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A Rehabilitation First—Tournament Between Teams of Nursing Home Residents with Chronic Stroke

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Abstract

Purpose: This study describes the BrightArm™ Duo virtual reality system (Bright Cloud International Corp., Highland Park, NJ) and determines its clinical benefit for maintenance of upper extremity function in nursing home residents who are chronic poststroke.
Materials and Methods: Participants sat at a low-friction robotic table with tilt and lift capability and interacted with serious games through computerized supports that measured forearm movement and grasp. The rehabilitation simulations were designed to improve arm and hand function, increase range of motion, and improve emotional well-being and cognition (attention, memory, and executive functioning). After 8 weeks of initial intensive therapy, there were three booster periods at 8-week intervals, each consisting of four sessions over 2 weeks. The last booster was a tournament competition, where pairs of residents played games collaboratively from remote nursing homes. Participants were evaluated before and after each booster period using standardized clinical measures.
Results: Range of motion improved for 18 out of 23 upper extremity movement variables ($P=0.01$) between pre- and post-tournament assessment, and the residents self-reported that they enjoyed playing with a partner (score of 4.7 out of 5.0). Participants were able to reduce game completion time through cooperative play (teamwork), and the times improved with successive sessions of the tournament. Affected hand and arm function and depression levels were maintained (no decline) after the tournament.
Conclusions: A rehabilitation tournament using virtual reality between teams of nursing home residents chronic poststroke is the first of its kind in clinical practice. This study demonstrates its effectiveness in improving range of motion of the upper extremity while engaging residents in the maintenance program at their nursing home.

Introduction

The mortality rate poststroke keeps declining,[1] resulting in 7 million Americans who are stroke survivors.[2] Of these, 40 percent are left with moderate to severe disability,[3] and only 5 percent recover their upper extremity (UE) function fully. Societal costs associated with stroke could more than double to $240 billion by 2030[4] due to the aging of America.

According to statistics published by the American Health Care Association, there are about 16,000 skilled nursing facilities (SNFs) in the United States, housing close to 1.4 million long-term residents.[5] Statistics show that only small percentages of these residents are independent in activities of daily living, and 80 percent are wheelchair users and dependent on the SNF staff for their meal preparation, personal hygiene, and medication administration.[6,7] Even those that are ambulatory and have no cognitive impairments have been found to be highly sedentary when their activity pattern of sitting/lying, standing, and stepping was measured with a monitor.[8] This reduced quality of life, coupled with lack of socializing with their loved ones, results in depression, which affects one in every two SNF residents.[9,10]

The quality of life is even more diminished for the 15 percent of stroke survivors who become SNF residents.[11] Stroke impairs arm and hand function, resulting in reduced range of movement and weakness or in complete loss of movement in the affected arm. Therefore these SNF residents rely on the use of one arm only when attempting to perform activities of daily living.[12] Stroke affects not only

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their arm function, but also their ability to focus, their memory, and decision-making.[13]

Health maintenance programs provided by SNFs are aimed at preserving arm function, flexibility, balance, and slowing down age-related cognitive decline. However, studies have not shown significant benefit to depression and self-esteem from participation in an SNF health maintenance program.[14] Furthermore, such programs are not rehabilitation interventions, lacking in the number of task-oriented repetitions and strength training, as well as the appropriate length of training, cognitive training, and emotional uplifting that is needed, especially by those who survived a stroke.

A virtual reality study of SNF residents found that the experimental group showed significant cognitive improvements, whereas controls showed progressive decline.[15] Many elderly stroke survivors are also depressed.[16,17] Side effects of depression medication (such as digestive problems, restlessness, headaches, or insomnia[18]) may be avoided through nonpharmacologic approaches such as virtual reality custom games.

Computer games have been introduced in SNFs to provide leisure therapy and some degree of physical exercise.[19] For example, the Nintendo (Kyoto, Japan) Wii™ was used to help prevent falls[20] and improve physical activity and quality of life in older adults.[21] However, using off-the-shelf game consoles is difficult for stroke survivors with spastic arms. Although the combined benefits of exercise and socializing have been studied,[22] there are no clinical studies to date that have explored team competitions in a well-controlled clinical trial. The research study presented here is the first to include a tournament between SNFs. The rehabilitation tournament was conducted at the Roosevelt Care Center (RCC) and JFK Hartwyck at Edison Estates (HEE), two SNFs located 8 miles apart, in Edison, NJ.

Materials and Methods

Tournament configuration

The tournament used two BrightArm™ Duo systems (Bright Cloud International Corp., Highland Park, NJ) (FIG. 1) remotely located at RCC and HEE. Each system consisted of a low-friction robotic rehabilitation table, sensorized forearm supports used to track arm movement and grasp strength, a laptop computer used to render a library of adaptable therapeutic games, and an output display.[23,24] Each teammate controlled one of the two avatars in the game, using his or her most affected arm. An arm-specific mapping between the real and the virtual spaces enabled both arm avatars to have normal function in virtual reality.

Multiplayer games were supported using the synchronization scheme illustrated in FIG. 2. Players 1 (Host) and 2 (Client) interacted with their respective BrightArm Duo system through the interface that tracked arm position and grasp. The laptop of each system transmitted the locally captured player information to the remote system laptop over the Internet. The BrightArm systems accessed the Internet through a DSL modem at RCC and a wireless Mifi Jetpack® (Verizon, New York, NY) at HEE. The Host Laptop used the hand position/grasp strength of Players 1 and 2 to determine interaction with game objects and displayed updated

