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Virtual Reality: A Breakthrough in Pain Management?

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ABSTRACT

Virtual reality is a computer-generated scenario in which the user can interact in 3 dimensions so that the user feels that he or she is part of the scene. Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage. Pain is often undertreated and this comes along with several consequences, such as anger, depression, anxiety, workplace absenteeism, underemployment, unemployment and fear, among others. In the past decade, there has been need to find a safer way of controlling chronic pain without the necessary complication of opioid misuse. Virtual reality has been proved to be a safer adjunct for this. Several studies have reported that virtual reality is quite effective for pain management, with participants reporting significant relief of symptoms. The discovery of the use of virtual reality in the management of pain may prove to be a breakthrough in pain medicine, saving people from the complications of prolonged opioid use and opioid misuse. However, more research still has to be done to fully establish the mechanism of action and use of virtual reality in pain management, especially in the management of chronic pain. This would be a true breakthrough, allowing the full safety and effectiveness of virtual reality to be harnessed.

Keywords: Pain, virtual reality, breakthrough

1. INTRODUCTION

Sherman and Craig (2002) defined virtual reality as a computer-generated scenario in which the user can interact in 3 dimensions so that the user feels that he or she is part of the scene. The virtual reality system consists of the external tools (senses); internal tools (trackers,

gloves, joysticks, etc.); a system of graphic imaging rendering that creates the virtual environment; and the software and database. These work together, making the virtual reality system facilitate the interaction between the senses (olfactory, auditory, visual or haptic) and a virtual reality, to enable the person experience the virtual reality as if it were real (Riva, 2006; Matijevic *et al.*, 2013). The characteristics of the components of virtual reality used may greatly influence the response of the users, necessitating appropriate choices of the component before use (Rand *et al.*, 2005; Dahlquist *et al.*, 2007; Mahrer and Gold, 2009; Gupta *et al.*, 2017).

The International Association for the Study of Pain defined pain as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (Merskey *et al.*, 1979). Pain is a personal experience, it is a subjective phenomenon. McCaffrey and Beebe (1989) explained that “pain is whatever the person experiencing it says it is.” Hence, pain management should be beyond management of the underlying tissue injury, since the experience may be emotional. Plato described pain as a penalty arising from within the body, which may be more of an emotional experience (Kumar and Elavarasi, 2016).

Pain, being a broad concept, can be classified based on different criteria. The classification can be based on duration, location, intensity, type of patient, the circumstances of the pathology, etc. (Thienhaus and Cole, 2002). Based on the duration of pain, pain can be largely classified into acute and chronic pain (Turk and Okifuji, 2001; Mcpherson *et al.*, 2004). Acute pain is defined as pain of less than three (3) to six (6) months; and chronic pain is pain that persists beyond 6 months, or after tissue healing is complete. However, acute and chronic pain are no longer defined based on their duration alone anymore, as it has been discovered that beyond the duration, the two types of pain differ in underlying pathologies and characteristics (Jacox *et al.*, 1992; Carr and Goudas, 1999; Chapman and Nakamura, 1999; Dunajcik, 1999; Jacobsen and Mariano, 2001).

As much as pain is a common concept, it is often undertreated (Carr and Goudas, 1999). Several consequences have been related to untreated and undertreated pain. These include anger, depression, anxiety, workplace absenteeism, underemployment, unemployment, fear, among others (Teoh and Stjernsward, 1992). However, over the years, pain management has received focus with the development of different methods of managing pain, and safety as a major consideration (Becker *et al.*, 1997; Butler *et al.*, 1997; Fox *et al.*, 2000). One of such forms of management is virtual reality.

The concept of virtual reality has existed for several decades, but has received more attention than ever in recent times. This development has been largely attributed to technological advancements and substantial investment in the industry (Van Bottenburg and Salome, 2010). This intervention has been found to be useful for pain management (Kuhlen and Dohle, 1995; Rose *et al.*, 1996; Jack *et al.*, 2001; Reid, 2002; Tarr and Warren, 2002; Fulk, 2005; Haik *et al.*, 2006; Mirelman *et al.*, 2010; Albiol-Perez *et al.*, 2015). Virtual reality has been reported to have enhanced safer practicing and training environment, and also ensured customization of treatment needs with increased flexibility of assessment and training procedures (Sveistrup, 2004; Rizzo and Kim, 2005).

