Virtual Reality Application for Pain Management: User Requirements

Ioan Alexandru Bratosin[1], Ionel Bujorel Pavaloiu[2], Nicolae Goga[3], Andreea Iuliana Luca[4]
Department of Engineering in Foreign Languages, University Politehnica of Bucharest, Bucharest, Romania[1, 2, 3]
Faculty of Psychology and Education Science, University of Bucharest, Bucharest, Romania[4]

***Abstract*—The usage of fully immersive Virtual Reality applications for pain relief is still in an exploratory stage. In consequence there is a need to understand the user perspective and wishes regarding this kind of product. To address this issue, this paper presents quantitative research in order to establish the functional and non-functional requirements of our application. Voluntary response sampling was used for the research (N = 55). The inquiry form contained questions regarding serious game content, eagerness for testing, performance, resource consumption optimization, portability, data security, accessibility. The questionnaire was shared via Google Forms. The answers were collected and interpreted. The study revealed that a significant part of the participants was willing to test the application and that they would use an immersive Virtual Reality application during a normal treatment session if the opportunity is available. As functional requirements, the following were considered important: the presence of animals in game, a bright environment and nature-based background sounds. The following non-functional requirements were considered important: game optimization, portability, data security, accessibility, graphics quality and a short learning curve.**

Keywords—Virtual Reality; user requirements; serious games; therapy

I. Introduction

A subject of major significance for researchers is the usage of software application like serious games in fields like psychology [1,2], economics [3], medicine [4,5], automotive industry [6], etc. One of the ideas for serious games is to examine research hypotheses [7] in a safe and controlled environment. Another purpose is to facilitate the instruction of personnel with the objective of significantly decreasing the material and human resource costs [7].

In order to provide the best user experience during different test phases of the application or during personnel training, there is a prerequisite to ensure that the functional and non-functional requirements are properly defined for the type of application being developed. A user questionnaire can be used to examine the suitability of the requirements [8, 9], depending on the type of target population, while the method of sampling can range from convenience or voluntary sampling to random simple, stratified, or clustered sampling [10].

Virtual reality (VR) pain therapy is a new domain [11], where the applications developed are not created based on a predefined template or established requirements. The applications used in VR therapy (VRT) for pain relief range from non-interactive VR applications [12], interactive VR application not meant for pain relief [13] to custom made applications [11]. All of them had one factor in common, they provided a certain efficiency in pain relief and all users would recommend the therapy. Another thing to notice is the variety in the applications used, they do not have a standard and they are not based on predefined requirements for virtual reality therapy [12, 13].

The main benefit of this research and the approach presented is the definition of a functional and non-functional requirement template on which VR software applications for pain relief therapy can be developed. This would ease the creation of VR applications meant for pain relief as well as improving the effects of VR on pain treatment as the applications created would be developed around the user's needs.

This paper is divided in two main sections after presenting Section 1, Introduction. The second section presents a literature review containing the state of the art in the use of user questionnaires for obtaining relevant data. This section is divided in 2 sub-sections. The first sub-section deepens the subject towards a more specific topic; functional and non-functional requirements (FRs and NFRs) for software application and the second sub-section that describes the use of serious games, VR applications in medicine and the need for establishing a suitable protocol for defining the FRs and NFRs. The third section contains the evaluations done on the user questionnaire in order to verify its validity and relevance towards the presented research subject. The section starts with a description of the user's opinion on multiple functional and non-functional requirements and continues with an evaluation of their relevance by taking into consideration statistical parameters of the responses.

II. Literature Review

Assessing the usability of an application is a very important part in the development process [14] and it can be assessed through various methods, such as quantitative measures. Although questionnaires are among the best-known measures of user experience (UX), due to the high heterogeneity of the instruments [15], choosing the best tool to assess UX became a difficult task. Each of these formats has advantages and disadvantages which will be discussed further. In this regard, an extensive analysis has been made [15], indicating that the majority of usability questionnaires contain short items measured on a Likert scale. The System Usability Scale (SUS) is a short – 10 items – questionnaire that can be used to assess the general impact of an application. This questionnaire is highly employed due to the short completion time and flexible structure and it can be used in many practical settings, such as medical field [16], including the adaptation on applications for pain [17].

