Integrative virtual reality therapy produces lasting benefits for a young woman suffering from chronic pain and depression post cancer surgery: a case study

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ABSTRACT

This case study was part of an evaluation of the BrightArm Duo Rehabilitation System for treating the effects of chronic upper body pain following breast cancer surgery. The subject was a 22-year old woman with burning and stabbing pain in the right upper arm. Training consisted of playing custom bimanual 3D games while seated at the gravity-modulating robotic table for 16 sessions over 8 weeks. Standardized assessments demonstrated a meaningful improvement in motor, cognitive and emotive domains with a statistically significant reduction in pain. Gains transferred to daily activities enabling the subject to resume full time employment, driving and socializing.

1. INTRODUCTION

The psychological, social and behavioral impact of cancer at a young age can be tremendous (Zebrack, 2011). As the number of young cancer survivors increase, their quality of life after cancer treatment becomes an important concern (Quinn, Gonçalves, Sehovic, Bowman, & Reed, 2015). With improved detection and progress in management of breast cancer (Kenyon, Mayer, & Owens, 2014), the survivors need improved rehabilitation approaches to address and overcome the resulting complications from that treatment. Depression and chronic pain in shoulder and arm following breast cancer surgery are highly prevalent and can lead to life-long psychological, cognitive and physical impairments. It is important to have rehabilitation techniques that can produce long lasting benefits for women, while being gradated in difficulty, interactive and fun.

Virtual reality (VR) offers benefits for other diagnostic conditions and provides a new and unique opportunity in the rehabilitation of women with breast cancer. VR analgesia, pioneered by Hoffman (Hoffman, Doctor, Patterson, Carrougher, & Furness, 2000) for burn wound care, has subsequently been used to reduce chemotherapy-related distress in women with breast cancer (Schneider, Ellis, Coombs, Shonkwiler, & Folsom, 2003), or anxiety for children with cancer (Gershon, Zimand, Pickering, Rothbaum, & Hodges, 2004). Virtual reality has great potential for use in acute and chronic pain by providing a non-opioid 'virtual analgesic' response (Triberti, Repetto, & Riva, 2014). This 'distraction from pain' response has also been studied for its ability to provide sustained benefits for pain control in cold pressor tests (Rutter, Dahlquist, & Weiss, 2009). Virtual reality therapy has been tried in breast cancer to alleviate symptoms during chemotherapy (Schneider et al., 2003). However, to the authors' knowledge no clinical trials have been conducted to study VR effectiveness in breast cancer survivors with post-surgical chronic upper body pain and related depression.

The BrightArm Duo Rehabilitation System (Bright Cloud International, New Jersey, USA) is an experimental robotic platform that modulates gravity loading on the upper extremities (UEs). The ability to unload gravity makes it appropriate for individuals with weak arms and diminished ability to grasp, such as those suffering from chronic UE pain. BrightArm Duo uses VR to engage the patient in upper body bimanual

integrative exercises that provide motor and cognitive training and affective relief. This integrative virtual rehabilitation has been found to be beneficial in prior BrightArm Duo studies of elderly individuals with chronic stroke residing in skilled nursing facilities (House et al., 2015). These earlier studies have shown benefits to cognition and depression reduction, which in theory could benefit breast cancer survivors with the same type of impairments. Thus, a feasibility study was conducted (N=6) to explore the feasibility of BrightArm Duo Rehabilitation System for the treatment of chronic pain in breast cancer survivor post-surgery, and who also have depression and cognitive deficits. The case described here was the youngest subject participating in that study.

2. METHODS

2.1 The BrightArm Duo rehabilitation

The BrightArm Duo Rehabilitation System consisted of a robotic rehabilitation table, two computerized forearm supports, a 27″ monitor, a laptop computer for the therapist, a remote clinical server and a library of custom integrative rehabilitation games. The library of custom games was developed in Unity 3D (Unity, 2016) for uni-manual and bi-manual motor (shoulder, elbow, grasp), emotive (depression) and cognitive (executive function, focusing, short-term and delayed memory, working memory and task sequencing) training. The subject interacted with these serious games through active arm movement and power grasp, both being tracked in real time. The forearms of the subject were placed onto low-friction supports outfitted with two 770 nm LED towers and a rubber pear bulb connected to an internal differential pressure sensor. The hand position was determined with better than 0.5 mm accuracy. Subject's grasp strength of the rubber pear was measured by the pressure sensor and communicated wirelessly to the laptop station at a data rate better than 40 packets per second. Each session, the system automatically adapted to the subject's forearm movement and grasp capabilities. Game difficulty, session duration, gravity unloading/loading (gravity assistance/resistance during training) on her upper extremity, were all gradated over the length of the training (House et al., 2015). Tilting upwards provided resistance when moving away from the trunk. Conversely, tilting downwards assisted weak arm movement.