In the past decade, there has been a need to find a safer way of controlling chronic pain without the necessary complication of opioid misuse, and virtual reality has been proved to be a safer adjunct for this (Gershon *et al.*, 2004; Chan *et al.*, 2007; Hoffman *et al.*, 2008; Maani *et al.*, 2011; Mosso *et al.*, 2012; Jones *et al.*, 2016).

2. PRINCIPLE OF MANAGEMENT OF PAIN USING VIRTUAL REALITY

As a modality that has been discovered to have therapeutic value in the management of pain, it is important to understand, the principle by which this therapeutic value is achieved. The principles by which virtual reality helps in managing acute and chronic pain vary. The process of acute pain management has been largely related to the distraction of the individual from the pain (Distraction Therapy). This is because pain requires attention and people have limited capacity for paying attention (Villemure and Bushnell, 2002). Hence, an individual who is experiencing pain and is immersed in the “pleasurable” world of virtual reality, has limited attention left to process the pain signals in the body (Melzack and Wall, 1965; Malloy and Milling, 2010; Hoffman *et al.*, 2011). Dahlquist *et al.* (2007) suggested that in distracting an individual from his or her pain, interactive distraction, such as virtual reality, is more effective than passive distraction.

In the management of chronic pain, however, there are more opinions suggesting that the use virtual reality in combination with cognitive behavioural therapy (CBT) is the effective principle of pain control (Shiri *et al.*, 2013; Loreto-Quijada *et al.*, 2014; Morris *et al.*, 2015; Garcia-Palacios *et al.*, 2015). The pain pathways involving attention, emotion, concentration, memory, touch, auditory and visual senses are altered directly or indirectly through this concept (Gold *et al.*, 2007; Mahrer and Gold, 2009; Garrett *et al.*, 2017). The subjective perception of pain by the individual is changed by altering the sensory, cognitive and affective traits of pain (Mura, 2010). The overall reduction in activities in the pain matrix may lead to consequent increase in the activity in the anterior cingulate cortex and orbitofrontal regions of the brain (Li *et al.*, 2012). Hoffman (2004) opined that virtual reality may change the physical registration of pain by the pain and not just the perception of the stimuli. The exact neurophysiologic mechanisms involved in chronic pain modulation are unknown. It is suggested that the descending inhibitory pathways in the CNS are involved in this process (Sharar *et al.*, 2008). However, there is more evidence suggesting that virtual reality works based on the principle of distraction than on direct or indirect alteration of the sensory, cognitive and affective traits (Bantick *et al.*, 2002; Malloy and Milling, 2010; Gupta *et al.*, 2017) and more research has to be carried out to explore this area.

3. EFFICACY OF VIRTUAL REALITY IN PAIN MANAGEMENT

Over the years, several works have been done to ensure safe and effective management of pain, especially with the rise in incidence of opioid abuse around the world. Following the attention virtual reality began to receive, it has been considered important for its efficacy to be investigated. Several studies have reported that virtual reality is quite effective for pain management, with participants reporting significant relief of symptoms (Cole *et al.*, 2009; Saring-Bahat *et al.*, 2010; Patterson *et al.*, 2010; Botella *et al.*, 2013; De Tommaso *et al.*, 2013; Ramachandran and Seckel, 2013; Wiederhold *et al.*, 2014). It has been found to be quite effective in women, men, and children alike. There are evidences supporting the use of virtual reality therapy in the management of fibromyalgia, pruritus, phantom limb pain, pain from physical trauma, chronic headache, migraine, pains from burns, among others (Hoffman *et al.*, 2001; Cole *et al.*, 2009; Leibovici *et al.*, 2009; Patterson *et al.*, 2010; Botella *et al.*, 2013; Ramachandran and Seckel, 2013; Shiri *et al.*, 2013; De Tommaso *et al.*, 2013). Studies have

shown that virtual reality can be used as a safe adjunct or alternative to the use of opioids (Hoffman *et al.*, 2000; Hoffman *et al.*, 2001; Gershon *et al.*, 2004; Patterson *et al.*, 2006; Chan *et al.*, 2007; Sharar *et al.*, 2007; Van Twillert *et al.*, 2007; Hoffman *et al.*, 2008; Maani *et al.*, 2008; Maani *et al.*, 2011; Mosso *et al.*, 2012).