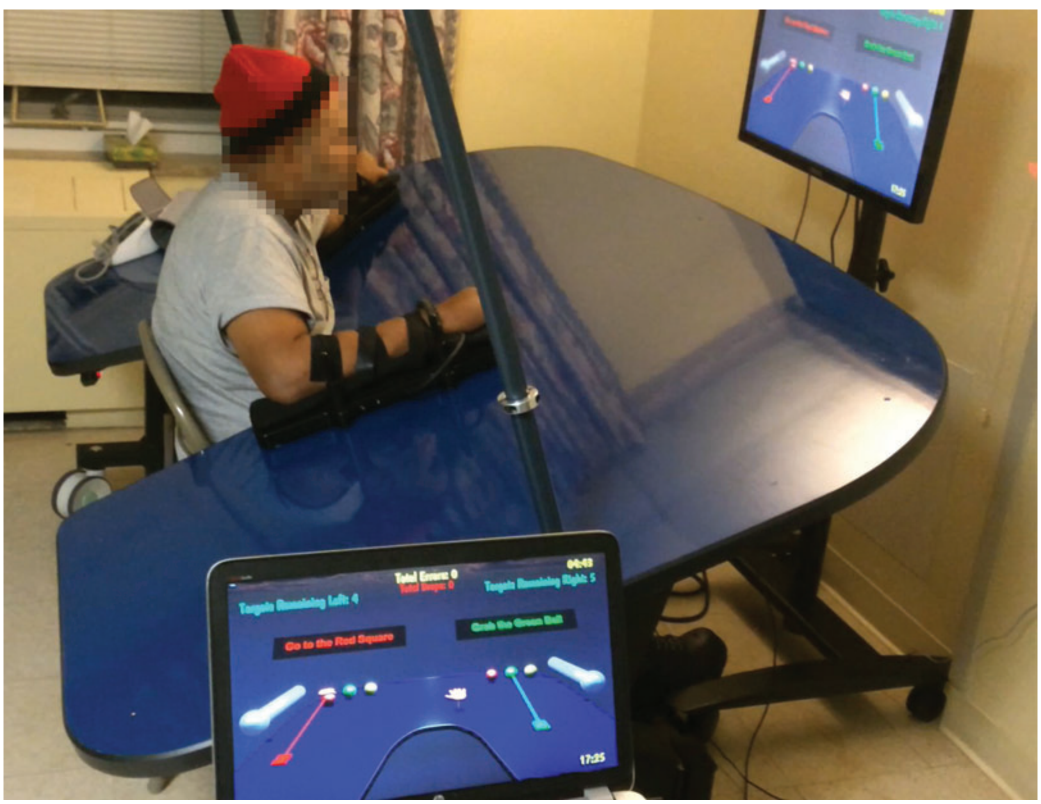

FIG. 1. BrightArm Duo system with a participant training at the ‘‘Pick & Place’’ game when the work surface is tilted upward.[18] ©Bright Cloud International Corp. Reprinted by permission. (Color images available at www.liebertonline.com/g4h)

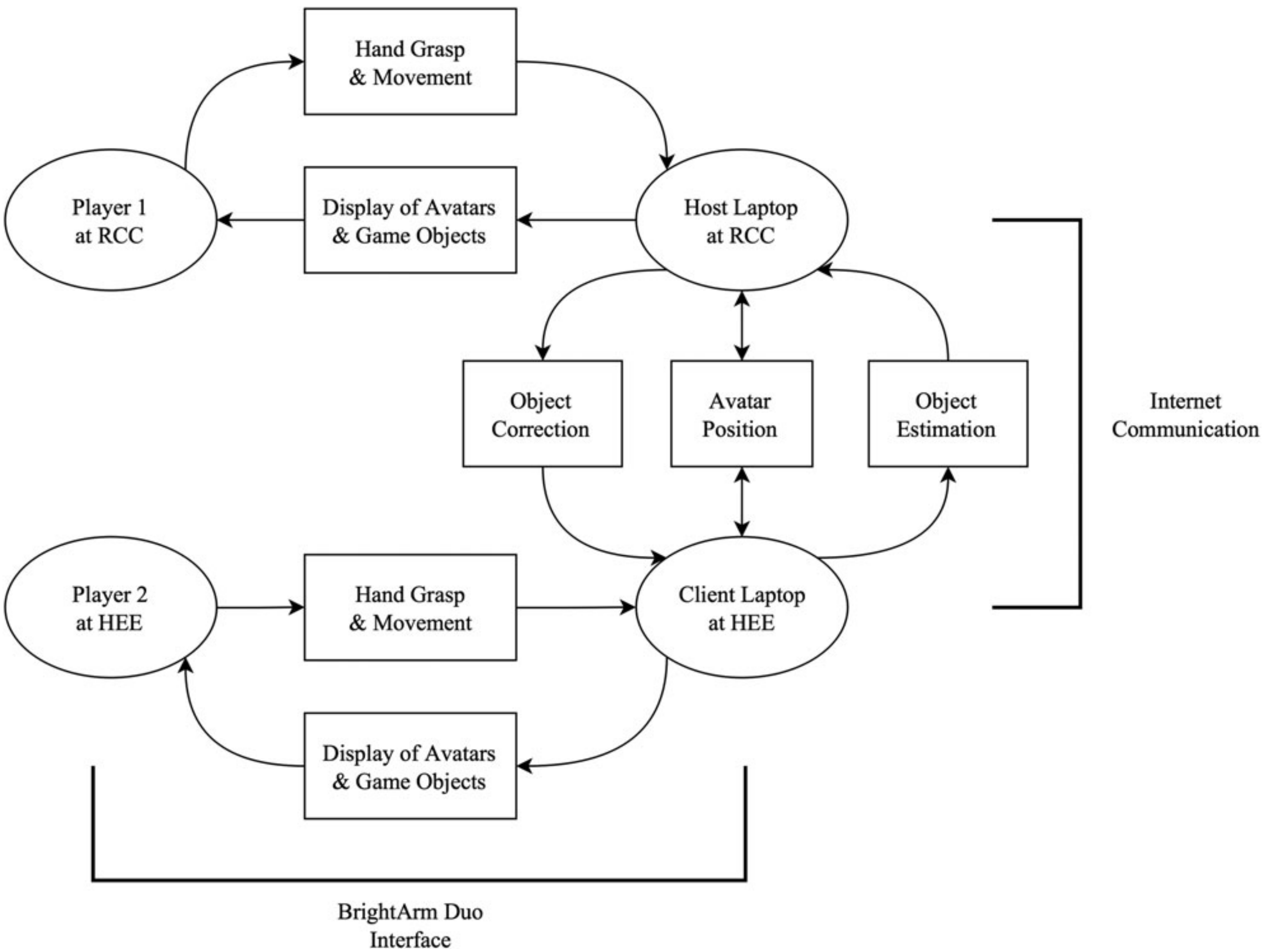

FIG. 2. Synchronization scheme between laptops of two BrightArm Duo systems remotely located at two skilled nursing facilities (Roosevelt Care Center [RCC] and JFK Hartwyck at Edison Estates [HEE]) to support tournament team play. ©Bright Cloud International Corp. Reprinted by permission.