Figure 1. *BrightArm Duo Table tilted upwards with two arm supports for user interaction and therapist laptop rendering Pick & Place game to the 27″ monitor. © Bright Cloud International Corp. Reprinted by permission.*

Figure 2 shows the screen images of the nine games used in the study. In *Breakout 3D*, the subject bounced a virtual ball toward an array of crates using paddle avatars. The game trained shoulder abduction/adduction or flexion/extension depending on the orientation of the crates, as well as focusing and executive function. The matching card games *Card Island* and *Remember that Card* trained short-term and delayed visual and auditory

memory, grasp strength, shoulder abduction/adduction, and shoulder flexion/extension. For *Musical Drums*, the subject controlled drum stick avatars to strike a series of notes that drifted across (up to four) drums. This game trained focusing and motor control. The *Xylophone* game trained short-term auditory and visual memory by having the subject repeat a sequence of musical notes using mallet avatars. In *Pick & Place*, the subject grasped a ball from among multiple choices and then moved it to a fixed target of matching color, using shoulder flexion/extension or abduction/adduction arm movements. The game trained working memory and motor control as subject was asked to follow an ideal straight line to the target. Playing *Arm Slalom* induced shoulder rotations in order to guide a skier avatar through a downhill slalom course. In the *Avalanche* game, the subject controlled pickaxe and shovel avatars through grasp and arm movements. The task was to break and clear a series of ice walls so to free people trapped in a cottage. In *Treasure Hunt*, the subject used one or two shovel avatars to clear sand and uncover a series of buried treasures, before they were buried again by periodic sand storms.