There is significant research supporting the use of virtual reality in the management of acute pain, however, this cannot be said about chronic pain, necessitating need for research in this area (Li *et al.*, 2012; Keefe *et al.*, 2012). Only few studies have examined the efficacy of virtual reality in the management of chronic pain. It has recently been discovered that virtual reality can be used to augment hypnosis in the treatment of chronic pain (Oneal *et al.*, 2008). However, it is currently unknown whether virtual reality has an effect on chronic pain or not, even though some studies have reported relief of pain symptom in participants (Jones *et al.*, 2016).

4. BREAKTHROUGH OR NOT?

Over the years, opioids have been largely used in the management of pain. However, in recent years, cases of opioids misuse, addiction and dependence have increased and become alarming, resulting in the death of millions of individuals around the world (Vowles *et al.*, 2015; Hser *et al.*, 2015; Rudd *et al.*, 2016). Several studies have revealed that virtual reality is quite efficacious in the management of pain, and can be used as an adjunct or alternative in pain management (Hoffman *et al.*, 2000; Hoffman *et al.*, 2001; Gershon *et al.*, 2004; Patterson *et al.*, 2006; Sharar *et al.*, 2007; Van Twillert *et al.*, 2007; Chan *et al.*, 2007; Maani *et al.*, 2008; Hoffman *et al.*, 2008; Mosso *et al.*, 2012; Jones *et al.*, 2016). This situation has stimulated pain physicians to look for other methods of pain control that are effective, but safer than the use of opioids (Jones *et al.*, 2016). Hoffman *et al.* (2007) also reported that the analgesic effect produced by virtual reality is similar to the magnitude of pain relief produced by clinically relevant doses of systemic opioids.

The discovery of the use of virtual reality in the management of pain may prove to be a breakthrough in pain medicine, saving people from the complications of prolonged opioid use and opioid misuse. However, a lot of research still has to be done to fully establish the mechanism of action and use of virtual reality in pain management, especially in the management of chronic pain. This would be a true breakthrough, allowing the full safety and effectiveness of virtual reality to be harnessed.

5. CONCLUSION

In conclusion, virtual reality has been suggested as an effective and safer approach to the management of pain. It can be used in place of opioids, thereby helping the fight against opioid abuse. However, due to the differences in the characteristics of acute and chronic pain, the approach does not follow the same principle in the management of the two types of pain. While there are several studies supporting the use of virtual reality in the management of acute pain, there are limited studies to support the use in the management of chronic pain. More research has to be carried out to investigate the effectiveness of virtual reality in the management of chronic pain. This may prove to facilitate better pain management.