game objects and avatars to Player 1. The Client Laptop also used the hand/position of Players 1 and 2 to estimate interaction with game objects and then communicated interaction with the Host Laptop, which in turn communicated a correction back to the Client Laptop. The Client Laptop displayed to Player 2 the avatars and corrected position of game objects based on the correction it received from the Host Laptop. Both the Client and Host Laptops captured performance data for both Player 1 and Player 2, for postsession evaluation.

Study design

The study described here was a component of a longitudinal controlled study of the BrightArm Duo system use in the maintenance of SNF residents who were in the chronic phase poststroke. This longitudinal study consisted of the initial 8-week intensive training (described by House et al.[23]), followed by two booster periods and a tournament, which are discussed here. Each booster lasted 2 weeks (with two sessions per week), and boosters were interspaced by 8 weeks of no BrightArm therapy. Subjects played 45–50 minutes independently during the first two booster periods. This was shortened to 30 minutes per session during the tournament to eliminate need for rest breaks. Session training difficulty was set at the maximum table tilt of 20° upward to increased perceived gravity loading on the UEs.

Before and after the booster period or tournament, subjects underwent occupational therapy and cognitive/emotive evaluations.

The unimanual UE function was assessed with the Fugl–Meyer Assessment (FMA),[25] a standardized measure with a maximum score of 66. It measures shoulder movement synergies, volotional movements of the wrist, finger flexion, and ability to grasp. An FMA score below 19 (±2) points is indicative of severe impairment.[26]

Bimanual UE function was evaluated using the Chedoke Arm and Hand Activity Inventory (CAHAI-9) test.[27] This evaluation rates the degree of independence in performing nine bimanual activities of daily living (opening a jar of coffee, calling 911, drawing a line with a ruler, pouring a glass of water, wringing out a washcloth, doing up five buttons, drying the back with a towel, putting toothpaste on a toothbrush, and cutting medium-resistance putty) and has a maximum score of 81 signifying complete independence.

Arm range of motion was measured using standard mechanical goniometers.

Cognitive evaluations were completed by a neuropsychologist consultant postbooster periods and post-tournament.

Standardized neuropsychological measures used were the Beck Depression Inventory, Revised[28] and the Trail Making Test (TMT).[29] The Beck Depression Inventory is a standardized test for depresson severity with a scale of 0–13 points indicating minimal depression and scores above 29 indicating severe depression. The TMT is a timed test in which the subject has to connect numbers in ascending order (Trails A) or a sequence of alternating numbers and letters, also in ascending order (Trails B). The first portion of the test measures the cognitive area of attention, whereas the second part measures executive functions. The evaluating clinicians were blinded to the therapy methodology and scope.

Game protocol

During the booster sessions, each subject trained independently, controlling one game avatar with each hand/arm. The protocol composed up to nine different games,[30] with 68 percent of the exercise time attributed to the games ‘‘Breakout 3D,’’ ‘‘Card Island,’’ and ‘‘Pick & Place.’’ FIG. 3a shows the ‘‘Breakout 3D’’ game scene, where two paddle avatars were used to bounce a virtual ball toward an array of crates. Subjects controlled the left and right paddle avatars using their left and right arms/hands. ‘‘Card Island’’ is our version of the known short-term spatial and visual memory game (FIG. 3b), but placed on a tropical island. Subjects used left and right hand avatars to flip cards in order to make matches. ‘‘Pick & Place’’ is a game that involves grasping and moving virtual balls of a fixed sized (FIG. 1). A barrier in the middle that hand avatars could not cross insured both hands were used to clear the board in both ‘‘Pick & Place’’ and ‘‘Card Island.’’

The tournament protocol was similarly balanced so 67 percent of the exercise time was composed of the games ‘‘Breakout 3D,’’ ‘‘Card Island,’’ and ‘‘Pick & Place.’’ The tournament session included multiplayer versions of these games, with one avatar guided by the subject at HEE and the other avatar by the remote teammate at RCC. For ‘‘Breakout 3D,’’ each teammate controlled one of the paddles and would take turns hitting the ball. The subjects coordinated card selections using the left (HEE) and right (RCC) hand avatars to make matches in ‘‘Card Island.’’ Subjects largely played ‘‘Pick & Place’’ in parallel, with the HEE participant completing the left side and the RCC participant completing the right side of the scene.

The remainder of the tournament session included multiplayer versions of ‘‘Musical Drums’’ (FIG. 3c) and ‘‘Kites’’ (FIG. 3d), originally developed for the BrightBrainer™ system (Bright Cloud International Corp.).[30] ‘‘Musical Drums’’ is a game where participants strike a series of notes that drift across one of four drums. Each teammate controlled one drumstick, with a barrier in the middle to insure each note can be reached by only one participant. In ‘‘Kites,’’ participants fly kite avatars through moving rings with a matching color. Cooperation between teammates was essential as the kite with the wrong color could block the right correct kite from passing through a ring.

