unlikely to tap the full potential of games in stroke recovery. Instead, we encouraged therapists to identify a target motion to and then design a game in a different setting utilizing that motion.

We did not introduce participants to Looking Glass during the design phase. However, we did allow them to browse the gallery of 3D objects available for use in games.

2) Implementation Phase

After the pair agreed on a design for their therapeutic game, we asked them to create it using Looking Glass. We provided a changing set of reference materials including a paper tutorial, a reference guide, and in-software tutorial.

VII. THERAPY GAME DESIGN STUDY RESULTS

All four pairs of therapists successfully designed a therapeutic game and created an initial level of their game. In this section, we summarize the games therapists envisioned and lessons learned from the design and creation process.

A. Therapists Game Visions

Pair 1 designed a game in which the player collects objects floating in a river. They imagined the player collecting and sorting objects from the river into different containers: one for fruit, one for fish, and one for trash. Pair 1 discussed two different motion goals for their game: gross shoulder motion and precise shoulder motion. While developing their design, they discussed designs targeted at both gross and precise motion. They opted to focus on gross shoulder motion.

Pair 2 designed a game in which the player needs to slice through a series of objects with a sword. To successfully slice the objects, the player needs to slice in a given direction with a given speed. Pair 2 designed this game to address gross shoulder motion. One member of the pair had previously played a similar Nintendo Wii game.

Pair 3 began with the goal of asking the player to pick up and move physical objects. After discussing picking berries in a forest and flowers, they eventually settled on a game in which the player has to move obstacles such as a bush or an evil magician out of the path of a game character.

Pair 4 wanted to create a game that encouraged Heather to practice opening and closing her hand. In their game, they mapped the opening and closing of the hand to the horizontal position of a fish in a fish tank. By opening and closing her hand, Heather could move the fish back and forth across the aquarium in order to collect falling food pellets, while avoiding a shark at one end of the aquarium which would eat the player's fish if the player's hand clenched closed too tightly.

B. Lessons Learned from Game Design

1) The Origins of Ideas

In designing their games, therapists drew heavily on their experience in occupational therapy. Occupational therapists typically focus on purposeful actions, actions that help a therapy client achieve a goal drawn from daily life. For a client like Heather, a therapist might design exercises that help her to practice skills related to cooking. In fact, all of our pairs started designing their games by thinking about how they would work with Heather in a clinical practice. One therapist commented "In real life, I'd like to have her do food preparation tasks." Another stated "My first thought is to do a cooking like thing." While one group initially considered focusing on an activity that Heather could do with her grandchildren, ultimately all four pairs elected to work on motions related to cooking.

Once the pairs had identified a specific motion to use within the game, they considered ways to incorporate the target motion into a game. For example, pair 1's game originated in a discussion about ways to use the motion of stirring a pot within a game. The pair imagined the spoon as a magic wand; when the player circled around an object in the water, that object would disappear. Later, they decided to focus on gross shoulder motion. In their revised game, the player picks up sorts them into boxes by category (fruit, fish, and garbage).

Three of the therapists initially found the process of designing a therapeutic game difficult. One participant struggled with the emphasis on one motion: "This is so hard, focusing on one motion". This is a contrast to clinical practice in which therapists encourage clients to perform purposeful, task-directed motions that often incorporate a variety of kinds of motion. Another participant struggled to think about games: "This is the weirdest thing I will ever design for a 65 year old."

2) Customizing Challenge

Participant pairs envisioned customizing game challenges in two main ways 1) using non-uniformly random tasks and 2) increasing the difficulty to match Heather's progress.

In a typical game, interactive game objects are often distributed randomly (but uniformly) in a scene. While our participants described wanting the player to perceive game objects as being random, they wanted to concentrate the appearance of game objects in therapeutically useful locations. For instance, in the fish tank game, the participants wanted Heather to primarily work to more fully open her hand. However, the therapists wanted Heather to have to learn to control her hand motion better when closing too. To accomplish both of these goals, "the majority of the food would fall to the right [open hand], but the fish would tend to gravitate to the left." Sometimes food would also fall on the left, forcing Heather to control her hand motion in this space in order to avoid having the fish eaten by the shark. Based on therapists' discussions and designs, this problem of selecting non-uniformly random positions for targets is important both while setting up a game scene and during game play.

After a discussion about the merits of gross motion versus fine control for Heather, one participant noted "We could tweak this in different ways to accomplish different goals." Over the course of game design, all participants considered how their games could appropriately increase in difficulty to address different goals. Pairs envisioned decreasing the size of objects (to increase the required motion precision), changing the spacing and motion characteristics, and the rate at which new objects appear. All of these changes were tied into the functionality of their programs in non-trivial ways. One important challenge in the design of authoring environments for therapeutic games will be to allow therapists to easily and efficiently specify policies for increasing difficulty.

