Rev. Roum. Sci. Techn.– Électrotechn. et Énerg.
Vol. **66**, *1*, pp. 63–68, Bucarest, 2021

VIRTUAL REALITY TOOLS FOR PAIN MANAGEMENT

IOAN ALEXANDRU BRATOSIN[1], IONEL BUJOREL PĂVĂLOIU[1], DENISA CACULIDIS-TUDOR[2], ANDREEA I. LUCA[2], NICOLAE GOGA[1], IOANA R. PODINA[2], ANDREI VASILĂTEANU[1]

Key words: Virtual reality, Pain management, Acute pain, Attention.

Pain control is a difficult task to accomplish, especially without using potentially addictive drugs like opioids. Failure in providing a comprehensive pain control plan by using opioids can lead to lowering the quality of life and addiction that will further worsen the patient condition. In the last years, immersion in Virtual Reality proved its values as a technique for clinical pain management to accompany and lower the regular opioid dosage. The current paper describes this technique, as well as the novelties introduced by our team in a gamified VR setting for pain management.

1. INTRODUCTION

Poorly managed pain has a detrimental effect on many aspects of life, such as quality [1], mood, or daily functioning [2]. Several previous studies have pointed out the importance of pain relief, as well as the development of effective treatments [3, 4] thus serving as motivation for the current application.

The common occurrence of pain, either chronic or acute, calls for different methods of management, as well as treatments that could be available and widely disseminated, without significant resources spent. Therefore, the current application has been prompted by the need for an effective method of reducing pain and as such, turned to virtual reality (VR) which has proven its merits and deserves further consideration [5]. The paper structure is divided in literature review where we describe the state of the art, application, and methodologies of VR therapy, an overview of our application where we explain our application scenarios, methods, and unique traits and the last section describing the development process, user flow, interaction and innovation of our application, and conclusion.

2. LITERATURE REVIEW

The interest in the study of pain management was marked by the formulation of the gate control theory in 1965 [6], which proposes that a mechanism in the dorsal horns of the spinal cords acts like a gate that inhibits and facilitates the transmission of pain signal from the body to the brain. Another major role was represented by the increased understanding of plasticity and complexity of pain processing [7].

Pain is a complex emotional and sensory experience that varies in duration, quality, intensity, location, and unpleasantness and can vary among individuals [8]. On the one hand, situational or emotional factors that coexist with the experience of pain can alter the intensity of pain perceptions, on the other hand, cognitive factors, such as attention, cognitive control, expectations, or aversive significance of the experience, can as well affect pain perceptions [7].

Acute pain is related to sudden injury, signaling actual or potential damage, and it usually disappears when the underlying cause of the pain has been treated. However, acute pain experiences can sometimes persist in a transition to chronic pain [9]. The International Association for the Study of Pain defines chronic pain as the pain that persists past the healing phase following an injury [10].

The first line of treatment in pain management is represented by pharmacological interventions. Although efficient, pharmacological pain therapies, especially the use of opioids, have several shortcomings [11], such as addiction [12,13] or spinal cord stimulation [14]. Thus, there is an increased need to develop alternative interventions and techniques that reduce pain perception. One such promising candidate is virtual reality (VR) for pain management that allows a powerful immersion in the virtual environment, contributing to mechanisms of pain relief.

VR technology has been proven to be useful in reducing pain and distress (*i.e.*, anxiety, anger) in a wide array of situations [5,15,16] such as burn wound care [17], chemotherapy, and radiotherapy [18, 19], dental procedures [20], for both adults and children [21–23]. Studies showed that participants immersed in VR reported reduced levels of pain, and a better overall experience [24].

The capability of VR to reduce pain is based on active distraction, but also on focus shifting mechanisms, two well-researched pain-buffering processes [25], as well as on building skills that modulate the processing of pain sensations through embodiment in virtual reality, a technique successfully used in phantom limb pain [26]. The exact mechanisms behind VR's actions are yet to be identified; however, there is an increased body of research investigating the complex interplay of cortical activity associated with immersive VR [24]. Through a combination of technologies (*i.e.*, head-mounted displays, joysticks, controller wands, data gloves, motion trackers, trackpads, etc.), VR environments create a multi-sensorial experience, facilitating active exploration and the shift of attention away from the painful stimuli [15].

