The use of virtual reality as a treatment medium for autonomic dysfunction across three diagnostic groups: *Case Studies*

A pilot project

Holly, Janet BHSc P.T. MSc
Bridgewater, Courtney B.Eng, MSc

The Ottawa Hospital Rehabilitation Centre, Canada; The Ottawa Hospital Research Institute: Epidemiology Program
Ottawa, Canada;
jholly@toh.ca ; cbridgewater@toh.ca

Capt Lambert, Anne-Marie CD, BSc

Canadian Forces Health Services Centre Ottawa, Department of Defense, Government of Canada
Anne-Marie.Lambert@forces.gc.ca

Abstract—**Three patient case studies, will illustrate novel techniques for using virtual reality technology to treat patients with complex rehabilitation needs. The patients were respectively diagnosed with Complex Regional Pain Syndrome (CRPS), persistent pain with post-concussion syndrome and persistent pain with Post-Traumatic Stress Disorder (PTSD). The common treatment goal for these patients is to use VR to promote top down regulation of the autonomic nervous system (ANS) by using VR to challenge the patients in small exposures. The exposure and subsequent required control by the patients will promote creation of new adaptive neural plastic networks. The patient treatment sessions were complete on a Computer Assisted Rehabilitation Environment (CAREN) Extended system (MotekForce link, The Netherlands) located at The Ottawa Hospital Rehabilitation Centre (TOHRC). The outcome measures to evaluate the treatment effectiveness will demonstrate changes in The World Health Organization categories of tissue dysfunction, patient activities and participation.**

*Keywords—**autonomic nervous system, PTSD, CRPS, pain, concussion, virtual reality.***

I. Introduction

There are several diagnostic conditions that include autonomic nervous system dysfunction. Patients with conditions in which the autonomic nervous system (ANS) is involved can be functionally impaired and these symptoms can have a profound impact on quality of life.

Patients commonly seen at the TOHRC CAREN frequently exhibit activation of the sympathetic portion of the ANS. Diagnostic groups which exhibit these autonomic symptoms include persistent pain populations, complex regional pain syndrome (CRPS) populations [1], concussion, traumatic brain injury (TBI) and acquired brain injury (ABI) [2] [3] as well as post traumatic distress disorder (PTSD) [4]. Patients often present with two or more of the above diagnostic groups. In these conditions, the sympathetic nervous system is commonly found to be activated and the patients are found to be frequently, if not constantly, to be in a fight-or-flight response mode. Activation of the sympathetic nervous system is achieved by releasing increasing levels of epinephrine and norepinephrine causing signs of increased arousal, vigilance and selective attention in the brain. [5] In the CAREN environment, both civilian and military physiotherapists have been inducing sympathetic activation in small doses in order to challenge the nervous sytem of patients for adaptive neuroplastic changes.

II. Diagnostic Cases

A. PTSD

In patients with PTSD, the severity of PTSD symptoms is positively correlated with elevated urinary norepinephrine concentration in the cerebrospinal fluid as compared to control subjects have been found. Lipov. in 2013 suggests that targeted treatments to decrease CNS noradrenergic activity could be effective in the treatment of PTSD. [5] Activities that activate higher order brain centres have the ability to decrease lower-order brain activity responsible for responding to these increased levels of noradrenergic chemicals. Mindfulness, yoga, biofeedback and music therapy have been studied and has been found effective at downregulating the lower order brain activity and decreasing autonomic sympathetic nervous system vigilance. This leads to the hypothesis that individuals can control the sympathetic nervous system consciously. [2] McLay et al., 2014 demonstrated some successes with the use of virtual reality for the treatment of individuals with post combat PTSD. [6] In the virtual reality environment, specific applications that created increased levels of arousal, demonstrated by increasing heart rate, increased sweating and rapid scanning of the eyes, were chosen to activate the sympathetic nervous system in patients diagnosed with PTSD and pain. Patients had been taught individualized techniques of breathing and relaxation to be used once arousal commenced. Patients were encouraged to continue to engage in the virtual environment if they could maintain control over their increased vigilance. As soon as the patient felt they no longer could control their symptoms, the application was paused. The patient regained control and returned to their resting levels prior to exposure to the virtual reality application. Impairments monitored during the application included heart rate, sweating, eye scanning and pain. Length of time the participant could engage in the application was tracked from one session to another to slowly increase the exposure.