3) Interactions

We asked our therapist pairs to design their games on paper before beginning implementation in order to capture their visions of the kinds of games that could be valuable in stroke rehabilitation. As anticipated, participants' discussions and designs revealed needs to improve the support for detecting the gestural and fine hand movements.

Two of the four pairs envisioned using simple gestures as part of game play at some point during their design process. One pair considered having players trace a circle around an object in order to make it disappear. Another pair wanted players to slice through objects in different directions (e.g. top to bottom or diagonally from the top left) at different speeds to provide varied neuromuscular training.

In addition to gesture, one pair wanted to create a game that would help Heather to improve her grasping control. They initially wanted the player to repeatedly grasp and release an object. They eventually settled on a game in which they mapped opening and closing the hand to the position of a fish in a fish tank. This suggests a need for precise hand tracking .

C. Lessons Learned from Game Creation

1) Provide a Model of Game Development

In our first two sessions, we provided participants only with documentation describing the functionality of different components within the user interface. While our participants understood the functionality of individual methods and control flow statements within the interface, they struggled to conceptualize the process of creating a game. Participants were unsure about how to accomplish tasks that they knew needed to occur. For example, one participant asked "Is it recognizing that we want the knight to be the player?"

In subsequent sessions, we included a three step process for creating a game: 1) create the opening scene, 2) link the player's motion to game responses and 3) add other responses to situations that occur within the game world. We explained this model through a brief tutorial in which participants constructed a simple game. While all four pairs constructed a simple version of their designed game, pairs 3 and 4 made rapid progress, which resulted in more detailed final games.

2) Avoid Calling Attention to Hardware

In our first two user tests, we verbally introduced the Wii remote and webcam and briefly explained what both devices can detect. While it was not our intent, this introduction encouraged therapists to explicitly focus on input devices. Rather than considering only the motions they wanted the player to perform, therapists worried about which input device to select. This focus on input devices led to additional trouble in trying to determine the mappings between events and input devices. In the words of one participant "I feel like there would be different options for using the balls [web camera] vs. the Wii remotes." In subsequent sessions, we simply placed the Wii remotes and the colored balls for the web camera color tracker on the table prior to the session. When we didn't introduce the input devices, participants concentrated on the motions they wanted from the player. The environment prompted them to set up the appropriate hardware when they were ready to test their game.

D. Improving the Efficiency of Game Creation

At the end of each session, we asked both participants for their reactions and suggestions about the game creation process. One therapist commented "It is time consuming. [Therapists] are going to want to know that the results are there." Therapists are already time constrained. Minimizing the time necessary to create a game is an important challenge for environments designed for therapeutic use.

While the need for efficiency is hardly surprising, observing therapists designing and building therapeutic games provided valuable insight into the kinds of programming supports that can be most effective in reducing the implementation time for therapeutic games. For example, many of the games that the therapists either designed and built or discussed involved a set of objects with similar behavior such as flakes of fish food that disappear when the fish eats them or objects floating in a river that the player needs to collect and place in a box. As she was beginning to set up events for game objects, one participant commented "Oh wow, we have to do each one." For her game, the requirement to set up events for each object greatly increased the amount of work necessary to create the game. While existing novice programming environments such as Scratch [25] and Kodu [24] allow users to copy objects with associated behaviors, several of the games therapists designed incorporated objects with differing appearance but the same behavior. To more intuitively support sharing behaviors across different types of objects, we have added events for lists of objects(e.g. `When` **`<object> collides with any of <list>`**`)`.

VIII. CONCLUSIONS AND FUTURE WORK

The results of our two studies suggest that it is possible to create tools that enable therapists to author games for stroke rehabilitation. All of the pairs in our second study used the Looking Glass tool to generate a version of their proposed games with no programming experience prior to their participation in our study. With additional time, we believe all pairs could have completed a therapeutic game playable by a person with stroke. However, therapists have limited time. To enable widespread clinical use, we will need to further ease the process of creating and customizing the difficulty of stroke games. However, our version of Looking Glass and design guidelines are already enabling therapists to create rehabilitation games for research use. In this work, we focused on therapists' early experiences developing therapeutic games. To identify additional requirements for therapy-centered programming environments, we are currently conducting game lifecycle studies in which therapists' create games using Looking Glass for individuals with stroke and revise them based on those individuals' experiences and progress.

AUTHORS

Caitlin Kelleher is an Assistant Professor of Computer Science and Engineering. Jack Engsberg is an Associate

Professor of Occupational Therapy. Rachel Proffitt Simon Tam, and Matthew May worked on this project as part of their Clinical Doctorate in Occupational Therapy, Masters in Computer Science, and Bachelors in Computer Science degrees, respectively.

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