Tournament teams

Table 1 summarizes the characteristics of the seven experimental subjects, including the affected arm, months poststroke, UE motor function, and cognition metrics. There

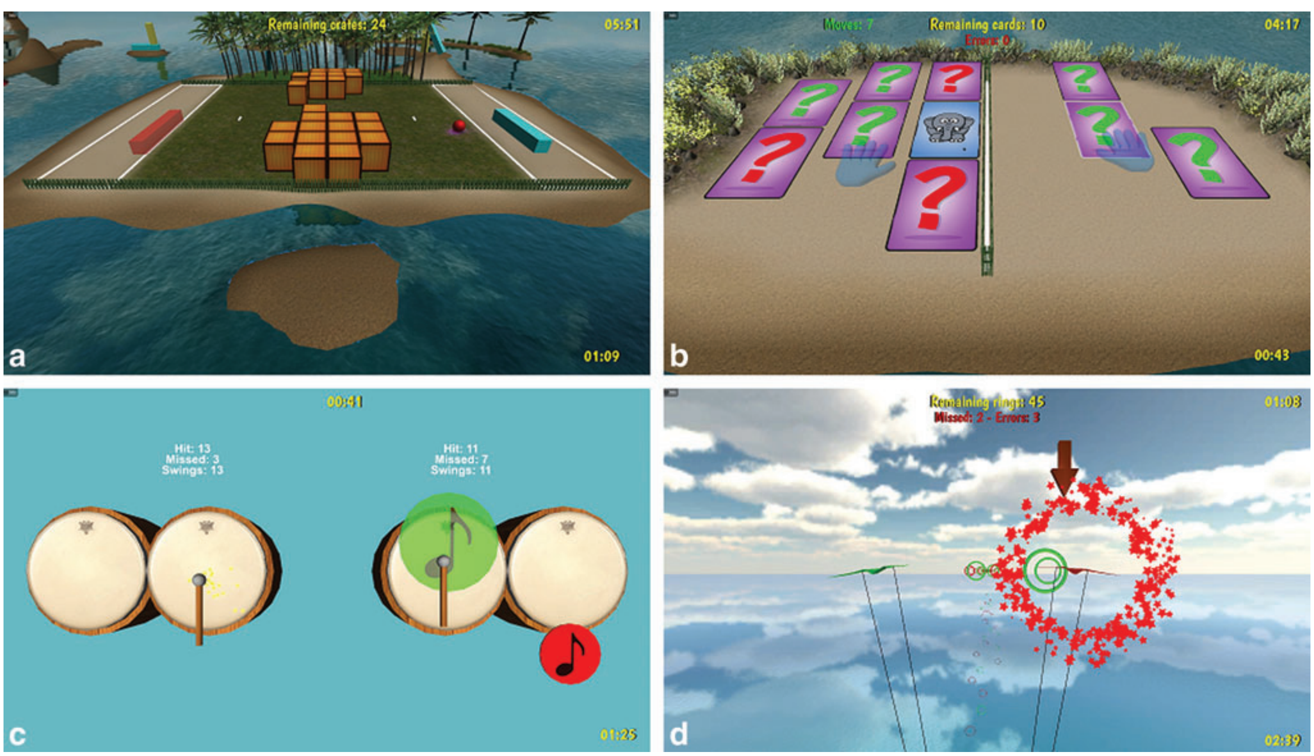

FIG. 3. Screen image of the games **(a)** ‘‘Breakout 3D,’’ **(b)** ‘‘Card Island,’’ **(c)** ‘‘Musical Drums,’’ and **(d)** ‘‘Kites.’’ ©Bright Cloud International Corp. Reprinted by permission. (Color images available at www.liebertonline.com/g4h)

TABLE 1. PARTICIPANT CHARACTERISTICS AND INITIAL RECRUITING ASSESSMENTS FOR TOURNAMENT TEAMS OF CHRONIC STROKE RESIDENTS OF TWO SKILLED NURSING FACILITIES

	Tournament ID, system location						
	Team 1		*Team 2*		*Team 3*		*Team 4*
	RCC	*HEE*	*RCC*	*HEE*	*RCC*	*HEE*	*HEE*
Gender	Female	Male	Male	Female	Male	Male	Male
Age (years)	69	50	72	87	85	61	62
Months since stroke	162	36	64	126	116	93	89
Affected side	Left	Right	Left	Left	Left	Right	Right
Upper extremity function and cognitive assessment							
FMA	5	24	4	30	6	14	26
CAHAI	9	18	9	15	10	9	13
TMT-A (seconds)[a]	>120	31	74	>120	>120	51	>120
TMT-B (seconds)[a]	>300	130	167	>300	>300	105	>300

[a]Indicates a lower score (time) is better for selected metrics.
CAHAI, Chedoke Arm and Hand Activity Inventory; FMA, Fugl–Meyer Assessment; HEE, JFK Hartwyck at Edison Estates; RCC, Roosevelt Care Center; TMT, Trail Making Test.

were two females and five males between the ages of 50 to 87 years (mean [standard devation] = 69.7 [13.3] years). Ethnically there was one African American, one Spanish, and five white participants. The inclusion and exclusion criteria for the study are detailed by House et al.[23]

For the tournament, the creation of competitive teams was largely driven by geography. Subjects at RCC who had low UE motor function based on their FMA scores were matched with subjects from HEE who had higher FMA scores. Subjects having longer times (worse cognition) for the TMTs (TMT-A and TMT-B) were paired with subjects having shorter times (better cognition). Team 4 was composed of a study researcher at RCC playing with a subject with lower cognitive function from HEE, so to have an even number of teammates.

All subjects were self-consented using a written form approved by Western and JFK Health System Institutional Review Boards (independent boards overseeing research involving human subjects), which reviewed and approved the protocol for this study in accordance with federal guidelines.

Results

Tournament performance

Team rankings were disclosed to participants at the beginning of tournament sessions as a motivational tool. Given game difficulty was uniform for all teams, a reasonable performance indicator was the average completion times normalized by the completion rates, such as fraction of notes hit in ‘‘Musical Drums’’ or rings captured in ‘‘Kites.’’ Table 2 illustrates the normalized completion time in minutes for the five games in the tournament competition. The competition for first place was between Teams 1 and 3 across the five games, with Team 3 achieving best overall performance. The third place was split between Teams 2 and 4, with Team 4 coming out on top. Lower performance by Teams 2 and 4 relative to Teams 1 and 3 may be tied to the cognitive level of the HEE team member with moderate impairment in UE function.