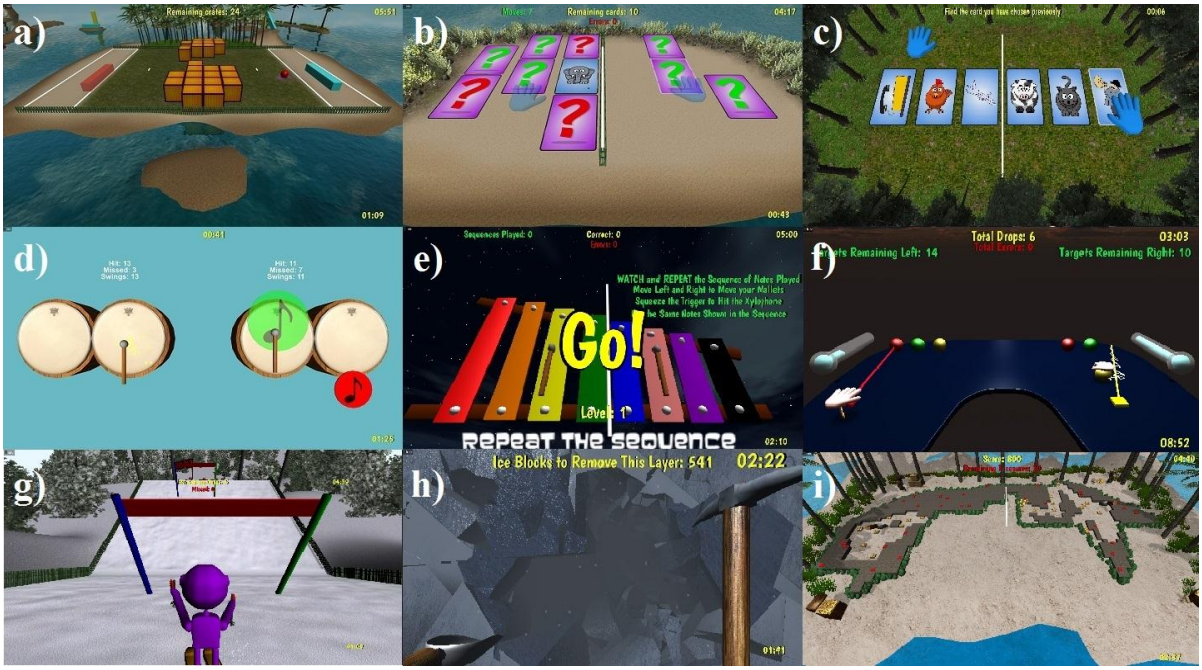

Figure 2. *Nine game screen images: a) Breakout 3D; b) Card Island; c) Remember that Card; d) Musical Drums; e) Xylophone; f) Pick & Place; g) Arm Slalom; h) Avalanche; i) Treasure Hunt. © Bright Cloud International Corp. Reprinted by permission.*

2.2 Training Protocol

The feasibility study followed a single subject A1-B1-A2-A3 design with training (B1) consisting of a total of 16 sessions, two sessions per week for 8 weeks. Standardized assessments of motor, cognitive and emotive state were performed pre-training (A1), post-training (A2) and at 8-week follow-up (A3). The training sessions progressed from 20 minutes to 50 minutes in duration, and the BrightArm Duo robotic table was tilted upwards progressively from a minimum of 0° (horizontal) at the start of the protocol to a maximum of 20° in the last training sessions (House et al., 2015). This corresponded to gravity unloading at the beginning of the therapy then progressively increased gravity loading as the subjects trained in later sessions. The Western Institutional Review Board, an independent board overseeing research involving human subjects, reviewed and approved the study protocol in accordance with Federal Guidelines. The subject was recruited at the University Pain Medicine Center (Somerset, NJ) and training took place at Roosevelt Care Center, a clinical facility in Edison, NJ in summer 2015. The subject received a $25 monetary compensation for each session attended however to the authors' knowledge this was not her primary reason for participation. The subject was genuinely interested in this experimental therapy to help manage her upper body pain symptoms.

2.3 Subject Characteristics

The subject was a 22-year old single woman of a mixed race, African American and White, with post-surgical chronic pain for the preceding 9 years. This chronic pain was localized to right upper arm and was burning, throbbing and stabbing in nature. She occasionally also reported pain in lower back, upper back, breast, hip and neck which was described as nagging. The subject reported that moving made her pain worse and nothing made it better. She had severe depression, difficulty socializing and had one suicidal attempt. As a consequence of her

pain she kept her right arm in a sling which resulted in employment difficulties. She worked as a certified nursing assistant in home health care with hourly work that she would have to cancel many times due to pain. She was recruited from the University Pain Medicine Center where she followed up routinely with a pain medicine physician with a reported pain level of 6 to 8 on Numerical Pain Rating Scale (Paice, & Cohen 1997) and not undergoing any physical or occupational therapy at the time of her enrollment in the experimental study. The surgical procedure on her breast reported when she was 13 years old did not have any medical records for verification of diagnosis. She underwent lumpectomy of her right breast again in 2008 and cyst removal from left breast in 2007. She reported taking Tromodol 50 mg and Percocet 10 mg at pre-training. She had tried multiple therapies in the past as indicated in her clinical notes. These ranged from pain medications, to physical therapy twice a week for 10 weeks from January to April 2014, to home exercises,

2.4 Data Collection Instruments

Therapy session data (B1) included supported arm reach baseline on the BrightArm Duo table (as measured by overhead digital cameras used in tracking), power grasp strength baseline (as measured by a forearm support grasp sensor), heart rate and blood pressure. In addition B1 data included the number of active movements and grasp repetitions for each arm during a session, as well as game performance data (score, errors, completion time) collected during play. Pain was assessed using the Numeric Pain Rating Scale (NRS) administered verbally by the attending OT. This pain measure has validity in measuring cancer-related pain intensity (Paice & Cohen, 1997). Skin temperature was measured during the sessions with basis wristwatch that was worn on the subject's unaffected arm. Blood pressure and pulse were measured before and after each session using Omron 7 Series upper arm blood pressure monitor.

