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To cite this article: Rosaria De Luca, Michele Torrisi, Adriana Piccolo, Giovanni Bonfiglio, Provvidenza Tomasello, Antonino Naro & Rocco Salvatore Calabrò (2017): Improving post-stroke cognitive and behavioral abnormalities by using virtual reality: A case report on a novel use of nirvana, *Applied Neuropsychology: Adult*, DOI: [10.1080/23279095.2017.1338571](https://doi.org/10.1080/23279095.2017.1338571)

To link to this article: <http://dx.doi.org/10.1080/23279095.2017.1338571>



Published online: 11 Oct 2017.



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## Improving post-stroke cognitive and behavioral abnormalities by using virtual reality: A case report on a novel use of nirvana

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### ABSTRACT

Cognitive impairment, as well as mood and anxiety disorders, occur frequently in patients following stroke. Aim of this study was to evaluate the effects of a combined rehabilitative treatment using conventional relaxation and respiratory techniques, in a specific rehabilitative virtual environment (by using Bts-Nirvana). A 58-year-old woman, affected by hemorrhagic stroke, underwent two different rehabilitation trainings, including either standard relaxation techniques alone in a common clinical setting or the same psychological approach in a semi-immersive virtual environment with an augmented sensorial (audio-video) and motor feedback (sensory motor-interaction). We evaluated the patient's cognitive and psychological profile before and after the two different trainings, by using a specific psychometric battery, aimed to assess cognitive status, attention processes and to estimate the presence of mood alterations, anxiety and coping strategies. Only at the end of the combined approach, we observed a significant improvement in attention and memory functions, with a nearly complete relief of anxiety symptoms and an improvement in coping strategies. Relaxation and respiratory techniques in a semi-immersive virtual reality environment, using Bts-Nirvana, may be a promising tool in improving attention process, coping strategies, and anxiety in individuals with neurological disorders, including stroke.

### KEYWORDS

Anxiety; Bts-Nirvana; virtual reality

### Introduction

Stroke is one of the main causes of mortality and the leading cause of disability in industrialized countries. Stroke is a neurological syndrome caused by a focal disruption in the cerebral blood flow due to occlusion (ischemic stroke) or rupture of a blood vessel (hemorrhagic stroke). Intracerebral hemorrhage has an overall incidence of 24.6 per 100,000 person-years and is associated with a high case fatality (Poon, Bell, & Salman, 2015). Stroke severity and progression are often assessed by using standardized measures, such as the National Institute of Health Stroke Scale (NIHSS), which contains 13 items and measures severity of impairment in consciousness, orientation, gaze, motor function, sensation, language, speech, and inattention (Lyden et al., 1999), and the modified Rankin scale that measures handicap or death on a scale of 1–6. Following stroke, especially after right hemisphere lesions, several psychological changes may arise, being depression and anxiety the most common (Koivunen, Harno, Tatlisumak, & Putaala, 2015). This may be directly related to the brain injury with the disruption of monoaminergic pathways and/or to the sudden worsening of

the quality of life triggered by the event, although previous pathological personality traits could be exacerbated by the event. Previous studies indicate that post-stroke anxiety is common and persistent (Cumming, Blomstrand, Skoog, & Linden, 2016), and this is attributable to a feeling of impotence and uncertainty about the future. Some personality factors, as coping strategies, can contribute to reduce or increase anxiety's level. Moreover, it has been found that after stroke most of the patients may experience some abnormalities in cognitive functioning and may have enduring difficulties in specific cognitive domains, such as attention process and concentration, memory abilities, spatial awareness, perception, praxis, and executive functioning (Hurford, Charidimou, Fox, Cipolotti, & Werring, 2013). Thus, a specific neuropsychological assessment should be the mainstay of post-stroke patient's management. Limited evidence showed the relationship between cognition processes and anxiety. Relaxation techniques can be considered a useful tool, determining a positive emotional and psychological well-being. Among these techniques, diaphragmatic breathing (DB), progressive muscle

relaxation, and autogenic training are characterized by a significant association between physical and cognitive dimension. The use of standard relaxation techniques in treating anxiety in patients undergoing post-stroke rehabilitation have shown some potential positive effects (Golding, Kneebone, & Fife-Schaw, 2016).

In the last years, virtual reality (VR) and interactive video gaming, are emerging as promising treatment approaches in stroke rehabilitation, both for cognitive rehabilitation and mood/anxiety disorder treatment (Laver, George, Thomas, Deutsch, & Crotty, 2015). Commercial gaming consoles have been rapidly adopted in clinical settings, given that VR has the ability to induce a feeling of “presence” in the computer-generated world experienced by the user (Riva et al., 2007).