References

- [1] Albiol-Perez S., Forcano-Carcia M., Munoz-Tomas M.T., Manzano-Fernandez P., Solsona-Hernandez S., Mashat M.A., and Gil-Gomez J.A. 2015. A novel virtual motor rehabilitation system for Guillain-barre syndrome. *Methods of Information in Medicine* 54(2): 127-134
- [2] Bantick S.J., Wise R.G., Ploghaus A., Clare S., Smith S.M., and Tracey I. (2002). Imaging how attention modulates pain in humans using functional MRI. *Brain* 125: 310-319
- [3] Becker N., Bondegaard T.A., Olsen A.K., Slogren P., Bech P., and Erikson J. (1997) Pain epidemiology and health related quality of life in chronic non-malignant pain patients referred to a Danish multidisciplinary pain center. *Pain* 73: 393-400
- [4] Botella C., Garcia-Palacios A., Vizcaino Y., Herrero R., Banos R.M., and Belmonte M.A. (2013). Virtual reality in the treatment of fibromyalgia: a pilot study. *Cyberpsychology, Behavior and Social Networking* 16: 215-223
- [5] Butler R.J., Hartwig R., and Gardner H.H (1997). HMOs moral hazard and cost shifting in workers' compensation. *Journal of Health Economics* 16: 191-206.
- [6] Carr D.B. and Goudas L.C (1999). Acute pain. *Lancet* 353(9169): 2051-2058
- [7] Chan E.A., Chung J.W., Wong T.K., Lien A.S., and Yang J.Y. (2007) Application of a virtual reality prototype for pain relief of paediatric burn in Taiwan. *Journal of Clinical Nursing* 16 (4): 786-793
- [8] Chapman C.R. and Nakamura Y.A. (1999) Passion of the Soul: an introduction to pain for consciousness researchers. *Consciousness Cognition* 8: 391-422
- [9] Cole J., Crowle S., Austwick G., and Slater D.H. (2009) Explanatory findings with virtual reality for phantom limb: from stump motion to agency and analgesia. *Disability and Rehabilitation* 31: 846-854
- [10] Dahlquist L.M., McKenna K.D., Jones K.K., Dillinger L., Weiss K.E., and Ackerman C.S. (2007) Active and passive distraction using a head-mounted display helmet: Effects on cold pressor pain in children. *Journal of Health Psychology* 26: 794-801.
- [11] De Tommaso M., Ricci K., Laneve L., Savino N., Antonaci V., and Livrea P. (2013) Virtual visual effect of hospital waiting room on pain modulation in healthy subjects and patients with chronic migraine. *Pain Research and Treatment* 2013: 515730
- [12] Dunajcik L. (1999) Chronic nonmalignant pain. In: McCaffery M, Pasero C, eds. *Pain Clinical Manual*, 2nd ed. St. Louis, MO: Mosby Inc: 1999: 467-521
- [13] Fox C.D., Berger D., Fine P.G. *et al.* (2000) Pain assessment and treatment in the managed care environment. A position statement from the American Pain Society. Glenview, IL: American Pain Society
- [14] Fulk G. (2005). Locomotor training and virtual reality-based balance training for an individual with multiple sclerosis: a case report. *Journal of Neurologic Physical Therapy* 29(1): 34-42

- [15] Garcia-Palacios A., Herrero R., Vizcaino Y., Belmonte M.A., Castilla D., Molinari G., Banos R.M., and Botella C. (2015). Integrating virtual reality with activity management for the treatment of fibromyalgia: Acceptability and preliminary efficacy. *The Clinical Journal of Pain* 31: 564-572
- [16] Garrett B., Taverner T., and McDade P. (2017) Virtual reality as an adjunct home therapy in chronic pain management: An exploratory study. *JMIR Medical Informatics* 5(2): e11
- [17] Gershon J., Zimand E., Pickering M., Rothbaum B.O., and Hodges L. (2004). A pilot and feasibility study of virtual reality as a distraction for children with cancer. *Journal American Academy of Child and Adolescent Psychiatry* 43 (10): 1243-1249
- [18] Gold J.I., Belmont K., and Thomas D. (2007). The neurobiology of virtual reality pain attenuation. *Cyberpsychology, Behaviour, and Social Networking* 10(4): 536-544
- [19] Gupta A., Scott K., and Dukewich M. (2017) Innovative technology using virtual reality in the treatment of pain: Does it reduce pain via distraction, or is there more to it? *Pain Medicine* 19(1): 151-159
- [20] Haik J., Tessone A., Nota A., Mendes D., Raz L., Goldan O., Regev E., Winkler E., Mor E., Orenstein A., and Hollombe I. (2006). The use of video capture virtual reality in burn rehabilitation: the possibilities. *Journal of Burn Care and Research* 27(2): 195-197
- [21] Hoffman H.G. (2004) Virtual reality therapy. *Scientific American* 291(2): 58-65
- [22] Hoffman H.G., Chambers G.T., Meyer W.J., 3rd, Arceneaux L.L., Russell W.J., Seibel E.J., Richards T.L., Sharar S.R., and Patterson D.R. (2011) Virtual reality as an adjunctive non-pharmacologic analgesic for acute burn pain during medical procedures. *Annals of Behavioural Medicine* 41(2): 183-191
- [23] Hoffman H.G., Patterson D.R., and Carrougher G.J. (2000). Use of virtual reality for adjunctive treatment of adult burn pain during physical therapy: a controlled study. *The Clinical Journal of Pain* 16(3), 244-250
- [24] Hoffman H.G., Patterson D.R., Carrougher G.J., and Sharar S.R. (2001). Effectiveness of virtual reality-based pain control with multiple treatments. *The Clinical Journal of Pain* 17(3), 229-235
- [25] Hoffman H.G., Patterson D.R., Seibel E., Soltani M., Jewett-Leahy L., and Sharar S.R. (2008) Virtual reality pain control during burn wound debridement in the hydrotank. *The Clinical Journal of Pain* 24 (4): 299-304
- [26] Hoffman H.G., Richards T.L., Van Oostrom T., Coda B.A., Jensen M.P., Blough D.K., and Sharar S.R. (2007) The analgesic effects of opioids and immersive virtual reality distraction: Evidence from subjective and functional brain imaging assessments. *Anesthesia and Analgesia* 105(6): 1776-1783
- [27] Hser Y.I., Evans E., Grella C., Ling W., and Anglin D. (2015) Long-term course of opioid addiction. *Harvard Review of Psychiatry* 23: 76-89