Occupational therapy evaluations were done pre-training, post-training and at 8 week follow-up by a blinded Senior Occupational Therapist (OT) consultant who was not training the subject. This OT evaluation involved assessment of upper extremity function using the Fulg-Meyer Assessment – Upper Extremity Section (FMA)(Duncan, Propst, & Nelson, 1983), the Chedokee Arm and Hand Inventory – 9 (CAHAI-9)(S. Barreca et al., 2004) for bimanual tasks and the Jebsen Hand Function Test (JHFT)(Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969) for hand function. Arm and hand range of motion were measured using mechanical goniometers, shoulder strength was assessed using wrist weights, grasp strength was measured with a Jamar mechanical dynamometer and a Jamar pinch meter. In addition the subject was assessed for her degree of independence in activities of daily living (ADL) involving the upper extremity, using the Upper Extremity Functional Index 20 (UEFI-20) (Chesworth et al., 2014).

Neuropsychological evaluations were done by a blinded research assistant under the supervision of a licensed clinical neuropsychologist pre-training, post-training and at follow-up. These were measures of depression severity, attention/concentration, processing speed, learning, memory, and executive function. The standardized measures used were the Beck Depression Inventory, Second Edition (BDI-II),(Beck, Steer, & Brown, 1996) the Neuropsychological Assessment Battery Executive Functioning Module (Generation subtest) (White & Stern, 2003), the Hopkins Verbal Learning Test, Revised (HVLT-R) (Brandt & Benedict, 2001), the Brief Visuospatial Memory Test, Revised (BVMT-R) (Benedict, 1997), the Trail Making Test A and B (TMT) (Reitan, 1958). Alternate test forms were used whenever possible to minimize test-taking practice effects. Raw scores were utilized in all data analysis. Both evaluating clinicians were blinded to the therapy methodology and scope.

At the end of weeks 4 and 8 of VR training, the subject rated her experience on a custom paper-based subjective evaluation questionnaire with ten questions. The questions were: 1) "The system was easy to use?"; 2) "Playing games with my affected arm(s) was easy?"; 3) "I had no pain or discomfort in my upper body?"; 4) "Instructions given to me were useful?"; 5) "Playing games with both arms was easy?"; 6) "I was not bored while exercising?"; 7) "The length of the exercising in a day was appropriate?"; 8) "There were few technical problems?"; 9) "I would encourage others to used it?"; 10) "I liked the system overall?". Each question was rated on a 5-point Likert scale, from 1 meaning "strongly disagree" (least desirable outcome) to 5 meaning "strongly agree" (most desirable one). The subject could add free form comments on the evaluation form.

3. RESULTS

3.1 Training Intensity

The subject exercised a total of 20,130 active arm repetitions and 7,020 hand grasps. The BrightArm Duo tilt was gradually increased from 0° to 20° upwards over the study. Figure 3a show active arm repetitions increased from about 320 in session 1 to over 1,500 repetitions in session 16 with peak activity around session 5 and 11. Hand grasps increased from 45 in session 1 to 971 by session 16. The intensity of play increased with session number as well. If session length is normalized to maximum duration of 51.2 minutes, arm movement and hand

grasps would increase along a slope of 878 (p=0.18) and 1,011 (p<0.001) repetitions between session 1 and 16. The subject played a total of 412 games over a total of 567 minutes. The exercise length steadily increased from 21.2 minutes (session 1) to 51.2 minutes (session 16). Both game difficulty and subject performance increased over the study. Figure 3b illustrates how composite games rose from 43 (session 1) to 65 (session 16). The linear regression fit of the data points yielded a statistically significant trend line (p<0.001) corresponding to a 22 point increase in average game score from about 47 points in session 1 to about 69 points in session 16.