The System Usability Scale was created to assess the usability of a product or service and has been widely used in numerous areas such as VR rehabilitation and health services [18], VR learning [19] and VR training, and also for VR locomotion techniques [20] and it is one of the most widely used standardized questionnaires for the assessment of perceived usability [21]. A plethora of studies proved the reliability of SUS scale [22]. The SUS has many advantages, one of the most important being its flexibility [23] that allows it to assess a wide range of technologies.

Usability tests are conducted with either samples of participants who meet specific health criteria [18] or the general population [23], and most of the time is based on convenience sampling [24] a type of non-probability sampling used in research [25]. Apart from the sampling method, another issue to be taken into consideration is the sample size, which can be determined through statistical techniques by estimating the variance of the dependent measure(s) – for task-level measurements – or through more complex formulas and techniques in the case of problem-discovery usability measurement [26].

Overall, the heterogeneous state of art for UX questionnaires raises several issues to be taken into consideration when analysing perceived usability. However, as discussed above, questionnaires are one of the most widely used tools in assessing UX due to their efficiency and practicality. In addition to those, in the paper [27] is indicated that the usability research may benefit from VR technology for user research and human-product interaction.

A. *Functional and Non-functional Requirements for Medical Applications*

The process of developing software applications needs to fulfil several requirements, which are usually divided into functional requirements (FRs) and non-functional requirements (NFRs). FRs correspond to the capabilities of the system, whereas NFRs (e.g., being user-friendly, capability, performance, stability etc.) describe the overall proprieties that a system [28] must have and they may not be directly related to specific system components [29]. Due to their nature, NFRs – also called "system features" [30] - are more abstract requirements, therefore more difficult to define and quantify.

A recent analysis of requirements, made by Stamm et al. [31] for a VR intervention on a group of geriatric patients with chronic back pain in order to determine their importance, analysed the requirements for the overall system - software, hardware and gamification or game integration. Among the most important requirements, the participants listed: an individual briefing for the system, presenting instructions in a detailed manner and that the length of the exercise to be a maximum of 30 minutes (i.e., in accordance with the safe and healthy warning of the oculus advising 10-15 minutes break every 30 minutes). Also, the "user-friendly handling of the system" was important to ensure a safety regulation. Another important factor, highlighted by the authors, is the age of the participants, as elder participants have special requirements [32] and would need additional training in using the equipment.

B. *Virtual Reality in Medicine*

Virtual Reality is a domain that is continuously expanding its utility in the medical domain [33] due to its capabilities of simulating environments that closely resemble reality. The rendering of almost photorealistic scenes and the use of controllers with haptic feedback allows virtual reality surgical simulators to increase the skills of surgeons without endangering the patient. Medical applications can range from dentistry [34], intravenous-insertion, chest-tube insertion, central venous placement catheter simulators to therapeutic treatment of physical affection [35] or mental health disorders [36] like phobias.

VR and augmented reality (AR) are studied for their capabilities of increasing surgical accuracy, decreasing the overall length of surgery and improving surgery techniques [37] where the author shows the use of the enhanced view provided through the digital generated images. One of the research reviews was focused on pedicle screw placement where it was found that AR increased both accuracy and efficiency with thoracic pedicle screws. It was used as well in training up to 51 residents in this type of surgery and it was demonstrated that they had benefited from the AR technology. A clinical trial that used 20 patients for spinal fixations displayed a high level of 94.1% accuracy for the thoracic pedicle screw operation with the help of AR [38]. For the training mechanism in VR for spine surgery, in paper [39] it is revealed that the group which used the "ImmersiveTouch" VR simulator had better performance levels in all statistics like trajectory, depth of screw error and breach, compared with the control group that used the usual training methods. The success was determined by the 3D anatomical precision and representation of the model. The overall use of VR technology was reviewed [34], regarding the simulation of different medical procedures (i.e., laparoscopic [40] with LapSim, Lap Mentor, orthopaedics with TraumaVision, Procedicus KSA VR or other surgeries with Visible Ear Simulator). The HipNav VR simulator was developed for orthopaedics, and it contains a kinematic model of the hip joint and tools for specific procedures [41]. The main use of surgical simulators is to provide advanced training, automatic scoring and analysis of the intervention with objective metrics, so the VR surgical simulators improve overall performance and lead to less injury to patients during the real operation [42].