Moreover, VR applicability can be boosted by the sense of immersion in the environment, interactivity with the help of gamified elements, social interaction and customization of the VR application [27, 28]. The abovementioned factors found in virtual reality pain relief gamified applications contribute to the activation of distraction mechanisms. Distraction is a complex phenomenon involving processes that allow the individual to divert attention from nociceptive stimuli [29]. Potential mechanisms associated with VR distraction such as shifting the focus of attention and increasing the cognitive load to reduce attentional

[1] University POLITEHNICA of Bucharest, Department of Engineering in Foreign Languages, ioan.bratosin@gmail.com
[2] University of Bucharest, Department of Psychology, Bucharest, Romania

resources directed to painful stimuli have been effective in pain relief [15,30], proving a limitless potential for development.

3. OVERVIEW OF THE CURRENT APPLICATION

The current paper details the development of the "Penguin Helper" (Fig. 1), a gamified VR application for acute pain relief developed in 3D Unity2019 using C# language, Oculus SDK libraries, and plugins.

This is a customized VR application for adults undergoing medical procedures inflicting acute pain. Moreover, the participants' mission is to escort and protect several penguin characters on following a designated path to safety (Fig. 2). During their mission, participants will be confronted with several challenges requiring their full attention, as they will have to manage their limited resources to feed the penguin, chase the wild foxes that threat the life of the penguin characters, and gather food resources from specific areas (Fig. 3) while being under time pressure to reach the safety zone.

The scenario that the user must go through consists of finding multiple penguins (Fig. 2) on the map and escort them to safety while avoiding the foxes and keeping their satiety level above zero (Fig. 2). The satiety level of penguins can be filled by using the rations initially given or found by the player, that needs to be done regularly because it will decline over time, and the penguins will stop following the player if it reaches zero. Rations can be replenished by doing a secondary relaxing activity in the game like fishing (Fig. 3) or investigating multiple housing areas. One of the factors that the player must take into consideration is rationalizing between the penguins and the foxes, as the only way to ward off the wild foxes is to feed them meat or fish.

The goal of these challenges is to ensure interactivity and social interaction to shift the attention and focus from the pain the participants are feeling, towards the specific task at hand, a method that has proven to be effective [31,32].

The environment is set in three zones (Fig. 1) that depict cold, mild and warm weather. This three-region variation was applied to represent the emotions associated with pain sensations. The design is based on previous work [33,34], demonstrating that different virtual environments can induce different emotions such as anxiety, anger, or joy [35].

The participants always start in the first zone that has cold harsh weather. As they travel the world while accomplishing the given objectives, the environment gets warmer and more peaceful. The first zone includes a nighttime environment corresponding to the negative emotions evoked by pain, strengthened by specific sounds associated with bad weather. As the participant becomes immersed in the virtual environment and is distracted by the several tasks within the application, the perception of pain is altered, allowing positive emotions to be elicited. As the weather gets warmer, the intensity of pain should be reduced.

Previous work has shown that a sunny daytime virtual environment can elicit positive emotions such as joy. Thus, we chose to build a transition from the gloomy dark-weather to a sunnier one to create a correspondence with the physical and emotional improvement. While the accepted conclusion is that VR is an effective tool in pain reduction [25], most studies have focused on specific samples, such as burn patients [36], various chronic pains [37], or pediatric patients [21]. The current VR application targets a wider utility and is intended to be a customized intervention for acute pain.

As analyzed in multiple papers, the VR applications used for reducing pain perception are diverse but have some limitations. They use either VR equipment that renders a video, not allowing for user interaction [38–40], have limited control over the environment [41–43], or VR applications that have not been created with the purpose of pain relief [42]. As shown in the conclusions of previous papers [38–43] even by using low interaction VR applications, a certain noticeable effect of pain reduction was observed. Considering the previous results, we are aware that there is a need for a more specialized VR application for acute pain relief. To address this issue we are trying to create a VR environment that allows for user interaction has clear objectives, ease of use, and gives the

Fig. 1 – "Penguin Helper" climate variation divided into three areas.