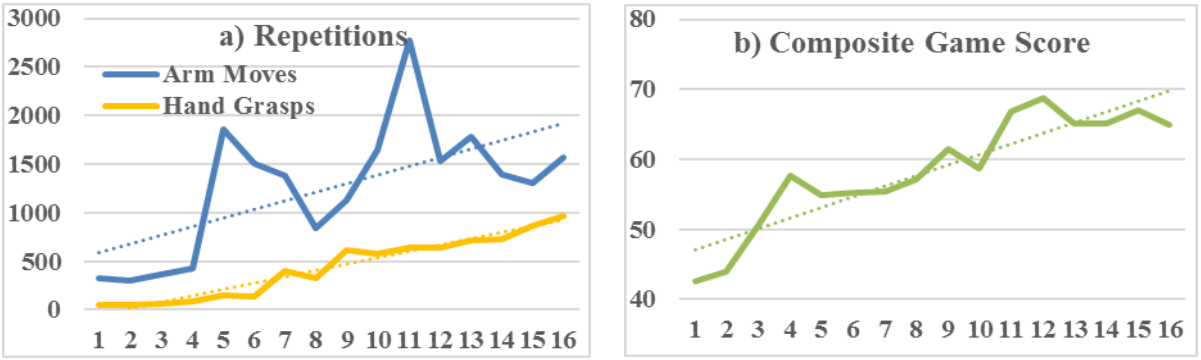

Figure 3. *a) Arm and hand repetitions and b) composite game score by session number for the cancer survivor experiencing post-surgery chronic pain. © Bright Cloud International Corp. Reprinted by permission.*

3.2 Pain and Skin temperature outcomes

The subject's reported pain and skin temperature was captured every session. Figure 4a illustrates the maximum upper extremity pain on the 10 point Numerical Pain Rating Scale by session number. As seen by the statistically significant trend line (p=0.01), there was marked reduction in reported pain of 4.4 points over the course of the study. Figure 4b plots the average skin temperature by session number as measured at the wrist of the subject's unaffected arm. The linear regression fit of the data points yielded a statistically significant trend line (p=0.001) corresponding to a 10.25°F increase in skin temperature over the 16 sessions. This is indicative of increased blood flow to the upper extremity in response to increased use of the affected arm.

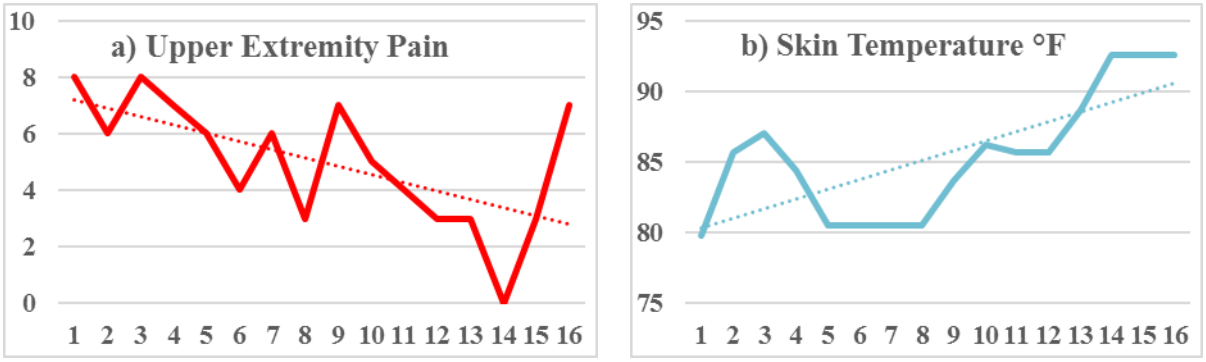

Figure 4. *a) Maximum upper extremity pain and b) affected arm skin temperature by session for the cancer survivor experiencing post-surgery chronic pain. © Bright Cloud International Corp. Reprinted by permission.*

3.3 Upper extremity active range of motion

The subject's range of motion was evaluated for the affected and unaffected arms at pre-training (A1), post-training (A2) and follow-up (A3). The elbow and finger values were within normal limits. In Table 1, 10 of 12 range of motion measures improved at A2 and A3 relative to A1. The affected arm maintained substantial gains at A3: Abduction (111°), Flexion (89°), Adduction (40°), External Rotation (31°), and Extension (19°). The unaffected arm improvements were more modest at A3: Flexion (16°), Abduction (10°), Extension (9°) with Internal Rotation moderately decreasing (20°). The minimal clinically important difference (MCID) is 8° for shoulder range of motion improvement (Salamh & Kolber, 2012).

