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Computer Games as Therapy for Persons with Stroke

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Abstract

Background: Stroke affects approximately 800,000 individuals each year, with 65% having residual impairments. Studies have demonstrated that mass practice leads to regaining motor function in affected extremities; however, traditional therapy does not include the repetitions needed for this recovery. Videogames have been shown to be good motivators to complete repetitions. Advances in technology and low-cost hardware bring new opportunities to use computer games during stroke therapy. This study examined the use of the Microsoft (Redmond, WA) Kinect™ and Flexible Action and Articulated Skeleton Toolkit (FAAST) software as a therapy tool to play existing free computer games on the Internet.
Subjects and Methods: Three participants attended a 1-hour session where they played two games with upper extremity movements as game controls. Video was taken for analysis of movement repetitions, and questions were answered about participant history and their perceptions of the games.
Results: Participants remained engaged through both games; regardless of previous computer use all participants successfully played two games. Five minutes of game play averaged 34 repetitions of the affected extremity. The Intrinsic Motivation Inventory showed a high level of satisfaction in two of the three participants.
Conclusions: The Kinect Sensor with the FAAST software has the potential to be an economical tool to be used alongside traditional therapy to increase the number of repetitions completed in a motivating and engaging way for clients.

Introduction

Each year, approximately 800,000 people in the United States experience a new or recurrent stroke.[1] About 65 percent of the survivors in the United States live with minor to severe impairments, such as hemiparesis.[2] Resulting deficits affect a survivor's quality of independent living and ability to perform activities of daily living.[3]

Although spontaneous recovery of movement has been seen, it usually completes by 6 months.[4] Research has shown that intensive mass practice allows for continued modification of neural organization and further movement gains following a stroke.[5,6] However, Lang et al.[7] have shown that patients recovering from a stroke are performing only 10–40 repetitions of a strengthening movement during a therapy session. This equals about 60 minutes twice a week during outpatient therapy.[8] The research suggests that this traditional therapy is just not enough to gain the benefits of neural reorganization to regain motor control of the effected extremities.

Computer games are very engaging and motivational.[2] Through harnessing the motivational characteristics of computer games, interventions can be developed that include a high number of repetitions, while keeping the client engaged and motivated.[2] Previous studies have shown that clients have a positive response to computer game therapy, finding it enjoyable and challenging.[9] In a study by Reinkensmeyer and Housman,[10] computer games were shown to be more interesting for stroke clients as opposed to traditional therapy practices. Furthermore, client motivation has been shown to yield favorable outcomes during rehabilitation therapy.[11]

Computer game therapy also offers a unique opportunity to grade the tasks used to control the games. By grading the movements required, clients are able to gradually gain mastery of the movement, adding challenges as the client's abilities increase. Involving the client in choosing games increases the client-centered care and enhances the client's engagement in the practicing of the movements.[12]

Recent advances as well as decreased costs in technologies, such as the hardware used to control the games, make customization easier than ever. Traditional virtual reality and specialized game systems can be extremely expensive ($10,000–$50,000) and require specially designed games for that system. The costs prohibit home use, requiring clients to travel to facilities equipped to handle such systems.[13] In 2010 Microsoft (Redmond, WA) released the Kinect™ Sensor for

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use with its Xbox® 360 game console. The Kinect Sensor cameras recognize individuals and can pick up movements of each person within its view. At its release the price of $150 is affordable in many settings, including small clinics and at home.[14] In addition, the Flexible Action and Articulated Skeleton Toolkit (FAAST) is freely available online and converts predefined body movements monitored by the Kinect to specified keystrokes or mouse control.[15] The combination of Kinect Sensor hardware and FAAST computer software can be used to play free Internet games using specific trunk or extremity movements customized to the individual client's needs. No information exists about the receptivity of this technology by persons with stroke. The purpose of this study was to examine the use of the Microsoft Kinect as a therapy tool to play existing computer games freely available on the Internet.

Subjects and Methods

A case study series was conducted with video analysis and key informant interviews to investigate the receptivity of stroke survivors to this form of therapy. Feedback was used to develop game controls, identify the potential impact, and inform future study samples.

Participant characterization

Three participants, two women and one man, 49–64 years old, were recruited for the study. All had sustained at least one monohemispheric stroke between 2 and 9 years prior to the study. Each participant had residual deficits in upper extremity function ranging from weakened hand grasp to little movement of the upper extremity. The study was approved by the Washington University in St. Louis School of Medicine Institutional Review Board, and informed written consent was obtained prior to participation.