Another application of VR technology is for pain management, due to the lack of negative effects after the treatment unlike opioids. To validate the effects of VR on acute or chronic pain, a significant number of randomized trials are required. A randomized trial was performed on 120 subjects, half VR, the other control to test the efficacy of VR [43]. The patients were hospitalized with an average pain score greater than 3 on a scale from 1 to 10. They have used an Oculus Gear set with a set library of VR application. The outcome was patient-reported pain using a numeric scale and then compared pre and post intervention and after 48 and 72 hours. The result obtained was a positive one, as there was an observed difference in favour of VR. The result was more noticeable on patient with pain score greater than 7. The major areas where VR interventions are used include burn and wound care, intravenous insertions, dental procedures and surgery, where the first target is anxiety reduction [43]. Most of the results support the use of Virtual Reality for pain management in paediatric populations. But as the study points out, there is a need for the standardization in this domain to facilitate the creation, and research of VR software and hardware for pain management purposes. The paper [44] shows a review of multiple studies that have conducted clinical studies to verify the efficiency of VR with encouraging results. It proposes as well the combination of VR with Music Treatments (MT) to further reduce pain through mechanism that implicates distractions, mood regulation, and engagement. Further research is required to explore the combination of the two treatment types and assess their effectiveness.

A major issue with the previously described applications in the review studies [11] and [33] is the definition of their requirements. The main component that is stressed and showed importance in reducing pain in VR therapy is the immersive quality of the application, ease of use and environment. These qualities can be vastly improved by applying a combination of standardized and customized user forms to obtain the expectations of the users before the actual implementation of the application. This would lead to an improved design method for VR software application as well as the improvement of the effect of VR on pain therapy.

The main objective of the current research is to establish a template on which the initial stage of development for VRT applications can be eased and improved. This would lead to an improvement in the quality of VRT software and to its effects on therapy.

In conclusion, Virtual Reality is a new technology that requires continuous research through randomized clinical trials, creation of viable functional and non-functional requirements and a robust and standardized framework to analyse its effects.

III. Game4Pain Requirements

Following the previous discussion, in this paper the focus is on establishing the proper functional and non-functional requirements for the current VR application that is being research and developed by us. The end purpose of this application is to be applied as a pain relief alternative or as a secondary option to opioids in order to decrease the consumption of pain ameliorating drugs.

The study used a sample population of 55, from which 32.7% (18) male and 67.3% (37) female. The majority were in the age group of 18-24 years old - 83.6% (46), with a few in the age group of 25-34 - 12.7% (12), while the 35-44 and 45-60 groups of ages contained each 1.8%, one person.

The questionnaire provided to the volunteers included a set of 3 questions regarding their experience with VR applications, if any and their willingness to test a VR application for pain relief if they had the occasion (Table I). The first question asked was if the participants have received any VR treatment before.

The following answers were recorded: 36 of them did not receive any, 5 received full immersive VR, 6 Mobile VR, 7 persons Games and only one person TV based treatment.

The majority of participants expressed their enthusiasm to try the VR application for pain relief if they had the occasion, 34 people gave a positive answer, 18 were undecided and only 3 persons would not like to try.

The second part of the questionnaire in Table II consisted in establishing the functional and non-functional requirements, for this part there were 13 questions with answers on a scale from 1 to 5. In this part of the form, the questions were about the importance of various elements in the game e.g., background music, sunlight level, complexity level, the importance of wildlife and NFRs e.g., data security, accessibility, graphics quality, learning curve.

A. *Functional and Non-functional Inquiry Form Analysis*

From the analysis of the form questions mean and standard deviation results from Table II, the results show that the majority of the respondents are enthusiastic regarding the test of a fully immersive VR application given the mean score of 4.27 out of 5 with a relatively low standard deviation of 0.95. For the next item there is a similar high interest in having animals in the game with a mean score of 4.25. Regarding the fishing system the average is almost in the middle with 3.33 but as the standard deviation reach 1.44 it signifies that the opinions are likely opposed. A majority would like to have a fishing system implemented as a functional requirement while others are not interested.

Another interesting finding is that the subjects would prefer a luminous setting that simulates sunlight as it seen in question 5 and 6 where they affirm that the presence of sunlight affects their mood in a positive way.