Aim of this single case study was to evaluate the effects of a combined rehabilitative treatment using specific conventional relaxation and respiratory techniques, in a specific virtual rehabilitative environment, that is, Bts Nirvana (Figure 1) in a post stroke patient.

## Material and methods

A 58-year-old woman, affected by hypertension and hemorrhagic stroke (right putaminal lesion) in the postacute phase (i.e., 5 months from the brain injury), came to our observation for a severe anxiety state and a mild cognitive deficit. The patient, right-handed, was an housewife, married with two sons. To manage her emotional and cognitive condition, as she refused to take psychotropic drugs, she underwent two different rehabilitation trainings: the first including the use of standard relaxation techniques in a usual clinical (i.e., setting face to face with therapist), namely standard approach; and the second treatment using the same psychological approach in a semi-immersive virtual environment (i.e., combined approach). The two training protocols were



**Figure 1.** Shows relaxation and respiratory techniques in a Semi-Immersive Virtual Reality Environment (marine landscape) using Bts Nirvana System.

separated by 2-week interval, to better evaluate the different effects of the trainings. Each rehabilitation program was articulated in three sessions/weekly, for 2 months; each session lasted at least 40 minutes. A blinded to treatment skilled neuropsychologist evaluated the patient’s cognition and psychological status in two separate sessions: before and after the two different trainings, by using a specific psychometric battery, including Montreal Cognitive Assessment (MOca Test; Toggia, Fitzgerald, O’Dell, Mastrogianni, & Lin, (2011)), Attention Matrices test, Hamilton Rating Scale for Anxiety (HRS-A; Hamilton, (1959)), and Depression (HRS-D; Hamilton, (1960)), and Coping Orientation to the Problems Experienced-New Italian Version (COPE-NVI; Sica, Magni, Ghisi, Altoè, Sighinolfi, Chiri, & Franceschini, (2008)). Table 1 summarizes the behavioral, psychometric, functional, and vital parameters at the times of assessment. These psychometric tools aimed at evaluating the global cognition and attention processes, and to point out the presence of mood alterations, anxiety and coping strategies. The general functional status was evaluated using the Functional Independence Measure (FIM; Keith, Granger, Hamilton, & Sherwin, (1987)). The principal vital parameters (such as oxygen and heart rate) were also monitored as a more objective marker of the treatment efficacy. Reliable change index (RCI) was used to evaluate whether a change in an individual’s score (i.e, between T0 and T1, and T2 and T3) was statistically significant or not (based on how reliable the measure is). RCI is defined as the change in an individual’s score divided by the standard error of the difference (SEdiff) for the test being used. The boundary value for statistical significance within the RCI is  $\geq 1.96$  (1.96 equates to the 95% confidence interval). In other words, the difference between the two scores (pre–post) has to be at least twice 185 the SEdiff (i.e., 1.96 times the SEdiff) to be significant.

## Conventional rehabilitative session

The standard relaxation technique consisted of DB, induced by the instructions of the therapist within a quiet and noiseless environment. DB is a breathing technique that uses the contraction of the diaphragm muscle to move air downward into the body, which increases diaphragm length and breathing efficiency and facilitates more efficient exhalation. During the first minutes, the therapist invites the patient to assume a comfortable posture to facilitate muscular relaxation with well supported back, legs slightly apart at the same width of shoulders, arms on the legs and loose jaw. In the next 25 minutes, she was guided to DB; then she was invited to breath without using the chest district but the abdominal one, prompting to

**Table 1.** Comparison of behavioral, psychometric, functional, and vital parameters at T0-T1-T2-T3; mean raw data are reported.