As teams were composed of both lower and higher functioning individuals (based on cognition) who share the same completion time, Table 2 independently lists the correlation of game completion times with the RCC participants’ and

TABLE 2. AVERAGE GAME COMPLETION TIME AND CORRESPONDING RANKINGS BETWEEN TOURNAMENT TEAMS OF CHRONIC STROKE RESIDENTS ACROSS TWO SKILLED NURSING FACILITIES

	Completion time (minutes) results for team ranking				*TMT-B correlations*			
					RCC		*HEE*	
Game	*Team 1 (2nd)*	*Team 2 (4th)*	*Team 3 (1st)*	*Team 4 (3rd)*	r	P	r	P
Average time	2.0	2.8	2.0	2.7	–0.99	0.0001[a]	0.99	0.0001[a]
‘‘Break Out’’	2.9	5.1	3.6	3.8	–0.96	0.048[a]	0.74	0.19
‘‘Card Island’’	2.0	2.7	1.6	2.7	–0.92	0.10	0.95	0.01[a]
‘‘Pick & Place’’	1.5	2.2	1.5	2.9	–0.99	0.02[a]	0.90	0.04[a]
‘‘Musical Drums’’	1.7	1.8	1.3	1.8	–0.79	0.29	0.82	0.11
‘‘Kites’’	2.1	2.3	2.1	2.5	–0.99	0.002[a]	0.87	0.07

Also shown is the correlation (r) between completion time and Trail Making Test-B (TMT-B) for Roosevelt Care Center (RCC) and JFK Hartwyck at Edison Estates (HEE) team members.
[a]Indicates statistical significance ($P < 0.05$).

HEE participants' TMT-B results. The correlations for RCC team members were strong and negative across games, with a statistically significant correlation for the overall completion time ($r = -0.99$ and $P = 0.0001$). The correlations for HEE team members were strong and positive across games, with a statistically significant correlation for the overall competition time ($r = 0.99$, $P = 0.0001$). This is an indication that the cognition of the HEE team member may be driving the overall completion time for the teams.

Table 3 lists the average timing (point in time) when active arm movements occurred as a percentage of the total game duration. A 50 percent value is expected when the arm motion is evenly distributed over an entire game. Lower/higher percentages imply the timing of when the arm activity occurred was biased toward the beginning/end of the game.

For ''Breakout 3D,'' the average timings of arm repetitions for study subjects from RCC (23–30 percent) were much lower than for those from HEE (44–53 percent), and the correlation with FMA assessments was statistically significant ($r = 0.88$, $P = 0.004$). This is an indication that higher functioning individuals (physically) were better able to sustain activity in ''Breakout 3D.''

The largest timing (65 percent) is for the HEE participant from Team 3 when playing ''Card Island,'' which aligns with observations that the HEE teammate monopolized the card matches at the start of the game.

For ''Pick & Place,'' there is a statistically significant correlation between the Team 3 subject's mean timing and TMT-A results ($r = 0.88$, $P = 0.004$), also indicating better performance on ''Pick & Place'' with higher cognition. The average timings were lower for higher functioning team members (31–43 percent) than for the lower functioning ones (45–47 percent), an indication that the team member with lower cognitive function was driving team performance.

For ''Musical Drums,'' the target notes for HEE subjects appeared later than for RCC participants, which is reflected in larger percentage timings for the HEE participants and negative correlations with TMT-A and TMT-B values, indicating lower average timings with higher cognition.

For ''Kites,'' the correlation ($r = 0.76$) between average timings and CAHAI-9 was statistically significant ($P = 0.04$). This significant result supports the idea that the bimanual ability of teams is important even though individual interaction by team members was unimanual.

Booster comparisons

The games ''Breakout 3D,'' ''Card Island,'' and ''Pick & Place'' accounted for two-thirds of the exercise time during the booster (B1.1–B2.4) and tournament (T1–T4) sessions. FIG. 4 shows the average completion time for these games plotted against session number, where shorter time is better. The regression analysis for ''Breakout 3D'' yields a nearly flat slope (–0.02 minutes; $P = 0.91$), suggesting that cooperative play during the tournament had minimal beneficial impact in improving this game performance. The linear fit for ''Card Island'' had a downward slope of –0.7 minutes between B1.1 and T4 ($P = 0.08$), suggesting cooperative play was somewhat beneficial to the matching time. ''Pick & Place'' has the clearest downward slope of –1.4 minutes, a statistically significant result ($P = 0.02$). Not only were subjects able to reduce time through parallel play, but the times improved with successive sessions of the tournament.

UE functional gains

During the 30-minute tournament sessions, subjects averaged a total of 355 active affected arm repetitions and 235 affected hand grasps per session. The booster sessions were longer (47 minutes), and the results for both arms were 1030 active arm repetitions and 712 hand grasps per session. Eighteen of 23 range-of-motion metrics improved during the tournament (T2 to T3), a statistically significant result ($P = 0.01$). This is an indication that BrightArm training systematically improved active arm range of motion for the study group. The shoulder extension of the affected arm improved 12.1° ($P = 0.03$) during the boosters, which is above the minimal clinically important difference of 8.3° for the shoulder. For the affected elbow, the mean pronation

Table 3. Average Timing (Point in Time) When Active Arm Movements Occurred as a Percentage of Total Game Duration

	''Break Out''		*''Card Island''*		*''Pick & Place''*		*''Drums''*		*''Kites''*	
Percentages for	*RCC*	*HEE*	*RCC*	*HEE*	*RCC*	*HEE*	*RCC*	*HEE*	*RCC*	*HEE*
Team 1	23%	44%	46%	56%	47%	43%	38%	53%	43%	45%
Team 2	30%	49%	52%	49%	43%	45%	40%	48%	35%	49%
Team 3	25%	53%	65%	43%	45%	31%	42%	53%	43%	46%
Team 4		53%		51%		52%		42%		43%
Correlations for	r	P	r	P	r	P	r	P	r	P
FMA	0.88	0.004[a]	–0.15	0.75	0.07	0.88	0.64	0.10	0.64	0.11
CAHAI	0.59	0.15	0.05	0.92	–0.01	0.99	0.67	0.08	0.76	0.04[a]
TMT-A	–0.45	0.29	0.33	0.47	0.88	0.004[a]	–0.77	0.03[a]	–0.20	0.67
TMT-B	–0.41	0.35	0.20	0.67	0.77	0.03[a]	–0.80	0.02[a]	–0.16	0.73

Also shown is the correlation (*r*) between these percentages and results on arm functional assessments (Fugl–Meyer Assessment [FMA] and Chedoke Arm and Hand Activity Inventory [CAHAI]) and neuropsychological tests (Trail Making Test [TMT]-A and TMT-B).