- [28] Jack D., Boian R., Merians A.S., Tremaine M., Burdea G.C., Adamovich S.V., Recce M., and Poizner H. (2001). Virtual reality-enhanced stroke rehabilitation. *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 9(3): 308-318
- [29] Jacobsen L. and Mariano A. (2001) General considerations of chronic pain. In: Loeser JD, Butler SH, Chapman CR, et al, eds. *Bonica's Management of Pain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins 241-254
- [30] Jacox A.K., Carr D.B., Chapman C.R. *et al.* (1992) Acute pain management: Operative or medical procedures and Trauma clinical practice guideline. No 1, Rockville, MD: US Department of Health and Human Services, Agency for Health Care Policy and Research. AHCPR publication 92-0032
- [31] Jones T., Moore T., and Choo J. (2016) The Impact of Virtual Reality on Chronic Pain. *PLoS One* 11(12): e0167523
- [32] Keefe F.J., Huling D.A., Coggins M.J., Keefe D.F., Rosenthal M.Z., Herr N.R., and Hoffman H.G. (2012) Virtual reality for persistent pain: A new direction for behavioural pain management. *Pain* 153(11): 2163-2166
- [33] Kuhlen T. and Dohle C. (1995) Virtual reality for physically disabled people. *Computers in Biology and Medicine* 25: 205-211
- [34] Kumar K.H. and Elavarasi P. (2016). Definition of pain and classification of pain disorders. *Journal of Advanced Clinical & Research Insights* 3: 87-90
- [35] Leibovici V., Magora F., Cohen S., and Ingher A. (2009) Effects of virtual reality for phantom limb pain: from stump motion to agency and analgesia. *Disability and Rehabilitation* 31: 846-854
- [36] Li A., Montano Z., Chen VJ., and Gold J.I. (2012). Virtual reality and pain management: current trend and future directions. *Pain Management* 1(2): 147-157
- [37] Loreto-Quijada D., Gutierrez-Maldonado J., Nieto R., Gutierrez-Martinez O., Ferrer-Garcia M., Saldana C., Fuste-Escolano A., and Liutsko L. (2014). Differential effects of two virtual reality interventions: Distraction versus pain control. *Cyberpsychology, Behaviour, and Social Networking* 17: 353-358
- [38] Maani C.V., Hoffman H.G., DeSocio P.A., Morrow M., Gaylin C., and Magula J. (2008). Pain control during wound care for combat-related burn injuries using custom articulated arm mounted virtual reality goggles. *Journal of CyberTherapy and Rehabilitation* 1(2): 193-198
- [39] Maani C.V., Hoffman H.G., Morrow M., Maiers A., Gaylord K., McGhee L.L., and DeSocio P.A. (2011). Virtual reality pain control during burn wound debridement of combat-related burn injuries using robot-like arm mounted VR goggles. *Journal of Trauma and Acute Care* 71 (1 Suppl): S125-130
- [40] Mahrer N.E. and Gold J.I. (2009) The use of virtual reality for pain control: a review. *Current Pain and Headache Report* 13(2): 100-109
- [41] Malloy K.M. and Milling L.S. (2010). The effectiveness of virtual reality distraction for pain reduction: A systematic review. *Clinical Psychology Review* 30: 1011-1018