Table 1. *Shoulder range of motion (degrees) for the post-surgery cancer survivor experiencing chronic pain. © Bright Cloud International Corp. Reprinted by permission.*

	Affected Shoulder					Unaffected Shoulder				
Variable	**A1**	**A2**	**A3**	**A2-A1**	**A3-A1**	**A1**	**A2**	**A3**	**A2-A1**	**A3-A1**
Flexion	58	150	147	+ 92	+ 89	132	146	148	+ 14	+ 16
Extension	23	73	42	+ 50	+ 19	58	77	67	+ 19	+ 9
Abduction	27	157	138	+ 130	+ 111	140	148	150	+ 8	+ 10
Adduction	0	56	40	+ 56	+ 40	33	50	40	+ 17	+ 7
Internal rot.	38	55	40	+ 17	+ 2	70	68	50	– 2	– 20
External rot.	50	78	81	+ 28	+ 31	82	77	75	– 5	– 7

3.4 Upper extremity strength

Table 2 lists arm and hand strength for the affected and unaffected arms pre-training (A1), post-training (A2) and follow-up (A3). All ten strength measures improved or remained the same as compared to A1. At follow-up, the gains in grip strength compared to pre-training were 231.3 N and 97.9N for the affected and unaffected hands, respectively. These results are 200% to 400% the MCID of 49 N for hand grip (Lang, Edwards, Birkenmeier, & Dromerick, 2008). At follow-up, the affected and unaffected hand two-finger pinch improved 29.8 N and 20.0 N, respectively and the 3-jaw pinch improved 36.5N for both hands, compared to pre-training. The affected shoulder strength had an impressive gain from 4.4N at A1 to 31.1N at A3, a 700% increase. The unaffected shoulder strength improvement was from 31.1N to 44.5N represents a more modest 40% increase.

Table 2. *Hand and arm strength for the post-surgery cancer survivor experiencing chronic pain. © Bright Cloud International Corp. Reprinted by permission.*

	Affected Shoulder					Unaffected Shoulder				
Variable	**A1**	**A2**	**A3**	**A2-A1**	**A3-A1**	**A1**	**A2**	**A3**	**A2-A1**	**A3-A1**
Hand Grip	68	262.4	299.4	+194.4	+ 231.3	115.7	218.0	213.5	+ 102.3	+ 97.9
Tip Pinch	0.0	31.1	29.8	+ 31.1	+ 29.8	11.1	23.6	31.1	+ 12.5	+ 20.0
3 Jaw Pinch	4.4	46.7	40.9	+ 42.3	+ 36.5	16.9	34.7	53.4	+ 17.8	+ 36.5
Ant. Deltoid	4.4	22.2	31.1	+ 17.8	+ 26.7	31.1	31.1	44.5	0.0	+ 13.3
Lat. Deltoid	4.4	22.2	31.1	+ 17.8	+ 26.7	31.1	31.1	44.5	0.0	+ 13.3

3.5 Upper extremity functional assessments

Functional assessments also improved at post-training (A2) and follow-up (A3) relative to pre-training (A1). Fugl-Meyer Assessment scores were 47 (A1), 58 (A2) and 56 (A3). The 11 and 9 point improvement at A2 and A3 respectively meet the MCID criteria of 9 points (Arya, Verma, & Garg, 2011). CAHAI-9 scores were 50 (A1), 63 (A2) and 63 (A3). The improvement of 13 points at A2 and A3 is twice the MCID of 6.3 points (Barreca, 2015), and is indicative of improved ability to perform bimanual ADLs. The metric UEFI-20 measurements were 18 (A1), 58 (A2) and 42 (A3). The improvement of 40 and 24 points at A2 and A3 were three to five times the MCID of 8 points (Chesworth et al., 2014). The JHFT for the affected hand was 79 (A1), 35 (A2) and 39 (A3) seconds. The subject was able to complete the manual tasks of JHFT in half the time post-training, and the speed improvement was maintained at follow-up.

3.6 Cognitive and emotive outcomes

Table 3 lists emotive and cognitive measures evaluated pre-training, post-training and follow-up. There was a notable reduction in depression severity of 16 points (A2) and 6 points (A3). Both values were above MCID of 5 points for BDI-II (Hiroe et al., 2005). The Trail Making Test Part B showed a reduction in time from 128 seconds at A1 to 49 seconds at A3. This was indicative of improved attention and processing speed. HVLT-R which measures verbal learning and memory was one cognitive measure that showed a systematic decline from

22 points at A1, to 20 points at A2, and 16 points at A3. This was offset by an increase in word generation from 5 at A1, to 6 at A2 and 9 at A3. There was a systematic increase BVMT-R, from 13 points at A1, to 18 points at A2 and 20 points at A3, indicative of improved visuo-spatial memory.