[a]Indicates statistical significance ($P < 0.05$).

HEE, JFK Hartwyck at Edison Estates; RCC, Roosevelt Care Center.

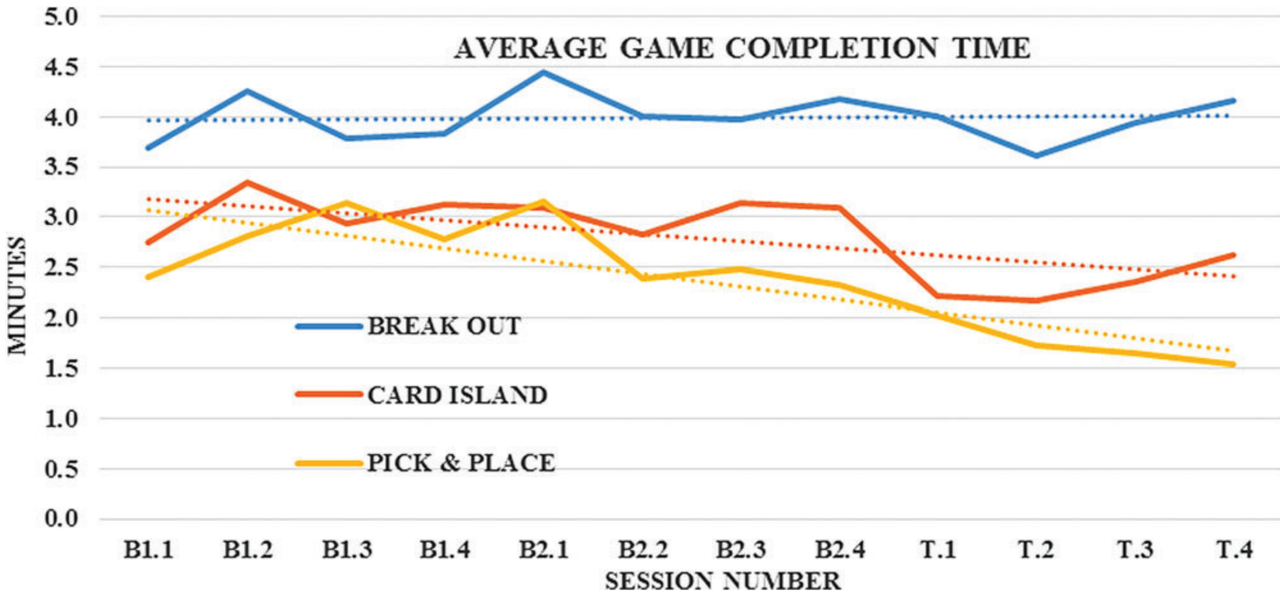

FIG. 4. Average game completion time for primary games (''Breakout 3D,'' ''Card Island,'' and ''Pick & Place''). Dashed lines represent linear trends determined using regression analysis. ©Bright Cloud International Corp. Reprinted by permission. (Color images available at www.liebertonline.com/g4h)

jumped 45.7° ($P = 0.02$), and mean flexion improved 6.9° ($P = 0.01$). Pronation for the unaffected elbow improved a smaller 9.6° ($P = 0.02$) during the two booster periods and 2.6° ($P = 0.03$) during the tournament.

CAHAI-9 improved 6 points from 15.9 prebooster (T0) to 21.9 pretournament (T2), a statistically significant result ($P = 0.02$). The value is about equal to the minimal clinically important difference (6.3 points), which supports the bimanual nature of the maintenance therapy. The gain during the tournament was a more modest 1.0 point, which may be a reflection of the unimanual nature of the tournament training and the reduced tournament session length. FMA improvement during tournament was 1.4 points, from 18.1 pretournament to 19.6 post-tournament ($P = 0.22$).

Emotive gains and technology acceptance

The depression level and session attendance were tracked for the seven experimental subjects chronic poststroke during the two booster periods and the tournament. The mean depression level dropped from 4.9 points prebooster 1 (T0) to 3.7 points post-tournament (T3). All Beck Depression Inventory-II measurements, including the difference (1.2), are below the minimal clinically important difference threshold of 5 points.[31] The attendance was 100 percent during Booster periods 1 and 2 and dropped to 93 percent during the tournament, as one subject decided to leave the study during the final tournament week.

Experimental group participants provided their subjective evaluation of the system by answering 10 questions post-tournament. The mean response score was 3.8 out of a maximum of 5.0 points. The two responses below 3.0 were ''Playing games with affected arm was easy'' (a score of 2.9) and ''No pain or discomfort'' (a score of 2.7). The response was 4.0 or better for the questions ''Like system overall'' (4.3), ''Not bored while exercising'' (4.0), ''Few technical problems'' (4.0), and ''Would encourage others to use it?'' (4.1). The highest response was 4.7 in answer to the question whether the individual ''Enjoyed playing with a partner?''

Discussion

Leisure programs in SNFs are designed to provide a level of pleasurable activities intended to break the monotony of resident life, reduce depression, and maintain cognitive function.[32] Some programs are meant to increase the level of physical activity so as to combat the generally sedentary life of the residents. Leisure activities are designed for group interaction that also improves socializing; however, these activities are facility bound and do not involve residents of other SNFs.[33] The other form of resident interaction at SNFs has been through group therapy sessions. Unfortunately, these are being capped by insurance policies.[34] Group therapy programs have been proven as effective as individualized therapy programs for walking for physical rehabilitation.[35] However, these exercise-based programs lack the motivational reward system provided by virtual rehabilitation.