Participants 1 and 3 had gross motor difficulties. Participant 3 had severely decreased range of motion, requiring a scooter for transportation and assistance for daily tasks. Increased tone caused movements that were unpredictable, especially when excited. Participant 1 had very limited range of motion, further inhibited by decreased botox injection effects. She could ambulate, however, used a wheelchair for distance and required assistance with daily activities because of limitations in her upper extremities. Participant 2 lacked fine motor control of her previously dominant right hand. This prevented her from completing writing tasks, typing, and other coordination movements during her daily activities.

Previous computer experience varied from no regular use to extensive use while at a previously held job. For those who used the computer, typing was limited to hunt and peck because of upper extremity limitations.

Protocol of games

The FAAST software (Fig. 1) uses information from the Kinect Sensor passed through a simple four-command control to provide computer input. The researcher became well acquainted with FAAST controls in order to quickly adapt any game to meet the therapy needs of the participant. The commands consisted of:

1. Action name—What action you wanted the participant to perform, such as left_arm_forwards

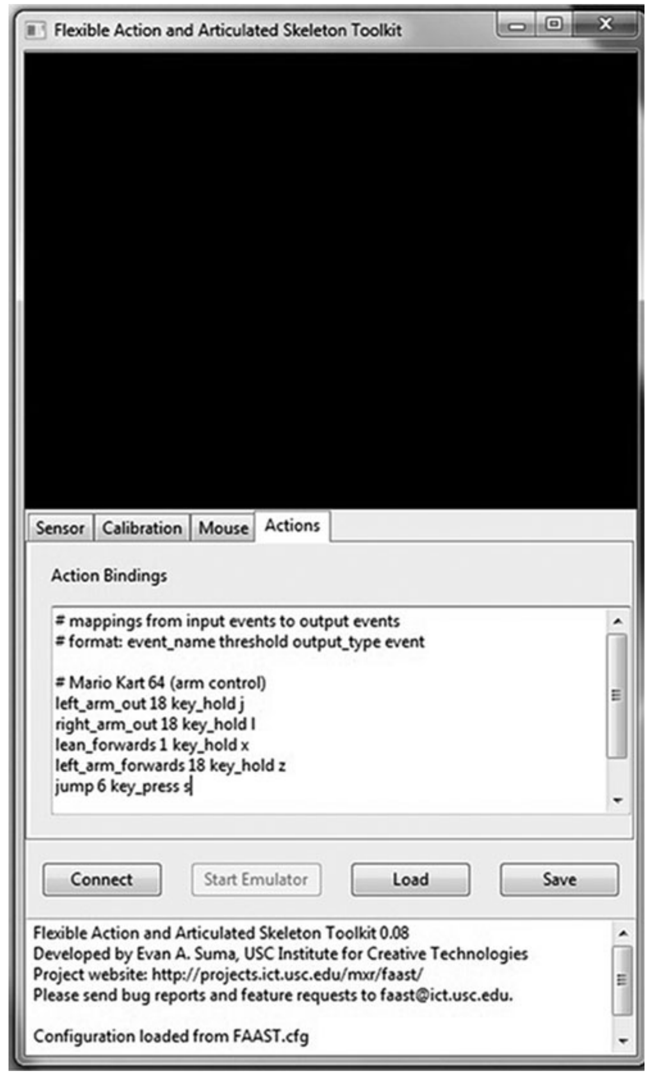

FIG. 1. Screen capture of the control screen of the Flexible Action and Articulated Skeleton Toolkit version used during the study.

2. Action threshold—How far (in inches) the participant needed to move in order to trigger the response
3. Virtual event type—What kind of response is triggered, such as a mouse click or a key press
4. Virtual event name—Which specific key or mouse button, such as left mouse button or key "y"

Games were chosen from those freely available on the Internet as applications (apps) for the Google Chrome Internet browser. The commands of the FAAST software were customized to the individual game play needs such as arrow key presses or mouse control and button clicks. All games required bilateral movements, with the affected side requiring a simpler movement to increase success with game play.

Participants came to the Human Performance Lab for a single visit of approximately 1 hour. Consent forms were read and signed, and background questions were answered in regard to home life, residual effects of the stroke, and previous experience with computers and computer games. Participant sessions were videotaped to allow counting of