B. CRPS

Complex regional pain syndrome is a sensory, vasomotor and autonomic disorder of an extremity which can result in disability and impacts to quality of life.[7] [8] [9] The pathophysiology of CRPS can be thought of as three major biological pathways: aberrant inflammatory mechanisms, vasomotor dysfunction and maladaptive neuroplasticity. [10] In patients with CRPS, there is a subset of individuals with strong autonomic symptoms. During therapy, patients with CRPS often demonstrate strong fight or flight responses to various therapeutic mediums. On questioning, these same responses are reported by the patients to occur in everyday life. These patients experience sweating, vertigo and extreme swelling of the limb. [7] [1] [10] These symptoms can be triggered and manifest themselves within seconds of the trigger. Therapists at TOHR have been using graded exposure to virtual environments with unique patient specific sensory triggers and coaching patients to learn to control the autonomic symptoms in the clinical environment. The underlying principle of treatment is that patients will be able to consciously control the autonomic symptoms using specific breathing and relaxation techniques found to be effective in each patient. Through controlled, repeated and progressive exposure to sensorimotor environments, maladaptive neural plasticity will be altered through new sensory learning. Pre and post outcome measures for pain, swelling, vertigo and sweating are used to achieve the appropriate therapeutic dosages and make necessary adjustments for the following session. Periodically outcome measures for lower extremity function and participation are rescored.

C. Post-Concussion Syndrome (PCS)

Virtual reality has previously been used for assessment of impairments and disabilities in patients suffering from brain injury. The specific areas that have been addressed are: executive dysfunction, memory problems, spatial problems, attention deficits and neglect. [11] The CAREN at TOHRC has been used to address all of the above areas, and in addition, therapists have started to include applications to address dysfunction in the ANS and autonomic symptoms in this population. As in treatment for CRPS and PTSD very short exposures to environments or task that induce PCS symptoms are initially used. Outcomes monitored in this population include: vertigo, headache, cognitive disturbance, and symptoms of autonomic dysfunctions (sweating, heart rate, pallor etc.). Pre-and post-measures, and time to reach baseline symptoms after treatment sessions are used to ensure the right therapeutic dosage is achieved.

See Appendix for pre/post data

III. .CONCLUSION

The findings of these three case studies provide insight into areas of further investigation of the use of virtual reality to alter the individual's environment to promote increasing arousal and activation of the sympathetic nervous system. This creates a repeatable and adaptable treatment environment to allow an individual to practice down regulation techniques to control the autonomic symptoms and create new adaptive neural networks.

REFERENCES

[1] C. Maihofner, F. Selfert and M. K, "Complex regional pain syndromes : new pathophysiological concepts and therapies.," *European Jouranl of Neurology,* pp. 649-660, 2010.

[2] J. Leddy, H. Sandhu, V. Sodhi, J. Baker and B. Willer, "Rehabilitation of Concussion and Post-conscussion Syndrome," *Sports Health,* vol. 4, no. 2, 2012.

[3] K. Meyer, "Understanding paroxysmal sympathetic hyperactivity after traumatic brain injury," *Surgical Neurology International,* vol. 5 (Suppl 13), p. S490–S492., 2014.

[4] J. Sherin and C. Nemeroff, "Post-traumatic stress disorder: The neurobioloigcal impact of psychological trauma," *Dialogues in Clinical Neurosciences,* vol. 13, no. 3, pp. 263-27, 2011.

[5] Eugene Lipov, "Post Traumatic Stress Disorder (PTSD) as an Over Activation of Sympathetic Nervous System: An Alternate View," *Trauma and Treatment,* vol. 3, no. 1, 2013.

[6] Robert McLay, V. Ram, J. Murphy, J. D. Spira, M. Wiederhold, B. Wiederhold, S. Johnston and D. Reeves, "Effect of Virtual Reality PTSD Treatment on Mood and Neurocognitive Outcomes," *Cyberpsychology, Behavior and Social Networking,* vol. 17, no. 7, pp. 439-446, 2014.