Virtual reality, by definition, involves synthetic worlds populated by avatars of local or *remote* participants.[36] Technology has been used in various maintenance programs, but to our knowledge this is the first distributed virtual environment used for the maintenance of function in residents poststroke from multiple SNFs. Specifically, residents with chronic stroke from two SNFs participated in a tournament. This tournament involved custom adaptable games developed for the BrightArm Duo system and constituted the last phase of a virtual reality–based maintenance program that lasted 22 weeks.

This unconventional form of rehabilitation was highly beneficial by itself: 18 out of 23 UE range of motion metrics ($P = 0.01$) improved between pretournament and post-tournament assessments. During the tournament subjects had an average of 355 arm movement repetitions and 235 hand grasps for the affected arm per session. The arm repetitions for booster sessions were substantially higher (1030), explained in part by the bimanual gameplay mode and 55 percent longer sessions. However, even the 355 arm repetitions in the tournament sessions represent more than a five-fold larger number compared with arm repetitions associated with conventional rehabilitation sessions[37] and is indicative of intensive virtual reality training prone to induce brain reorganization.[38]

The subjects overwhelmingly responded (score of 4.7 out of 5) that they enjoyed playing with a partner. Teams were able to reduce task completion time through cooperative play, with evolving game strategies observed during gameplay. This high level of technology acceptance is in line with that found in an earlier study of elderly stroke survivors who were residents of the same SNF.[39] Although in the earlier study participants played individually, rather than in teams, and on an older version of the BrightArm, their overall system rating was still 4.1 out of 5.

Although the tournament benefitted the participating residents, the study faced three challenges. First, it is difficult to find suitable teams of residents given the wide range of motor function and cognition levels. This is a limitation of the study, caused primarily by the small number of participants. Further investigation is needed on whether pairing subjects by similar levels of cognitive function would be preferred over teams with varying cognitive capability.

The second challenge was maintaining a tournament schedule across two facilities, which may explain why this particular form of therapy has never been tried before. The routine related to meal times and other activities (such as doctor visits) interfered with the times teams were scheduled to compete. The third challenge was individual lack of desire to compete on a given day, thereby breaking team cohesiveness. However, assigning rewards to team rankings in the future may prove a stronger motivator for tournament participants.

The maintenance study boosters and the tournament pointed to some needed changes in the BrightArm Duo system. The game protocol of the booster period was a little intense for participants after an 8-week hiatus from BrightArm therapy. This resulted in frequent rest breaks to complete the exercise protocol; therefore a gradated approach with increasing exercise time would be preferable. In contrast, the level of exercise was on the light side during the tournament. It would be beneficial to redesign the multiplayer games so to incorporate *bimanual* arm use for both players and to include some of the repetition intense games from the booster protocol. Furthermore, the BrightArm system hardware did not allow finger extension and arm rotation functions that would be beneficial to develop for higher stages of stroke recovery, which may be considered during the redesigning of the system.

This study presents a new form of rehabilitation and socialization for long-term care residents of SNFs. These initial findings will need to be validated by larger studies involving more subjects and more SNFs.

Acknowledgments

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Author Disclosure Statement

G.H. is CTO of Bright Cloud International Corp. G.B. is an inventor on a patent related to the technology described here and the majority shareholder of Bright Cloud International Corp. K.P. is a full-time and N.G. is a part-time employee of Bright Cloud International Corp. D.R. is a part-time employee and shareholder of Bright Cloud International Corp. F.D. is an Administrator of Roosevelt Care Center, and S.K. is a Director of Quality and Service Delivery at JFK Hartwyck Nursing & Rehabilitation Centers, the two skilled nursing facilities where the project study took place. J.H. has been a contractor for Bright Cloud International Corp.

References

1. Centers for Disease Control and Prevention. QuickStats: Age-adjusted death rate from stroke, by all races, white or black race, and sex—United States, 1999–2008. MMWR Weekly 2011; 60(10):316.
2. Go AS, Mozaffarian D, Roger VL, et al. Heart disease and stroke statistics—2014 update. A report from the American Heart Association. AHA statistical update. Circulation 2013; 129:e28–e292.
3. Rosamond W, Flegal K, Friday G, et al. Heart disease and stroke statistics—2007 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Circulation 2007; 115:e69–e171.
4. Ovbiagele B, Goldstein LB, Higashida RT, et al. Forecasting the future of stroke in the United States: A policy statement from the American Heart Association and American Stroke Association. Stroke 2013; 44:2361–2375.
5. Centers for Medicare & Medicaid Services. Nursing Home Data Compendium 2013 Edition. 2013. https://www.cms.gov/Medicare/Provider-Enrollment-and-Certification/CertificationandComplianc/downloads/nursinghomedatacompendium_508.pdf (accessed December 18, 2015).
6. Gavin-Dreschnack D, Volicer L, Morris C. Prevention of overuse of wheelchairs in nursing homes. Ann Long-Term Care Clin Care Aging 2010; 18:34–38.
7. Harris-Kojetin L, Sengupta M, Park-Lee E, Valverde R. Long-term care services in the United States: 2013 overview. National Center for Health Statistics. VitalHealth Stat 3(37). 2013.
8. Reid N, Eakin E, Henwood T, et al. Objectively measured activity patterns among adults in residential aged care. Int J Environ Res Public Health 2013; 10:6783–6798.
9. Bowman C, Whistler J, Ellerby M. A national census of care home residents. Age Ageing 2004; 33:561–566.
10. Nurse Leader Insider. Geriatrician offers advice for managing depression in nursing-home patients. June 25, 2004. Nursing Leader Insider. http://www.hcpro.com/NRS-40327-868/Geriatrician-offers-advice-for-managing-depression-in-nursinghome-patients.html (accessed December 20, 2015).
11. Jørgensen HS, Nakayama H, Raaschou HO, et al. Outcome and time course of recovery in stroke. Part I: Outcome. The Copenhagen Stroke Study. Arch Phys Med Rehabil 1995; 76:399–405.
12. Nakayama H, Jørgensen HS, Raaschou HO, Olsen TS. Compensation in recovery of upper extremity function after stroke: The Copenhagen Stroke Study. Arch Phys Med Rehabil 1994; 75:852–857.