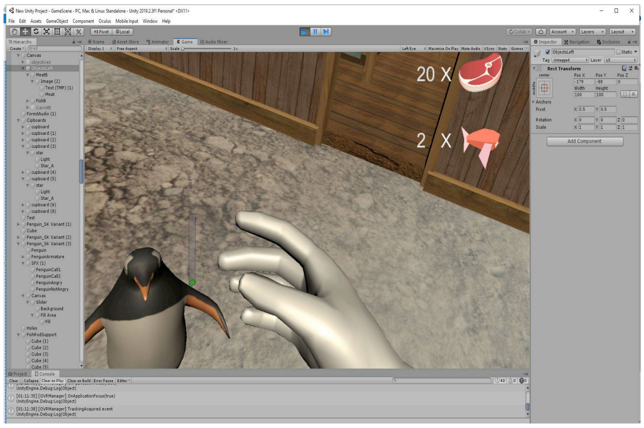

Fig. 2 – Game objective: finding and escorting penguins.

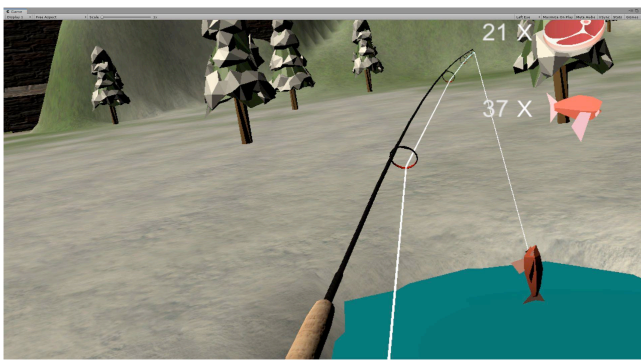

Fig. 3 – Fishing activity: replenishing rations.

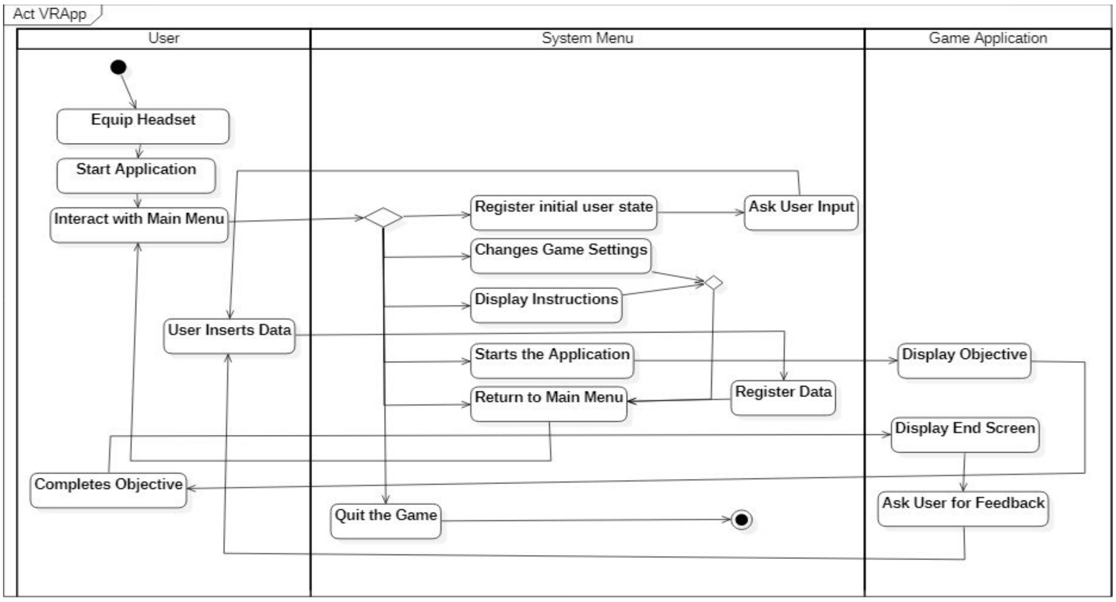

Fig. 4 – "Penguin Helper" activity diagram.