[7] S. Bruehl, "Subgroups of CRPS," in *International Association for the Study of Pain SIG CRPS Annual Meeting*, Zurich, 2015.

[8] B. S. Galer, J. Henderson, J. Perarander and M. P. Jensen, "Course of symptoms and quality of life measurement in complex regional pain syndrome: A pilot survey," *Journal of Pain and symptom Management,* vol. 20, no. 4, pp. 286-292, 2000.

[9] M. A. Kemler and H. C. de Vet, "Health-related quality of life in chronic refractory reflex sympathetic dystrophy (Complex Regional Pain Syndrome Type 1)," *Journal of Pain and Symptom Management,* vol. 20, no. 1, pp. 68-76, 2000.

[10] J. Marinus, L. B. F. Moseley, R. Barron, C. Maihofner, W. Kingery and J. Hilten, "Clinical features and pathophysiology of complex regional

pain syndrome.," *The Lancet,* vol. 10, pp. 637-48, 2011.

[11] F. Rose, B. Brooks and A. Rizzo, "Virtual Reality in Brain Damage Rehabilitation: Review," *Cyberpsychology and Behaviour,* vol. 8, no. 3, pp. 241-262, 2005.

Appendix: Clinical Data

Case A: PTSD and Pain

Numerical Pain Rating Scale		**Visual attention - scanning for threats**	
Pre	Post	Pre	Post
8/10	5/10	Constant visual scanning for threats with increased resp rate in VR environment	No longer scans for threats in VR environment. Normal resp rate. Progressing therapy to community program – busy stores etc.
Walking		**Sweating**	
Pre	Post	Pre	Post
L/S Pain immediately with walking	Can walk 1:10 without increasing sympto	Back/chest in VR environment	Does not happen in VR environment
Sleep		**Other**	
Pre	Post	Pre	Post
With use of pharmaceuticals for sleep average sleep 4 hours	With use of pharmaceuticals 8 hours sleep	Unable to approach silently from behind without fight response	Able to approach silently from behind and make physical contact without fight response

Case B: CRPS

Numerical Pain Rating Scale		**Lower Extremity Functional Scale**	
Pre	Post	Pre	Post
2/10- 8/10	0/10- 3/10	31/80	40/80
Vertigo/nausea		**Sweating**	
Pre	Post	Pre	Post
Nausea to the point had lost weight secondary to appetite loss – 30lb In daily life: Dizzy –room spins and somersaulting and frequent moments of spatial orientation disruption In VR environment nystagmus	Appetite restored – no nausea No dizziness in daily life, no room spins or somersaults. In VR environment – no nystagmus elicited	Back, right foot	none
Visual attention – Scanning for threats		**Walk/Run**	
Pre	Post	Pre	Post
In VR apps with buildings frequent scanning and heightened attention	In VR apps with buildings normal focus, no increased visual screening	Unable to run secondary to severe increases in pain and legs give way	1.5km at speed of 2.15 mph If he stays at this pace and distance no increases in pain and no giving way of legs
Sleep		**Other**	
Pre	Post	Pre	Post
Broken at 3-4 hours	Restorative at 8 hrs	Body schema – could not see right knee	Able to see right knee in body schema

Case C: PCS

Numerical Pain Rating Scale		**Functional Outcome Measure**	
Pre	Post	Pre	Post
4/10	1/10	Canadian Occupational Therapy Performance Measure (COPM) Task 1. Better balance Importance 8/10, Performance 4/10, Satisfaction 3/10 Task 2. Climbing stairs Importance 8/10, Performance 5/10, Satisfaction 1/10 Task 3. Reduce pain in left hip Importance 8/10 Performance 8/10, Satisfaction 1/10	COPM Task 1. Better balance Performance 7/10, Satisfaction 8/10 Task 2. Climbing stairs, Performance 7/10, Satisfaction 9/10 Task 3. Reduce pain in left hip Performance 8/10, Satisfaction 8/10