TABLE I. User Attitude Towards VR for Pain Relief Therapy

Question	**Answer variant**	**Percentage of N=55**
Have you ever received a Virtual Reality treatment? If so, what type?	None	65.5%
	Full Immersive VR (e.g. Oculus Headset VR)	9.1%
	Mobile VR	10.9%
	Games	12.7%
	TV	1.8%
Would you prefer a full immersive VR experience over a normal TV/Game intervention during treatment?	Yes	61.8%
	No	5.5%
	Maybe	32.7%
Would you like to try a Virtual Reality game for the amelioration of pain, alongside usual treatment?	Yes	69.1%
	No	9.1%
	Maybe	21.8%

TABLE II. FR AND NFR FORM RESPONSE ANALYSIS

Question	Mean/ Standard deviation
1.How Interested would you be in testing a fully immersive VR application during treatment? (1 = Not at all, 5 = Very much)	4.27/0.95
2.Are you interested in having animals in the game? (1 = Not at all, 5 = Very much)	4.25/1.004
3.Are you interested in having the option to fish in the game? (1 = Not at all, 5 = Very much)	3.33/1.44
4.Would you prefer music or nature sounds to run in the background? (1 = Music; 5 = Nature)	3.65/1.40
5.Do you think that the level of sunlight in a game affects your mood in a positive way? (1 = Not at all, 5 = Very much)	3.96/1.05
6.Do you think that the level of sunlight in real life affects your mood in a positive way? (1 = Not at all, 5 = Very much)	4.22/1.08
7.How important you consider optimizing resource consumption. (How well the game runs on your device). (1 = Not important at all, 5 = Very important)	4.38/0.87
8.How important you consider the game having a short learning curve. (to be easy to learn) (1 = Easy, 5 = Hard)	3.33/1.14
9.How Important is Portability (ability to run on different operation system devices) (1 = Not important at all, 5 = Very important)	3.89/0.99
10.How Important is Data Security. (1 = Not important at all, 5 = Very important)	4.67/0.58
11.How Important is Accessibility (1 = Not important at all, 5 = Very important)	4.60/0.60
12.How Important is the Graphics quality (1 = Not important at all, 5 = Very important)	4.40/0.87
13.How would you consider the application having an in-depth Game Mechanics (the number of actions you can do in a game and the complexity) (1 = Simple Game, 5 = Complex Game)	3.98/0.83

As non-functional requirements regarding the application difficulty in question 8, the opinions are pointing towards an average learning curve, but with a high game complexity in question 13. There is a need to take in consideration the age of the group as its mostly young adults, and they would lean towards a challenging game, but due to the nature of the application as it is meant to be enjoyable to the target audience of persons that suffer from acute or chronic pain, therefore a slightly simpler application with a short learning curve would be more appropriate. In regard to NFRs for accessibility, graphics quality, data security, portability and resource consumption, all the results with high means of 4.40 and deviations under 1 indicate that they are essential in developing the application.

B. Scale Assessment

To validate the measurements from (Table III) a Principal Component Analysis (PCA) with varimax rotation was used [45]. By Kaiser's criterion, 5 principal components were extracted with Eigen values over the cutoff of 1. The final components chosen based on having at least three variables with a minimal loading of 0.3 [46] where Component 1 (I1, I5, I6, I7) and Component 2 (I9, I10, I11, I12), resulting in a total variance of 37.84%.

TABLE III. FR AND NFR FORM QUESTIONNAIRE

Item Number	Question
I1	How Interested would you be in testing a fully immersive VR application during treatment?
I2	Are you interested in having animals in the game?
I3	Are you interested in having the option to fish in the game ?
I4	Would you prefer music or nature sounds to run in the background?
I5	Do you think that the level of sunlight in a game affects your mood in a positive way?
I6	Do you think that the level of sunlight in real life affects your mood in a positive way?
I7	How important you consider optimizing resource consumption.(How well the game runs on your device).
I8	How important you consider the game having a short learning curve.(to be easy to learn)
I9	How Important is Portability(ability to run on different operation system devices)
I10	How Important is Data Security.
I11	How Important is Accessibility
I12	How Important is the Graphics quality
I13	How would you consider the application having an in depth Game Mechanics(the game and the complexity)

Next, to identify the latent factors measured, an exploratory factor analysis (EFA) was applied by using IBM SPSS v.25 software [47], with a principal axis factor extraction method and varimax rotation. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy had an acceptable value of (KMO = 0.57) using the minimum acceptable value of 0.50 [48], and Bartlett's Test of Sphericity was significant ($p < .001$).