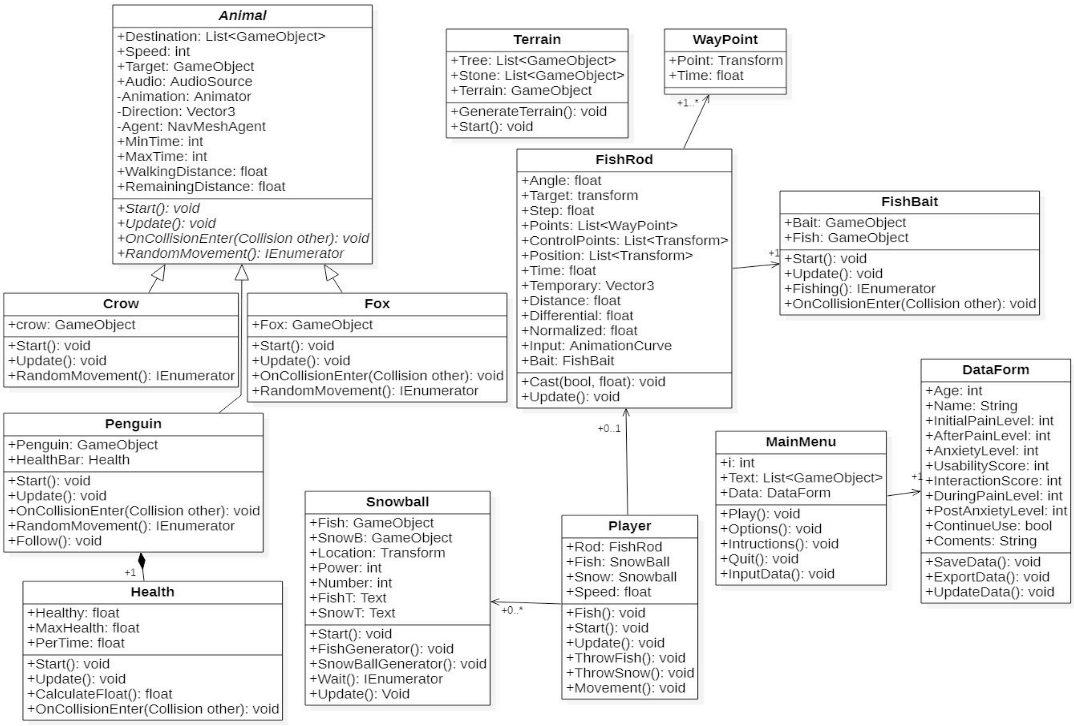

Fig. 5 – "Penguin Helper" class diagram.

patient the feeling of freedom in exploring. These attributes are important in the VR experience provided to the patient to lessen the perception of pain.

4. VIRTUAL REALITY APLICATION

The application was developed with a specific user activity flow in mind, to streamline the data gathering process of the user state (Fig. 4). After the user equips his Oculus VR headset and associated Oculus hand controllers, he will have a choice between registering his parameters at the start or end of the game and customize certain features of the application from system settings. The user parameters that we are focusing on are anxiousness, initial pain intensity, pain intensity during the game and after, also application usability and side effects. The application mechanics and object interactions were modeled after the class diagram (Fig. 5) that depicts the game objects relationships, constraints and dependencies between environmental and active objects. As presented (Fig. 5), the game has a module "DataForm", consisting of a self-reported post-experience questionnaire. The questions will be addressed to the patient after the end of the game and will provide a better understanding of the participant's experience during the game. This module compiles the data to provide a readable report with highlighted focus points like pain reduction effect, immersion, ease of use, and overall experience. The data provided from the in game questionnaire will be compared with the patient pulse measurements before the use of application and after the

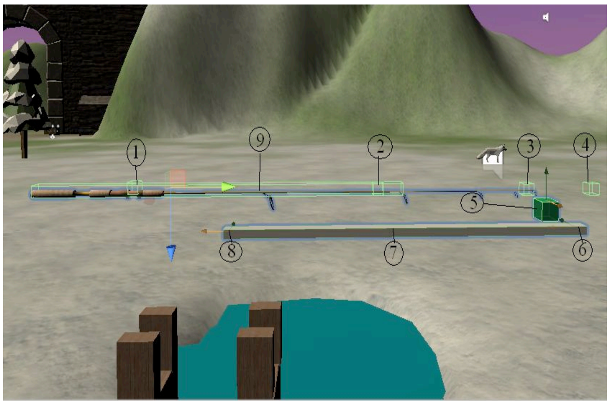

Fig. 6 – Fishing rod structure.