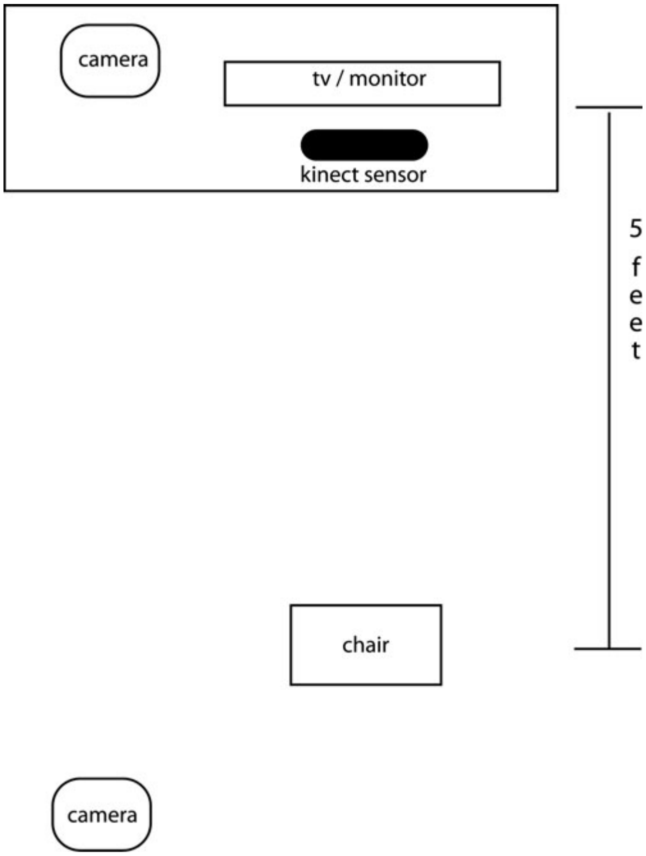

FIG. 2. Room setup used during study participant sessions.

movements, and comments made during game play were transcribed.

Before participants arrived the room was set up with two cameras and a chair situated approximately 5 feet in front of a large computer monitor and the Microsoft Kinect Sensor (Fig. 2). A set of simple controls was brought up in FAAST, as well as a well-known game such as solitaire, for control demonstration.

Previous experience playing computer games was discussed, and a game with which the participant was familiar was set up for therapeutic play on the computer. Controls were customized to allow the participant to play the games within his or her abilities. After the subject played a known game and became comfortable with the Kinect and FAAST for controls, a novel game was introduced to the participant.

"Solitaire" is the traditional card game with stacking of cards with the end goal to get all cards to the piles by suit from ace to king. "Mahjong" is a tile matching game that requires finding open paired tiles to remove them from the board, with the end goal to remove all tiles. "Solitaire" and "Mahjong" are both controlled with mouse movements and left mouse button clicks. Mouse movements were controlled with the nonaffected side, the shoulder was flexed, and movement of the hand moved the mouse on the screen. Shoulder flexion or abduction with the affected arm was used to click or hold the mouse button.

"Pinball" was a virtual version of the arcade game using flippers to keep a metal ball from falling out of the playable area. Flippers were controlled with shoulder flexion of the upper extremity of the corresponding side of the paddle, utilizing both affected and nonaffected extremities. To start the game, or "shoot" the ball in the playing area, the player would abduct the nonaffected shoulder.

"Entanglement" uses hexagonal pieces on a game board; each piece has curving lines through it, and the aim is to create the longest path of a continuous line from the start before running into a wall. Game play required shoulder abduction to the affected side in order to rotate the game piece with shoulder flexion of the nonaffected side to "set" the position. Additional controls such as restarting a game once it ended were controlled with the mouse by the therapist to make transitions faster.

"Angry Birds" has the goal of "shooting" birds out of a sling shot at structures on the other side of the screen in order to "kill" the pigs protected within the structure. Controls included mouse movements as well as mouse button holds and click. Mouse movement was again controlled by the hand on the nonaffected side, mouse clicks required shoulder flexion of the affected side, and button holds were done with shoulder abduction of the affected side.

A summary of game controls can be found in Table 1.

All games were found free online and played within the Google Chrome Internet browser. Commonly known game controls were set up before the participants arrived in the lab ready to be adjusted based on client abilities. The "Pinball" game interest was not known before the meeting; however, less than 3 minutes elapsed from finding the game to the participant first testing the controls. Fast controls are spelled out on a chart that anyone with basic computer knowledge can follow to set up the four-part command lines.

Outcome measures

After playing two games participants were then given an adaptation of the Activity Perception Questionnaire of the Intrinsic Motivation Inventory (IMI). Questions were selected from the validated and reliable IMI in order to fit the needs of this particular study. Participants were also engaged in a key-informant interview to get their opinions of the intervention

Table 1. Extremity Use During Game Play

	Participant 1		*Participant 2*		*Participant 3*	
	Known	*Novel*	*Known*	*Novel*	*Known*	*Novel*
Affected	Shoulder abduction and flexion	Shoulder abduction	Shoulder flexion	Shoulder abduction and flexion	Shoulder abduction and flexion	Shoulder flexion
Nonaffected	Mouse control	Shoulder flexion	Mouse control	Mouse control	Shoulder flexion	Shoulder abduction

Table 2. Individual Scores of the Intrinsic Motivation Inventory

	Participant 1	*Participant 2*	*Participant 3*
Score	96	73	89
Total possible score	98	98	98

presented and determine if after a limited introduction they believed this intervention would be useful therapy.