Table 3. *Emotive and cognitive outcomes for the post-surgery cancer survivor experiencing chronic pain. *indicates sign reversed so all positive differences in table indicates improvement. © Bright Cloud International Corp. Reprinted by permission.*

Variable	A1	A2	A3	A2-A1	A3-A1	Variable	A1	A2	A3	A2-A1	A3-A1
BDI-II	37	21	31	*+ 16	* + 6	HVLT-R	22	20	16	– 2	– 6
TMT-A	20	22	22	* – 2	* – 2	BVMT-R	13	18	20	+ 5	+ 7
TMT-B	128	66	49	* + 62	* +79	Word Gen	5	6	9	+ 1	+ 4

3.7 Subject Attendance and Testimonial.

The subject completed the 16 sessions of the protocol over a period of 9 weeks. She postponed two sessions early on due to back pain related to work and unrelated to BrightArm training. She reported no side-effects from the VR therapy such as cyber sickness or headache. The subject evaluated the system by answering the ten questions. The average response was 3.6/5 at the two sampling times (week 4 and week 8). The lowest scores were for the questions: "I had no pain or discomfort in my upper body?" (1.5); "Playing games with my affected arm(s) was easy?" (2.0); "I would encourage others to used it?" (3.0); "The length of the exercising in a day was appropriate?" (3.5). The responses averaged a rating of 4 between week 4 and 8 for the questions: "The system was easy to use"; "Playing games with both arms was easy?"; "There were few technical problems?"; "Instructions given to me were useful?". The highest evaluation score was 5.0/5 for the questions: "I was not bored while exercising?" and "I liked the system overall?" which shows excellent technology acceptance of the BrightArm Duo.

At follow-up (A2) the subject was asked if she would provide a testimonial. In compliance to IRB Human Subject's Regulations her identity is not disclosed, although she included her name in the email sent in late May 2015. This email is included here with subject's approval, as it provides her opinion on the impact that the experimental therapy had on her life.

"*I've just completed my 8 weeks of physical therapy. This therapy section helped me tremendously. Before I started this therapy my right arm had no use me and there was so much pain! There were things I couldn't do like driving, getting dressed, taking a shower, playing with my nephew....I was working on and off, I couldn't hang out with my friends, my life basically stopped, and it was very depressing. But now I'm driving, I'm back working full time, I'm catching up with friends AND there's no pain. I'm extremely happy with the results, this is my third time trying therapy for my arm and this the only one I saw results from. The therapy sessions consist of games....yes you are literally sitting in a chair in front of a computer playing games, though they were challenging it was also very fun, well for me it was. Dr. Burdea and his team gave me back my life because I thought it was over literally. I recommend everyone that's having this problem to try this therapy session, it works tremendously and it is fun (did I mention it's actually games you play on a computer) yes and everyone is very friendly. So thank you Bright Cloud International.*"

The subject was referring to BrightArm Duo in the physical therapy reported in this testimonial. She has compared VR games to the traditional physical therapy she had undergone in the past which did not work for her. The immersive games induced bilateral high repetitions and engaged the participant with rewarding feedback for effort. These features made the rehabilitation training with BrightArm Duo distinctly different from her prior traditional therapy

4. CONCLUSIONS

Childhood cancer survivors have an increased risk of complications later in life and rehabilitation with better outcomes will greatly improve the quality of life in these women (Kenney et al., 2004). In this study, the 22-year old female subject showed marked reduction in shoulder and arm pain of 4.4 points on the NRS scale which is much higher than the MCID of 2.17 for NRS established for people with surgical and post-surgical shoulder pain (Michener, Snyder, & Leggin, 2011). This is an encouraging finding considering the impact of VR therapy on chronic pain in other conditions such as fibromyalgia has shown no benefits for pain intensity (Garcia-Palacios et al., 2015). However, the benefits of VR therapy in cancer related pain during acute painful procedures, hospitalization and chemotherapy has been studied and shown to be beneficial (Chirico et al., 2016). Visual

distraction has been one of the theories put forth for explaining these beneficial effects on pain (Triberti et al., 2014). Although, in this study, the positive effect on pain intensity cannot be completely attributed to the phenomenon of visual distraction. As reported in other literature (Loreto-Quijada et al., 2014), the distraction from pain could be insufficient to cause the accompanied improvements on motor and cognitive aspects of function measured at post-training and maintained at 8-week follow up. It is also likely that the 16-session protocol used in this study resulted in better outcomes than the 10-session protocol reported in other studies of VR in chronic pain of fibromyalgia (Botella et al., 2013).