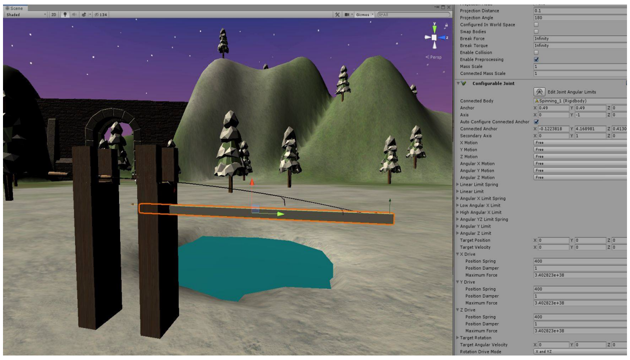

Fig. 7 – Fishing rod bending on runtime.

use of application to see if any difference has appeared between users that have tried the VR game and regular patients that have not used it.

The penguin, fox, and fishing rod game object's textures and design were edited using Blender editor. The body rigging, bones structure, and animations of the above objects were done as well in Blender. The foxes and penguins (Fig. 2) have four types of animations handled by the C# scripts, respectively: run, hit, walk, and idle animations. To provide a certain degree of realism, real animal sound effects were added for the corresponding game objects. One example is when the player hits a fox with a snowball. This action interrupts the current animation of the fox and will set it to run animation in a fluid motion while triggering a specific sound effect. The volume of the sound effects depends on a linear function to correctly render it based on object proximity in relation with the user. It peaks at a distance of one meter and it fades at 10 meters. An exception to the animation process is the fishing rod.

The body of the rod (Fig. 6) contains multiple bones that allow the mesh structure to be deformed. The deformation process is controlled using C# scripts take into consideration the weight of the fish caught, the weight of the rod, the force applied by the player, and the configurable joints position in space at a given time.

The rod game object is composed of the rigged structure containing ten bones, four points used for calculating the Bezier curve (1–4), a dynamic object used as a reference point to calculate the rod deformation (5); two configurable joints (6) and (8) attached to a rectangular game object (7), with non-rendered mesh connected to a secondary non-rendered object (9). The two configurable joints (6) and (8) have elastic properties set. On the left side of the selected grey object (7), we place the one configurable joint, that allows angular motion on the X and Y-axis in order to allow the bending to take place all around the rod's Z-axis and disabled the normal motion on all three axes so that the grey object doesn't separate from the rod.

On the right end of the object, we placed the second joint that has normal and angular motion enabled on X, Y, and Z-axes. The axes' drive properties were set to an arbitrary value to prevent a joint failure or abnormal bending. The Drive is the force that Unity uses to rotate the joint around its three local axes by the position spring and position damper drive torques. These types of settings were used in order to gain a dynamic point of reference to use in our scripts. The dynamic point is used to calculate the Bézier curve for our rod's four control points P (Fig. 6) that manipulate the bones' position in the mesh causing its deformation.

We applied the Cubic Bézier curve formula ten times for calculating each bone position and rotation by incrementing the t_0 value by i after each iteration for the initial bone position and target position t_1:

$$t_0 = \frac{(i+1)}{10},\ i \in \mathrm{Z} \,\middle|\, 1 \le i \le 10, \qquad t_1 = t_0 + 0.1. \tag{1}$$

After calculating t_0 and t_1 for each bone we used the vales in Cubic Bézier curve equation to find the start and target position for each bone and then use the bone start and target values to calculate the relative position:

$$bone_i = (1-t_0)^3 P_0 + 3(1-t_0)^2 t_0 P_1 + 3(1-t_0) t_0^2 P_2 + t_0^3 P_3, \tag{2}$$

$$target_i = (1-t_1)^3 P_0 + 3(1-t_1)^2 t_1 P_1 + 3(1-t_1) t_1^2 P_2 + t_1^3 P_3, \tag{3}$$

$$relativePosition_i = target_i - bone_i. \tag{4}$$

The values obtained were used to calculate the final bone rotation by applying a quaternion rotation function and then calculating the quaternion Euler angles thus obtaining a natural bending (Fig. 7).

The aim of replicating the real fishing experience by using complex physics is to increase realism and offer the possibility for the participant to actively engage within the virtual environment, like in [44,45]. By actively interacting with the virtual world, and performing a relaxing activity such as fishing, the participant's attention is relocated away from the painful stimuli.

Throughout the game design phase, we considered the physical restriction that might affect the patient during the treatment or medical procedure. Therefore, we mapped all the controls and interactions on a single controller that can be adjusted for right-hand or left-hand use.