By Kaiser's criterion [48], there were 5 factors with Eigen values above the cutoff of 1; however the procedure could not be completed due to a Haywood case [49]. As advised in IBM SPSS statistics a downside for this criterion may be the overestimation of the number of factors to retain. Most of the present communalities are lower than 0.70, therefore, Kaiser's rule might be inappropriate for this type of data. By Cattell's criterion [50], the scree plot and the previous principal component analysis suggest 2 extraction factors. Therefore, the analysis was executed with 2 fixed extraction factors. According to [51], only the items with a interpreted factor loading with an absolute value more than 0.3 were taken in consideration. Based on this cutoff, three items were not included in the analysis due to having too much uniqueness (I2, I3, I8), and the final structure included Factor 1 (I1, I4, I5, I6, I7) and Factor 2 (I9, I10, I11, I12, I13). The EFA resulted in a 10-item scale, explaining 34.53% of the total variance (Table IV).

Furthermore, the reliability analysis indicated an acceptable internal consistency for Factor 1 ($\alpha = 0.78$) and a modest one for Factor 2 ($\alpha = 0.65$). Although, a sample size of at least 50 is adequate for behavioral sciences, the internal consistency coefficient proved to be sensitive to both sample size and number of items, especially if the Eigen value for the first factor is lower than 6 [51]. Moreover, [52] showed that for sample sizes of 50, the loadings should be around 0.80 for a stable structure. In this case, a higher sample size may be advisable in the future.

TABLE IV. ITEM ANALYSIS AND FACTOR LOADINGS

Rotated Factor Matrix		
	Factor	
	1	2
I5	0.90	-
I6	0.78	-
I7	0.70	-
I1	0.56	0.34
I4	0.40	-
I11	-	0.78
I12	-	0.57
I9	-	0.55
I10	-	0.51
I13	-	0.31
Variance registered after rotation in %	34.53%	

Overall, the findings indicate that an adequate VRT application is required to have a simplified user interface to allow a fast comprehension of the system by the user with a robust framework that provides data security, accessibility and portability. A second important criterion is to have a simple objective, well described with simple game mechanics to avoid confusion. A third trait is immersion characterized by a high graphic quality, as immersion is the main goal of any VRT application. The analysis in this paper provides insight for how future work in this domain should be approached as well as what criterions VRT applications should follow.

IV. CONCLUSION

This article explored the establishment of functional and non-functional requirements for a Virtual Reality application that can be used for pain relief treatments based on the answers obtained from the user questionnaire using voluntary random sampling. The following high priority FRs and NFRs have been observed: immersive environment, presence of an illumination system that simulates daytime lighting, natural background sounds, interactive animal type objects, engaging mechanics, resource optimization, secure data storage, accessibility and improved graphics quality.

For future work, the goal is to implement the learned findings and requirements in a VR application meant for pain therapy. This application will be tested in a real environment where its effects can be observed. The experiment will be followed by a second questionnaire for user experience using the voluntary random sampling method, in order to verify the initial findings concerning the FRs and NFRs as well as its effect on pain relief.

REFERENCES

[1] I. C. Stănică, M. I. Dascalu, A. Moldoveanu, C. N. Bodea, S. Hostiuc, "A survey of virtual reality applications as psychoterapeutic tools to treat phobias", In Proceedings of ELSE 2016 The 12th International Scientific Conference eLearning and Software for Education, 2016, pp. 392-399.

[2] R. C. Popa, D. Gavajiuc, D. Grigore, N. Goga, A. Zaharia, "*A benchmark based on the automatic generation of ontology between the psychological and theological domains*", SSERS International Conference on Emerging Market Trends in Economics, International Relations, Business Management & Social Science Research, 2019, Reference ID: BCAT-09-P28.

[3] A. Bucciol, F. Landini, M. Piovesan, "Unethical behavior in the field: Demographic characteristics and beliefs of the cheater", Journal of Economic Behavior & Organization, 2013, Vol.93, pp. 248–257.

[4] I. A. Bratosin, I. B. Pavaloiu, A. Vasilateanu, N. Goga, G. Dragoi, D. Gavajuc, "Virtual reality therapy for pain", eLearning & Software for Education, 2020, Vol. 3, pp. 178-185.

[5] C.V. Marian, "*Artificial Intelligence Expert System Based on Continuous Glucose Monitoring (CGM) Data for Auto-Adaptive Adjustment Therapy Protocol – How to Make Sensors and Patients to Think Forward and Work Together?*", 2021 International Conference on e-Health and Bioengineering (EHB), 2021, pp.1-4.