13. Rao R, Jackson S, Howard R. Neuropsychological impairment in stroke, carotid stenosis, and peripheral vascular disease. A comparison with healthy community residents. Stroke 1999; 30:2167–2173.
14. Sung KW. The effect of a health maintenance program on physical function and mental health of the elderly in nursing homes [in Korean]. Taehan Kanho Hakhoe Chi 2007; 37: 478–489.
15. Optale G, Urgesi C, Busato V, et al. Controlling memory impairment in elderly adults using virtual reality memory training: A randomized controlled pilot study. Neurorehabil Neural Repair 2010; 24:348–357.
16. Hornsten C, Molander L, Gustafson Y. The prevalence of stroke and the association between stroke and depression among a very old population. Arch Gerontol Geriatr 2012; 55:555–559.
17. Hornsten C, Lovheim H, Gustafson Y. The association between stroke, depression, and 5-year mortality among very old people. Stroke 2013; 44:2587–2589.
18. Sommer BR, Fenn H, Pompei P, et al. Safety of antidepressants in the elderly. Expert Opin Drug Saf 2003; 2:367–383.
19. Keogh JW, Power N, Wooller L, et al. Physical and psychosocial function in residential aged-care elders: Effect of Nintendo Wii Sports games. J Aging Phys Act 2014; 22: 235–244.
20. Clark R, Kraemer T. Clinical use of Nintendo Wii bowling simulation to decrease fall risk in an elderly resident of a nursing home: A case report. J Geriatr Phys Ther 2009; 32:174–180.
21. Chao YY, Scherer YK, Montgomery CA. Effects of using Nintendo Wii™ exergames in older adults: A review of the literature. J Aging Health 2015; 27:379–402.
22. McHugh JE, Lawlor BA. Exercise and social support are associated with psychological distress outcomes in a population of community-dwelling older adults. J Health Psychol 2012; 17:833–844.
23. House G, Burdea G, Polistico K, et al. Integrative rehabilitation of resident chronic post-stroke in skilled nursing facilities: The design and evaluation of the BrightArm Duo. Disabil Rehabil Assist Technol 2015 July 28 [Epub ahead of print]. DOI: 10.3109/17483107.2015.1068384.
24. House G, Burdea G, Polistico K, et al. BrightArm Duo integrative rehabilitation for post-stroke maintenance in skilled nursing facilities. In: *ICVR 2015—Proceedings of the International Conference on Virtual Rehabilitation, Valencia, Spain*. Piscataway, NJ: IEEE; 2015: 207–214.
25. Duncan PW, Probst M, Nelson SG. Reliability of the Fugl-Meyer assessment of sensorimotor recovery following cerebrovascular accident. Phys Ther 1983; 63:1606–1610.
26. Woodbury ML, Velozo CA, Richards LG, Duncan PW. Rasch analysis staging methodology to classify upper extremity movement impairment after stroke. Arch Phys Med Rehabil 2013; 94:1527–1533.
27. Barreca S, Gowland C, Stratford P, et al. Development of the Chedoke arm and hand activity inventory: Theoretical constructs, item generation, and selection. Top Stroke Rehabil 2004; 11:31–42.
28. Beck AT Steer RA, Brown GK. *Manual for Beck Depression Inventory*, 2nd ed. San Antonio, TX: Psychology Corp.; 1996.
29. Reitan RM. Validity of the Trail Making Test as an indicator of organic brain damage. Percept Motor Skill 1958; 8:271–276.
30. Burdea G, Polistico K, Krishnamoorthy A, et al. A feasibility study of the BrightBrainer™ cognitive therapy system for elderly nursing home residents with dementia. Disabil Rehabil Assist Technol 2014; 9:323–335.
31. Hiroe T, Kojima M, Yamamoto I, et al. Gradations of clinical severity and sensitivity to change assessed with the Beck Depression Inventory-II in Japanese patients with depression. Psychiatry Res 2005; 135:229–235.
32. Cheng ST, Chow PK, Yu EC, Chan AC. Leisure activities alleviate depressive symptoms in nursing home residents with very mild or mild dementia. Am J Geriatr Psychiatry 2012; 20:904–908.
33. Tak SH, Kedia S, Tongumpun TM, Hong SH. Activity engagement: Perspectives from nursing home residents with dementia. Educ Gerontol 2015; 41:182–192.
34. U.S. Department of Health and Human Services. Centers for Medicare and Medicaid Services. Therapy Services. 11 Part B Billing Scenarios for PTs and OTs (Individual vs. Group Treatment) 2012, July 27. https://www.cms.gov/Medicare/Billing/TherapyServices/billing_scenarios.html (accessed October 16, 2015).
35. Renner CI, Outermans J, Ludwig R, et al. Group therapy task training versus individual task training during inpatient stroke rehabilitation: A randomised controlled trial. Clin Rehabil 2015 August 27 [Epub ahead of print]. doi: 10.1177/0269215515600206.
36. Burdea G, Coiffet P. *Virtual Reality Technology*, 2nd ed. Hoboken, NJ: Wiley Interscience; 2003.
37. Hayward KS, Brauer SG. Dose of arm activity training during acute and subacute rehabilitation post stroke: A systematic review of the literature. Clin Rehabil 2015; 29:1234–1243.
38. Marshall RS, Zarahn E, Alon L, et al. Early imaging correlates of subsequent motor recovery after stroke. Ann Neurol 2009; 65:596–602.
39. Rabin BA, Burdea GC, Roll DT, et al. Integrative rehabilitation of elderly stroke survivors: The design and evaluation of the BrightArm™. Disabil Rehabil Assist Technol 2012; 7:323–335.

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