5. CONCLUSION

The current paper detailed in brief the development and design of the "Penguin Helper" gamified VR application a prospective alternative to current VR systems for pain relief. The "Penguin Helper" intends to offer patients more options in choosing their pain treatment, as well as an intervention they can follow during their medical procedures in order to reduce the possibility of negative side effects of standard medication.

Our objective before the test phase consists of the implementation of a biofeedback system related to a current patient condition like the pulse that will influence the weather and sound system in the game. This approach increases patient's sense of control over their reactions by using the feedback provided by the VR application.

Received on February 13, 2021

REFERENCES

1. N. Katz, *The Impact of Pain Management on Quality of Life*, Journal of Pain and Symptom Management, **24**, *1*, pp. 38-47 (2016).
2. M. Duenas, B. Ojeda, A. Salazar, J. A. Mico, I. Failde, *A review of chronic pain impact on patients, their social environment and the health care system*, Journal of Pain Research, **9**, pp. 457–467 (2016).
3. N. Wells, C. Pasero, M. McCaffery, Improving the Quality of Care Through Pain Assessment and Management, In: R. G. Hughes (Ed.), Patient Safety and Quality: An Evidence-Based Handbook for Nurses, pp. 469-497, Agency for Healthcare Research and Quality (US), 2008.
4. C. E. Whitten, M. Donovan, K. Cristobal*, Treating Chronic Pain: New Knowledge, More Choices*, The Permanente Journal, **9**, *4*, pp. 9-18 (2005).
5. B. Mallari, E. K. Spaeth, H. Goh, B. S. Boyd, *Virtual reality as an analgesic for acute and chronic pain in adults: A systematic review and meta-analysis*, Journal of Pain Research, **12**, pp. 2053–2085 (2019).
6. R. Melzack, *Gate control theory: On the evolution of pain concepts*, Pain Forum, **5,** *2*, pp. 128–138 (1996).
7. P. A. McGrath, *Psychological aspects of pain perception*, Archives of Oral Biology, **39**, pp. 55-62 (1994).
8. M. C. Bushnell, M. Čeko, L. A. Low, *Cognitive and emotional control of pain and its disruption in chronic pain*, Nature Reviews Neuroscience, **14**, *7*, pp. 502–511 (2013).
9. F. Nees, S. Becker, *Psychological Processes in Chronic Pain: Influences of Reward and Fear Learning as Key Mechanisms – Behavioral Evidence, Neural Circuits, and Maladaptive Changes*, Neuroscience, **387**, *1*, pp. 72–84 (2018).
10. A. V. Apkarian, M. N. Baliki, P. Y. Geha, *Towards a theory of chronic pain,* Progress in Neurobiology, **87**, *2*, pp. 81–97 (2009).
11. E. E. Krebs, A. Gravely, S. Nugent, A. C. Jensen, B. DeRonne, E. S. Goldsmith, K. Kroenke, M. J. Bair, S. Noorbaloochi, *Effect of Opioid vs Nonopioid Medications on Pain-Related Function in Patients With Chronic Back Pain or Hip or Knee Osteoarthritis Pain: The SPACE Randomized Clinical Trial*, JAMA, **319**, *9*, pp. 872-882 (2018).
12. J. C. Ballantyne, S. K. LaForge, *Opioid dependence and addiction during opioid treatment of chronic pain*, Pain, **129**, *3*, pp. 235-255 (2007).
13. N. D. Volkow, E. B. Jones, E. B. Einstein, E. M. Wargo, *Prevention and Treatment of Opioid Misuse and Addiction: A Review*, JAMA Psychiatry, **76**, *2*, pp. 208-216 (2019).
14. R. V. Duarte, S. Nevitt, E. McNicol, R. S. Taylor, E. Buchser, R. B. North, S. Eldabe, *Systematic review and meta-analysis of placebo/sham controlled randomised trials of spinal cord stimulation for neuropathic pain*, PAIN, **161**, *1*, pp. 24-35 (2020).
15. R. Georgescu, L. A. Fodor, A. Dobrean, I. A. Cristea, *Psychological interventions using virtual reality for pain associated with medical procedures: A systematic review and meta-analysis*, Psychological Medicine, **50**, *11*, pp. 1795-1807 (2020).
16. P. Indovina, D. Barone, L. Gallo, A. Chirico, G. De Pietro, A. Giordano, *Virtual Reality as a Distraction Intervention to Relieve Pain and Distress During Medical Procedures: A Comprehensive Literature Review*, The Clinical Journal of Pain, **34**, *9*, pp. 858-877 (2018).
17. M. S. Bermo, D. Patterson, S. R. Sharar, H. Hoffman, D. H. Lewis, *Virtual Reality to Relieve Pain in Burn Patients Undergoing Imaging and Treatment,* Topics in Magnetic Resonance Imaging, **29**, *4*, pp. 203-208 (2020).
18. E. Bani Mohammad, M. Ahmad, *Virtual reality as a distraction technique for pain and anxiety among patients with breast cancer: A randomized control trial*, Palliative and Supportive Care, **17**, *1*, pp. 29-34 (2019).
19. D. Scates, J. I. Dickinson, K. Sullivan, H. Cline, R. Balaraman, *Using Nature-Inspired Virtual Reality as a Distraction to Reduce Stress and Pain Among Cancer Patients*, Environment and Behavior, **52**, *8*, pp. 895-918 (2020).