- [42] Matijevic Dunajcik, V., Secic A., Masic V., Sunic M., Kolak Z., and Znika M. (2013). Virtual reality in rehabilitation and therapy. *Acta Clinica Croatia* 52: 453-457
- [43] McCaffery M. and Beebe A. (1989). Pain: clinical manual for nursing practice. C.V. Mosby, St Louis.
- [44] Mcpherson M.L., Canaday BrR., Heit H.A., *et al.* (2004). A pharmacist's guide to the clinical assessment and management of pain. In: Science PPa, editor. University of Maryland, Baltimore: American Pharmacist Association.
- [45] Melzack R. and Wall P.D. (1965) Pain mechanism: A new theory. *Science* 150: 971-979
- [46] Merskey H., Albe Fessard D., Bonica J.J., Carmon A., Dubner R., Kerr F.W.L., Lindblom U., Mumford J.M., Nathan P.W., Noordenbos W., Pagni C.A., Renaer M.J., Sternbach R.A., and Sunderland S. (1979). Pain terms: A list with definitions and notes on usage. Recommended by the IASP subcommittee on taxonomy. *Pain* 6: 249-952
- [47] Mirelman A., Maidan I., Herman T., Deutsch J., Giladi N., and Hausdorff J. (2010). Virtual reality for gait training: can it induce motor learning to enhance complex walking and reduce fall risk in patients with Parkinson's disease? *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences* 66(2): 234-240
- [48] Morris L.D., Louw Q.A., Grimmer K.A., and Meintjes E. (2015). Targeting pain catastrophization in patients with fibromyalgia using virtual reality exposure therapy: A proof-of-concept study. *Journal of Physical Therapy Science* 27: 3461-3467
- [49] Mosso J.L., Obrador G.T., Wiederhold B., Wiederhold M., Lara V., and Santander A. (2012) Cybertherapy in Medicine- Experience at the Universidad Panamericana, IMSS and ISSSTE Mexico.
- [50] Mura G. (2010) Metaplasticity in virtual worlds: Aesthetics and Semantic Concepts. Hershey, PA: IGI Global. The Mediation Chamber; pp. 133-156
- [51] Oneal B.J., Patterson D.R., Soltani M., Teeley A., and Jensen M.P. (2008) Virtual reality hypnosis in the treatment of chronic neuropathic pain: a case report. *International Journal of Clinical and Experimental Hypnosis* 56(4): 451-462
- [52] Patterson D.R., Hoffman H.G., Palacios A.G., Jensen M.J. (2006). Analgesic effects of posthypnotic suggestions and virtual reality distraction on thermal pain. *Journal of Abnormal Psychology* 115, 834-841
- [53] Patterson D.R., Jensen M.P., Wiechman S.A., and Sharar S.R. (2010) Virtual reality hypnosis for pain associated with recovery from physical trauma. *The International Journal of Clinical and Experimental Hypnosis* 58(3): 288-300
- [54] Ramachandran V.S. and Seckel E.L. (2013) Using mirror visual feedback and virtual reality to treat fibromyalgia. *Medical Hypotheses* 75: 495-496
- [55] Rand D., Kizony K., Feintuch U., and Katz N. (2005) Virtual reality in neurorehabilitation. In: Textbook of neural repair and neurorehabilitation. Selzer M.E., Cohen L., Gage F.H., Clarke S., Duncan P.W., editors. New York: Cambridge Press.