Garcia-Palacios et al. (28) reported no benefit of VR therapy on depression in people with chronic pain due to fibromyalgia, whereas in this study, the depression scores decreased by 16 points on the BDI-II, which is a 32% improvement. The MCID for depression varies with initial severity (Button et al., 2015) and has been estimated to be 32% for individuals with prolonged depression which fits the profile of the subject in this study. A recent review by Chirico et al., (2016) (Chirico et al., 2016) summarizes the benefit of VR therapy in cancer on psychological variables such as state anxiety and painful procedures, the results of the present case study open the possibility to understand the impact of VR therapy in other variables such as depression. Chirico et al. (2016) also recommend including bio physiological variables in VR therapy research in cancer using biosensors for understanding physiological responses to the training. In this study, biosensors at the wrist of the unaffected arm showed a 10.25°F increase in skin temperature with the over the course of the 16 sessions conducted in the same indoor therapy room. This interesting finding is indicative of an increased thermal response during exercise that is likely during moderate to high intensity exercise (Neves et al., 2015) and was associated with improved outcomes in the subject. This may indicate increased blood flow to the arm with a beneficial effect for overall health of the arm (González-Alonso et al., 2015).

An average of 1,260 active arm repetitions and 440 hand grasps per session for the subject over the course of 16 sessions is an important characteristic of the BrightArm Duo therapy. This large number of induced arm repetitions has previously been reported (House et al., 2015) to benefit elderly stroke survivors in the chronic phase. The substantial benefits of this intensive therapy are indicative of application for chronic cancer pain populations as well. All standardized measures in this case study of range of motion, strength, UE function, attention, and memory improved at post-training. With the NRS pain level of 6 and 7 pre-training, the subject was unable to move her right arm and post training the regained range of motion in the arm along with simultaneous distraction from pain has shown to be the right combination of therapy for her. As seen from her own testimonial, the subject was able to transition to a full time job and returned to driving giving her maximal functional independence much desired at her young age.

A remarkable finding in this case study was that at 8-week follow up (A3) the majority of gains remained higher than A1, with no VR training after A2. The subject did not report playing any form of videogames during the no-VR phase and enjoyed reading and socializing for recreation. The maintenance effect with VR therapy has been shown in prior studies in 48 hour follow-up (Schneider et al., 2003), however a 8-week follow up has not been reported. The study of VR maintenance effect for rehabilitation therapy programs is as critical for chronic pain conditions as it is for rehabilitation of conditions such as stroke (Viñas-Diz & Sobrido-Prieto, 2015). This longitudinal study is lacking in the current VR literature related to cancer treatments (Chirico et al., 2016). This case study was able to establish the feasibility of a longitudinal study protocol to study these maintenance effects of VR therapy in chronic pain and depression.

This study, part of an n=6 feasibility evaluation of the BrightArm Duo system for upper body chronic pain, has obvious limitations to generalizability. However, the information detailed in this case study brings forth the qualitative aspects associated with BrightArm Duo training especially in younger individuals and helps examine the feasibility of the VR therapy in this sample of cancer survivors. The therapists can benefit greatly with an in-depth study of successful cases using BrightArm Duo system in rehabilitation to maximize benefits for their clients. In conclusion, initial findings demonstrate a meaningful reduction in chronic pain and physical, cognitive and psychological improvement for a young female subject. These suggest a need for controlled studies in young breast cancer survivors with pain and depression associated to post-surgical treatment of breast cancer.

Acknowledgements: Research reported here was supported by grant 1R43DA032224-01 from the National Institutes for Health/NIDA. We wish to thank Abby Eisner OT and Daniel Saldana who performed the clinical evaluations and Ms. Noreen Rana, the clinical coordinator for the study.

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