20. K. Tanja-Dijkstra, S. Pahl, M. P. White, J. Andrade, C. Qian, M. Bruce, J. May, D. R. Moles, *Improving Dental Experiences by Using Virtual Reality Distraction: A Simulation Study*, PLoS ONE, **9**, *3*, (2014).
21. R. Eijlers, E. M. W. J. Utens, L. M. Staals, P. F. A. de Nijs, J. M. Berghmans, R. M. H. Wijnen, M. H. J. Hillegers, B. Dierckx, J. S. Legerstee, S*ystematic Review and Meta-analysis of Virtual Reality in Pediatrics: Effects on Pain and Anxiety*, Anesthesia & Analgesia, **129**, *5*, pp. 1344-1353 (2019).
22. M. P. Kenney, L. S. Milling, *The effectiveness of virtual reality distraction for reducing pain: A meta-analysis*, Psychology of Consciousness: Theory, Research, and Practice, **3**, *3*, pp. 199-210 (2016).
23. S. Shahrbanian, X. Ma, N. Aghaei, N. Korner-Bitensky, K. Moshiri, M. J. Simmonds, *Use of virtual reality (immersive vs. non immersive) for pain management in children and adults: A systematic review of evidence from randomized controlled trials*, European Journal of Experimental Biology, **2**, *5*, pp. 1408-1422 (2012).
24. A. Li, Z. Montaño, V. J. Chen, J. I. Gold, *Virtual reality and pain management: Current trends and future directions*, Pain Management, **1**, *2*, pp. 147-157 (2011).
25. N. Ahmadpour, H. Randall, H. Choksi, A. Gao, C. Vaughan, P. Poronnik, *Virtual Reality interventions for acute and chronic pain management*, *The* International Journal of Biochemistry & Cell Biology, **114**, *105568* (2019).
26. M. Matamala-Gomez, T. Donegan, S. Bottiroli, G. Sandrini, M. V. Sanchez-Vives, C. Tassorelli, *Immersive Virtual Reality and Virtual Embodiment for Pain Relief*, *Frontiers* in Human Neuroscience, **13**, 279, pp. 114-125 (2019).
27. A. Pourmand, S. Davis, A. Marchak, T. Whiteside, N. Sikka, *Virtual Reality as a Clinical Tool for Pain Management*, Current Pain and Headache Reports, **22**, *8* (2018).
28. A. Won, J. Bailey, J. Bailenson, C. Tataru, I. Yoon, B. Golianu, *Immersive Virtual Reality for Pediatric Pain*, Children, **4**, *7*, (2017).
29. S. Dumoulin, S. Bouchard, C. Loranger, P. Quintana, V. Gougeon, K. L. Lavoie, *Are Cognitive Load and Focus of Attention Differentially Involved in Pain Management: An Experimental Study Using a Cold Pressor Test and Virtual Reality*, Journal of Pain Research, **13**, pp. 2213-2222 (2020).
30. K. M. Malloy, L. S. Milling, *The effectiveness of virtual reality distraction for pain reduction: A systematic review*, Clinical Psychology Review, **30**, *8*, pp. 1011-1018 (2010).
31. J. I. Gold, N. E. Mahrer, *Is Virtual Reality Ready for Prime Time in the Medical Space? A Randomized Control Trial of Pediatric Virtual Reality for Acute Procedural Pain Management*, Journal of Pediatric Psychology, **43**, *3*, pp. 266-275 (2018).
32. J. Piskorz, M. Czub, *Effectiveness of a virtual reality intervention to minimize pediatric stress and pain intensity during venipuncture*, Journal for Specialists in Pediatric Nursing, **23**, *1*, e12201 (2018).
33. I. A. Bratosin, I. B. Pavaloiu, A. Vasilateanu, N. Goga, G. Dragoi, D. Gavajuc, *Virtual Reality Therapy For Pain*, eLearning & Software for Education, **3**, pp. 178-185 (2020).
34. I. A. Bratosin, I. B. Pavaloiu, A. Vasilateanu, D. Gavajuc, N. Goga, *Angling in Virtual Reality for Pain Relief*, The 7th IEEE International Conference on E-Health and Bioengineering, Iasi, Romania, November 21-23, 2019.
35. A. Felnhofer, O. D. Kothgassner, M. Schmidt, A. K. Heinzle, L. Beutl, H. Hlavacs, I. Kryspin-Exner, *Is virtual reality emotionally arousing? Investigating five emotion inducing virtual park scenarios,* International Journal of Human-Computer Studies, **82**, pp. 48-56 (2015).
36. L. D. Morris, Q. A. Louw, L. C. Crous, *Feasibility and potential effect of a low-cost virtual reality system on reducing pain and anxiety in adult burn injury patients during physiotherapy in a developing country,* Burns, **36**, *5*, pp. 659–664 (2010).
37. T. Jones, T. Moore, J. Choo, *The Impact of Virtual Reality on Chronic Pain*, PLOS ONE, **11**, *12*, (2016).
38. D. Karaman, F. Erol, D. Yilmaz, Y. Dikmen, *Investigation of the effect of the virtual reality application on experimental pain severity in healthy*, Rev. Assoc. Med. Bras, **65**, *3*, pp. 446-451 (2019).
39. T. Koç Özkan, F. Polat, *The Effect of Virtual Reality and Kaleidoscope on Pain and Anxiety Levels During Venipuncture in Children*, Journal of PeriAnesthesia Nursing, **35**, *2*, pp. 206-211 (2020).
40. S. W. Hughes, H. Zhao, E. J. Auvinet, P. H. Strutton, *Attenuation of capsaicin-induced ongoing pain and secondary hyperalgesia*