Results

Participants played a known game for an average of 16 minutes; games included "Solitaire," "Mahjong," and "Pinball" based on client interest. Clients were then introduced to a novel game: either "Entanglement" or "Angry Birds." Novel games were played for an average of 12 minutes.

Throughout game play all three participants stayed engaged in the activities and commented that they enjoyed the novel way of playing games. Participant 1 owned a SaeboFlex (Saebo, Inc., Charlotte, NC) and occasionally used it as home therapy; she commented, "I would rather come home and play games like these instead of pick up balls with the Saebo." Participant 3 was laughing at himself frequently, especially while playing "Pinball": "It would be fun to play this with my grandkids, and they would love to see me looking like a fool!"

Five-minute sections of video were analyzed for repetition of movements. The participants averaged 34 repetitions of their affected side during each 5-minute interval. They had an average of 45 repetitions with their nonaffected side, or 4 minutes with their shoulder flexed controlling the mouse.

The scores of the IMI were varied, with two participants rating their perception of the activity as very highly and one as positively but not as highly (Table 2).

Discussion

The purpose of this study was to examine the receptivity of persons with stroke to the use of the Microsoft Kinect Sensor and FAAST software as a tool to increase repetitions in order to regain movement by playing existing computer games freely available on the Internet. A small sample was recruited to test the client reactions and ability to play games post-stroke.

Previous studies[2] have mentioned the motivating characteristics of videogame-based therapy. This study supported those findings and further demonstrated the games to be motivating when they were of the participant's choosing. Fast and easy customization of the game controls by a therapist allowed for a client-centered treatment that increased the participant's engagement in the activity.[12] The FAAST software is quick and easy to learn, allowing even those with limited computer knowledge to quickly learn the four-part commands to customize the software to individual client needs.

Extrapolating the repetition counts from 5 minutes of game play out to a typical session of 45 minutes equals approximately 300 repetitions of the effected upper extremity. This equals the repetitions that animal studies suggest are needed to regain motor control following stroke.[7]

The IMI results were mixed, with Participants 1 and 3 scoring very high and Participant 2 scoring lower. It is hypothesized that this was due to Participant 2 having only fine motor limitations. This participant scored lower on questions such as "I believe this activity could have some benefit for me" or "I think this activity is important for my improvement." As the movements that are customizable within FAAST are gross motor movements, she did not see the benefit where she is hoping to make further gains.

This study adds to the body of knowledge, providing evidence for further studies to examine the efficacy of the protocol. It also adds to the evidence showing the motivational factors of the videogames and that it is possible to play known games in a novel and therapeutic way.

Clinically, this study shows feasibility of the use of the Kinect Sensor with free Internet games within a clinical setting. The low cost of the hardware and the use of free games make the setup affordable to clinics and hospitals of all sizes and even for clients to use in their home for additional practice. The wide range of games available on the Internet and the flexibility of the FAAST software make the system customizable to the interests of many different clients.

Limitations of the study include the small sample size. The participants were only at the lab for 1 hour total, which limited the amount of time they were able to play the games; also, the movements used during game play were gross motor and did not challenge those with fine motor difficulties. The gross motor movements practiced were not specifically functional beyond game play; however, they would be necessary to provide the support needed to work on functional activities. Finally, only one visit does not allow testing of the efficacy as a treatment.

Future work would include an intervention study to test the effectiveness of the use of the protocol to improve function of stroke patients. Testing should include pre-, mid-, and post-testing using a variety of functional tasks and tests. Use of the video motion capture system can also add more precise information about gains in range of motion using this intervention.

In the future this protocol could be used not only in a clinic but also in the home, to expand the amount of practice time and repetitions to gain further benefits. Changes to the game controls can be made by the therapist during clinic visits, sending the new controls home on a flash drive. Another possible application would be the use in telerehabilitation, which would allow the therapist to observe game play and adjust controls remotely for clients unable to make it the clinic on a regular basis.

Summary

Using the Microsoft Kinect Sensor to play free Internet videogames can be a motivating addition to traditional therapy to increase movement repetitions to take advantage of neural plasticity. Future work should focus on the efficacy of the current protocol and on advancing the movements of play to be more functional beyond game play.

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Author Disclosure Statement

No competing financial interests exist.

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