- [56] Reid D.T. (2002). Benefits of a virtual play rehabilitation environment for children with cerebral palsy on perceptions of self-efficacy: A pilot study. *Journal of Pediatric Rehabilitation* 5(3): 141-148
- [57] Riva G. (2006) Virtual reality. In. Wiley Encyclopedia of biomedical engineering. Grad: Hoboken, NJ, USA: John Wiley and Sons, Inc.
- [58] Rizzo A.A. and Kim G. (2005) A SWOT analysis of the field of virtual rehabilitation and therapy. *Presence: Teleoperators and virtual environments* 14(2): 119-146
- [59] Rose F.D., Attree E.A., and Johnson D.A. (1996) Virtual reality: an assistive technology in neurological rehabilitation. *Current Opinion in Neurology* 9: 461-467
- [60] Rudd R.A., Seth P., David F., and Scholl L. (2016). Increases in drug and opioid-involved overdose deaths- United States, 2010-2015. *MMWR Morbidity and Mortality Weekly Report* 65: 1445
- [61] Saring-Bahat H., Weiss P.L., and Laufer Y. (2010) Neck pain assessment in a virtual environment. *Spine (Phila Pa 1976)*. 2010; 35(4): E105-E112.
- [62] Sharar S.R., Carrougher G.J., Nakamura D., Hoffman H.G., Blough D.K., and Patterson D.R. (2007). Factors influencing the efficacy of virtual reality distraction analgesia during postburn physical therapy: preliminary results from 3 ongoing studies. *Archives of Physical Medicine and Rehabilitation* 88 (12 Suppl 2), S43-49
- [63] Sharar S.R., Miller W., Teeley A., Soltani M., Hoffman H.G., Jensen M.P., and Patterson D.R. (2008). *Expert Review of Neurotherapeutics* 8(11): 1667-1674
- [64] Sherman W., Craig A. (2002) Understanding virtual reality: Interface, application, and design. California: Morgan Kaufmann
- [65] Shiri S., Feintuch U., Weiss N., Pustlnik A., Geffen T., Kay B., Meiner Z., and Berger I. (2013). A virtual reality system combined with biofeedback for treating pediatric chronic headache- a pilot study. *Pain Medicine* 14: 621-627
- [66] Sveistrup H. (2004). Motor rehabilitation using virtual reality. *Journal of NeuroEngineering and Rehabilitation* 1(1): 10
- [67] Tarr M.J. and Warren W.H. (2002) Virtual reality in behavioural neuroscience and beyond. *Nature Neuroscience* 5: 1089-1092
- [68] Teoh N., Stjernsward J. (1992) WHO cancer pain relief program: ten years on. IASP Newsletter.
- [69] Thienhaus O. and Cole B.E. (2002). Classification of Pain. Pain Management: A Practical Guide for Clinicians. 27-36
- [70] Turk D.C. and Okifuji A. (2001). Pain and taxonomies of pain In: Bonica's management of pain. Pp17-25., 3rd edition. Ed. Loeser J.D., Lippincott Williams & Wilkins, Philadelphia.
- [71] Van Bottenburg M. and Salome L. (2010). The indoorisation of outdoor sports: An exploration of the rise of lifestyle sports in artificial settings. *Leisure Studies* 29, 143-160

- [72] Van Twillert B., Bremer M., and Faber A.W. (2007). Computer-generated virtual reality to control pain and anxiety in pediatric and adult burn patients during wound dressing changes. *Journal of Burn Care and Research* 28(5), 694-702
- [73] Villemure C. and Bushnell M.C. (2002) Cognitive modulation of pain: How do attention and emotional influence pain processing? *Pain* 95, 195-199
- [74] Vowles K.E., McEntee M.L., Julnes P.S., Frohe T., Ney J.P., and van der Goes D.N. (2015). Rates of opioid misuse, abuse, and addiction in chronic pain: A systematic review and data synthesis. *Pain* 156: 569-576
- [75] Wiederhold B.K., Gao K., Sulea C., and Wiederhold M.D. (2014). Virtual reality as a distraction technique in chronic pain patients. *Cyberpsychology, Behavior and Social Network* 17(4): 346-352