[6] I. B. Pavaloiu, M. Y. Mzoughi, A. Vasilateanu, N. Goga, "Learning to drive cars in large cities", The 14th eLearning and Software for Education Conference – eLSE, 2018, Bucharest, Romania, pp 313-319.

[7] K., Mikhail, A. Obukhov, D. Dedov, "Formalization of the burning process of virtual reality objects in adaptive training complexes", Journal of Imaging, 2021, Vol. 7, no. 5: 86. https://doi.org/10.3390/jimaging7050086.

[8] M. Maguire, N. Bevan, "User requirements analysis a review of supporting methods", IFIP World Computer Congress, 2002, pp. 133-148.

[9] L. Lehtola, M. Kauppinen, "Suitability of requirements prioritization methods for market-driven software product development", Software Process: Improvement and Practice, 2006, pp. 7-19, https://doi.org/10.1002/spip.249.

[10] H. Taherdoost. "Sampling methods in research methodology; How to choose a sampling technique for research", International Journal of Academic Research in Management, 2016, Vol. 5, pp. 18-27.

[11] Z. Trost, C. France, M. Anam, C. Shum, "Virtual reality approaches to pain: toward a state of the science", PAIN, 2021, Vol.162, Issue 2 pp. 325-331 doi: 10.1097/j.pain.0000000000002060.

[12] C. G. Ford, E. M. Manegold, C. L. Randall, A. M. Aballay, C. L. Duncan, Assessing the feasibility of implementing low-cost virtual reality therapy during routine burn care, Burns, June 2018, Volume 44, Issue 4, pp 886-895, https://doi.org/10.1016/j.burns.2017.11.020.

[13] S. Benham, M. Kang, N. Grampurohit, Immersive Virtual Reality for the Management of Pain in CommunityDwelling Older Adults, OTJR: Occupation, Participation and Health, December 2018, Vol 39, Issue 2, pp. 90-96, https://doi.org/10.1177/1539449218817291.

[14] R. C. Popa, A. Vasilateanu, A. Doncescu, M. Goga, "*A semantic engine for organizational documents: A quantitative research for requirements definition*", 10th annual International Conference of Education, Research and Innovation, 2017, pp. 3968-3975.

[15] J. Brooke, "SUS: A "Quick and Dirty" Usability Scale", In Usability Evaluation, In Industry. CRC Press, 1996.

[16] M. Sathiyanarayanan, S. Rajan, "MYO armband for physiotherapy healthcare: A case study using gesture recognition application", 8th International Conference on Communication Systems and Networks (COMSNETS), 2016, pp. 1–6, doi.org/10.1109/COMSNETS.2016.7439933.

[17] F. Spyridonis, J. Hansen, T. M. Grønli, G. Ghinea, "PainDroid: An android-based virtual reality application for pain assessment", Multimedia Tools and Applications, 2014, Vol. 72(1), pp. 191–206, doi.org/10.1007/s11042-013-1358-3.

[18] R. Lloréns, E. Noé, C. Colomer, M. Alcañiz, "Effectiveness, usability, and cost-benefit of a virtual reality-based telerehabilitation program for balance recovery after stroke: A randomized controlled trial", Archives of Physical Medicine and Rehabilitation, 2015, Vol. 96(3), pp.418-425.e2. https://doi.org/10.1016/j.apmr.2014.10.019.

[19] A. Ewais, O. D. Troyer, "A usability and acceptance evaluation of the use of augmented reality for learning atoms and molecules reaction by primary school female students in palestine", Journal of Educational Computing Research, 2019, Vol. 57(7), pp. 1643–1670. https://doi.org/10.1177/0735633119855609.

[20] C. Boletsis, "A user experience questionnaire for VR locomotion: Formulation and preliminary evaluation", International Conference on Augmented Reality, Virtual Reality and Computer Graphics, 2020, pp. 157–167. https://doi.org/10.1007/978-3-030-58465-8_11.

[21] B. Klug, "An overview of the system usability scale in library website and system usability testing", Weave: Journal of Library User Experience, 2017, Vol. 1(6). https://doi.org/10.3998/weave.12535642.0001.602.