Psychological and Cognitive status		Conventional Techniques			Virtual Reality Tool		
Domain	Psychometric Test	T0	T1	RCI	T2	T3	RCI
Global Cognition	M0ca Test	19/30	21/30		22/30	27/30	
	Visuo-spatial/executive	4/5	5/5		5/5	5/5	
	Naming	3/3	3/3		3/3	3/3	
	Divided Attention	0/2	1/2	3.1	1/2	2/2	3.1
	Selective Attention	0/1	0/1		0/1	1/1	3.1
	Substained Attention	1/3	1/3		2/3	3/3	3.1
	Language	2/2	2/2		2/2	2/2	
	Abstraction	1/2	1/2		1/2	1/2	
	Delayed Recall	2/5	2/5		2/5	4/5	3.1
	Orientation	6/6	6/6		6/6	6/6	
Attention Process	AM Test	31.5	33.5	3.1	30.5	50.5	3.1
Anxiety	HRS-A	20	18		21	15	3.0
Depression symptoms	HRS-D	13	11		12	6	3.2
Coping Strategies	Cope-NIV	98	100		94	106	
	Social support	15	15		13	28	3.1
	Avoidance strategies	26	26		26	15	3.2
	Positive attitude	16	18		14	22	3.1
	Problem Solving	19	19		19	19	
	Turning to religion	22	22		22	22	
	Functional Status	FIM	70	75		75	90
Vital Parameter	Blood pressure Average value	192/85	190/83		150/72	129/65	
Vital Parameter	Heartbeat Average value	103	100		98	70	

Note. M0ca Test (Montreal Cognitive Assessment); cut-off =  $\leq 25$ . AM (Attentive Matrices Test); cut-off =  $\leq 30$ . HRS-A (Hamilton Rating Scale for Anxiety); cut-off =  $\geq 8$ . HRS-D (Hamilton Rating Scale for Depression) cut-off =  $\geq 8$ . Cope-NIV (Coping Orientation to Problems Experienced - New Italian Version); Range from 72 to 228. FIM (Functional Independent Measure); cut-off = 0–100. Blood Pressure's average value pre and post conventional and virtual treatment. Heartbeat's Average value pre and post conventional and virtual treatment.

hold a hand to stomach as self-monitoring function. In the final step, lasting 10 minutes, we asked to tell physical and emotional feelings experienced during the treatment.

### Virtual rehabilitation session

The same rehabilitative treatment (relaxation technique and DB) was realized in a semi-immersive virtual environment mediated by the BTS Nirvana System. BTS-Nirvana is the first therapeutic system aiding the rehabilitation process of patients affected by neuro-motor diseases through multisensory stimulation. BTS-Nirvana is particularly recommended in the rehabilitation therapy of patients with motor and cognitive dysfunctions caused by brain injury, including stroke. Standard BTS-Nirvana equipment is composed by 1 or 2 markerless infrared sensors, a workstation touch screen, camera supports (different models available), the BTS-Nirvana software and a Webcam. BTS-Nirvana is a movement-based system providing patients with VR scenarios to interact with. The system, connected to a projector or a big screen, reproduces an interactive series of exercises, and thanks to an infrared video camera analyzing the patient's movements, it creates interactivity. For our rehabilitative protocol, we used the virtual scenario with a marine landscape (Freshness & Water classic), and an augmented sensorial (audio-video) and motor feedback (sensory motor-interaction) (Figure 1).

### Results

At the end of the conventional training, using standard relaxation techniques (T1) including DB, the patient presented a significant improvement only in the attention functions; also, mood improved with a reduction of crying episodes and negative thoughts, but without significant changes. At the end of the respiratory training in the virtual environment, we instead observed a significant improvement in cognitive and behavioral functioning. In particular, a significant improvement in attention processes and verbal memory, and a reduction of anxiety symptoms (i.e., HRS-A: from 21 at T2 to 15 at T3; RCI = 3) were detected, as well as an optimization of the coping strategies in social support and positive attitude to the solution of problem, with an important decrease of the avoidance strategies (Table 1). Moreover, by monitoring the vital parameters, we found a gradually reduction of hearth rate and blood pressure (Table 1), which more objectively confirmed the anxiety relief.

Notably, the improvement in anxiety levels let the patient perform a better motor rehabilitation, given that prior to the VR training she was not able to undergo Lokomat.

### Discussion

Anxiety is a biological warning system that prepares us for action (Hoehn-Saric, McLeod, Funderburk, & Kowalski, 2004), as it is a multisystem response to a