during exposure to an immersive virtual reality environment, Pain Reports, **4**, *6*, (2019).

41. S. Dumoulin, S. Bouchard, C. Loranger, P. Quintana, V. Gougeon, K. L. Lavoie, *Are Cognitive Load and Focus of Attention Differentially Involved in Pain Management: An Experimental Study Using a Cold Pressor Test and Virtual Reality*, J Pain Res., **13**, pp. 2213-2222 (2020).
42. B. M. Garrett, G. Tao, T. Taverner, E. Cordingley, C. Sun, *Patients perceptions of virtual reality therapy in the management of chronic cancer pain*, Heliyon, **6**, *5*, (2020).
43. N. Deo, K. Khan, J. Mak, J. Allotey, F. J. Gonzales Carreras, G. Fusari, J. Benn, *Virtual Reality for Acute Pain in Outpatient Hysteroscopy: A Randomised Controlled Trial*, BJOG, **128**, *1*, pp. 87-95 (2020).
44. I. C. Stanica, F. Moldoveanu, M. I. Dascalu, A. Moldoveanu, G. P. Portellli, C. N. Bodea, *Neurohabilitation System using Virtual Reality and Myo Armband for Patients And Medical Personal Training* Rev. Roum. Sci. Techn.– Électrotechn. et Énerg., **65**, *2*, pp. 139-144, (2020).
45. O. M. Ferche, A. Moldoveanu, F. Moldoveanu, M. I. Dascalu, R. G. Lupu, C. N. Bodea, *Deep Understanding of Augmented Feedback and Associated Cortical Activations, for Efficient Virtual Reality Based Neuromotor Rehabilitation,* Rev. Roum. Sci. Techn.– Électrotechn. et Énerg., **63**, *2*, pp. 223-239 (2018).