perceived threat or danger. Anxiety reflects a combination of biochemical changes in the body, the patient's personal history and memory, and the social situation during acute stress. Thalamus has an important role in anxiety onset, given that it receives sensorial afferences, projecting them to different brain areas, including locus coeruleus, amygdala, orbitofrontal, and associative cortex. The exposition to an anxiogenic stimulus cause a modification of noradrenergic, serotonergic, and dopaminergic systems and an inhibition of gamma-aminobutyric acid (GABA) effects (Pilc & Nowak, 2005). It is reasonable to assume that patients with chronic anxiety disorders exhibit physiologic hyperarousal at rest or heightened physiologic responses to stressors (Hoehn-Saric, Hazlett, & McLeod, 1993). The most consistent finding in patients with anxiety is an increased muscle tension, whereas autonomic changes are found less consistently. Moreover, most studies of patients with anxiety rely on self-reports of somatic symptoms, despite the fact that somatic manifestations often correlate poorly with physiologic states and reactions, and cannot be taken at face value. Relaxation techniques, including DB, has been widely used for the treatment of anxiety state to facilitate management of symptoms in cardiac (Lee et al., 2003), gastric (Halland, Parthasarathy, Bharucha, & Katzka, 2016), and pulmonary diseases (Fernandes, Cukier, & Feltrim, 2011). Diaphragmatic breathing relaxation (DBR) has previously been considered as one of the most useful techniques to achieve reductions in stress and anxiety (Chen, Huang, Chien, & Cheng, 2016; Kim, Roth, & Wollburg, 2015). However, its use in stroke patients has not reported thus far, because autogenic technique have been preferred. DB has been shown to have a relaxing and stabilizing effect on the autonomic nervous system, by increasing carbon dioxide levels in the blood and strengthens parasympathetic nervous activity (Kneebone, Walker-Samuel, Swanston, & Otto, 2014). In our study, the monitoring of vital parameters was used as a potential tool to evaluate response to treatment, as pressure and heart rate are controlled by the autonomic system, which, in turn, is influenced by anxiety.

During the last decade a number of studies have been conducted in order to examine whether VR therapy can be an alternative treatment for anxiety disorders. Virtual reality, a system of human-computer interaction that allows researchers and clinicians to immerse people in virtual worlds, is gaining considerable interest as a research, education, and treatment tool. There are numerous strengths underlying the use of VR with rehabilitation. Indeed, VR may provide the opportunity for ecological validity, stimulus control and consistency,

real-time performance feedback, independent practice, stimulus and response modifications based on a user's physical abilities, a safe testing and training environment, the opportunity for graduated exposure to stimuli, the ability to distract or augment the performer's attention (Keshner, 2004). Specifically, the multisensory feedback, like the one used in our virtual scenario, can be considered a relevant tool to increase patients' involvement, and motivation leading to better rehabilitative outcomes. Moreover, the Knowledge of results during a task-oriented exercise in such a virtual environment, in addition to the knowledge of performance, may facilitate the reinforcement learning, by boosting neuplastic change.

Virtual reality has been used successfully to treat anxiety disorders such as fear of flying and post-traumatic stress disorder, as an aid in stroke rehabilitation, and as a behavior modification aid in the treatment of attention deficit disorder (Bordnick, Carter, & Traylor, 2011). About that, Calabrò et al. (2015) showed that robot-assisted movement training with virtual avatar may improve not only motor function (including gait, balance, and muscle force), but also mood, cognition, and coping strategies.

To the best of our knowledge, this is the first time that BTS-Nirvana System has been used as a tool in improving anxiety. We believe that identifying innovative techniques, relieving anxiety in patients with stroke is very important, given that an altered emotional state can compromise the motivation for rehabilitation treatments or slow down the recovery. Villani, Riva, and Riva (2007) have investigated the efficacy of VR, as a supported tool, in the relaxation process (Calabrò et al., 2015). The virtual experience was supported by a relaxing narrative, using a virtual environment, denominated *Relaxation Island* (European Project EMMA – IST-2001-39192). This protocol showed that the use of combined relaxation strategies in a specific virtual environment with a high level of presence, could be a promising rehabilitative approach (Villani et al., 2007).

Although we are not completely able to exclude the role played by the conventional treatment with a consequent cumulative effect, we believe that patient's improvement was mainly due to the effect of the combined approach by using VR, given that the changes of anxiety levels and cognitive abilities were greater between T2 and T3 than between T0-T1.

According to our findings, the state of relaxation also leads to an improvement in cognitive status coping strategies. As known, these consist of manners by which people face difficult situations, and can be functional or dysfunctional. After the VR treatment, our patient showed a reduction of avoidance strategies' use that is

a dysfunctional strategy and an increase of functional strategies as positive attitude.

## Conclusions

Relaxation and respiratory techniques in a semi-immersive VR environment, using proper and dedicated tools such as Bts-Nirvana, may be promising in improving attention process, coping strategies, and in reducing anxiety symptoms in patients with neurological disorders, including stroke. Future studies should be fostered to confirm our findings on this novel use of VR.

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