[22] A. Bangor, P. T. Kortum, J. T. Miller, "An empirical evaluation of the system usability scale", International Journal of Human-Computer Interaction, 2008, Vol. 24: 6, pp. 574-594.

[23] P. Lavrakas, "Encyclopedia of survey research methods", Sage Publications, Inc., 2008, https://doi.org/10.4135/9781412963947.

[24] H. Taherdoost, "Sampling methods in research methodology; How to choose a sampling technique for research", Social Science Research Network. 2016, https://doi.org/10.2139/ssrn.3205035.

[25] J. R. Lewis, "The system usability scale: Past, present, and future", International Journal of Human–Computer Interaction, 2018, Vol. 34(7), pp. 577–590, https://doi.org/10.1080/10447318.2018.1455307.

[26] J. Lewis, "Psychometric evaluation of the PSSUQ using data from five years of usability studies", Int. J. Hum. Comput. Interaction, 2002, Vol. 14, pp. 463–488. https://doi.org/10.1080/10447318.2002.9669130.

[27] F. Rebelo, P. Noriega, E. Duarte, M. Soares, "Using virtual reality to assess user experience", Human Factors, 2012, Vol. 54(6), pp. 964–982. https://doi.org/10.1177/0018720812465006.

[28] J. Burge, D. Brown, "NFRs: Fact or fiction?", 2002.

[29] F. Manola, "Providing systemic properties (Ilities) and quality of service in component-based systems", Institute for Defense Analyses, 1999, URL: http://www.objs.com/aits/9901-iquos.html.

[30] F. Khan, S. R. Jan, M. Tahir, S. Khan, F. Ullah, "Survey: Dealing non-functional requirements at architecture level", VFAST Transactions on Software Engineering, 2016, Vol. 4(1), pp. 27–33, https://doi.org/10.21015/vtse.v9i2.410.

[31] O. Stamm, R. Dahms, U. Müller-Werdan, "Virtual reality in pain therapy: A requirements analysis for older adults with chronic back pain", Journal of NeuroEngineering and Rehabilitation, 2020, Vol. 17, Artiicle no. 129, https://doi.org/10.1186/s12984-020-00753-8.

[32] A. Holzinger, G. Searle, T. Kleinberger, A. Seffah, H. Javahery, "Investigating usability metrics for the design and development of applications for the elderly", In Computers Helping People with Special Needs Springer, 2008, pp. 98–105. Springer. https://doi.org/10.1007/978-3-540-70540-6_13.

[33] J. Mazurek, P. Kiper, B. Cieślik, S. Rutkowski, K. Mehlich, A. Turolla, J. Joanna Szczepańska-Gieracha, "Virtual reality in medicine: a brief overview and future research directions", Human Movement, 2019, Vol. 20(3), pp.16-22. doi:10.5114/hm.2019.83529.

[34] T. Joda, G.O. Gallucci, D. Wismeijer, N.U. Zitzmann, "Augmented and virtual reality in dental medicine: A systematic review", Computers in Biology and Medicine, 2019, Vol. 108, pp. 93-100. https://doi.org/10.1016/j.compbiomed.2019.03.012.

[35] M. Costa, L. P. Vieira, E. O. Barbosa, L. Mendes Oliveira, P. Maillot, C. A. Ottero Vaghetti, M. Giovani Carta, S. Machado, V. Gatica-Rojas, R. S. Monteiro-Junior, "Virtual reality-based exercise with exergames as medicine in different contexts: A short review", Clinical practice and epidemiology in mental health: CP & EMH, 2019, Vol. 15, pp. 15–20. https://doi.org/10.2174/1745017901915010015.

[36] G. Riva, B. K. Wiederhold, F. Mantovani, "Neuroscience of virtual reality: From virtual exposure to embodied medicine", Cyberpshychology, Behaviour, and Social Networking, 2019, Vol. 22, pp. 82-96, DOI: 10.1089/cyber.2017.29099.gr.

[37] J. S. Yoo, D. S. Patel, N. M. Hrynewycz, T. S. Brundage, K. Singh, "The utility of virtual reality and augmented reality in spine surgery", Ann Transl Med., 2019; Volume 7 Suppl 5: S171, doi:10.21037/atm.2019.06.38.

[38] A. Elmi-Terander, R. Nachabe, H. Skulason, "Feasibility and accuracy of thoracolumbar minimally invasive pedicle screw placement with augmented reality navigation technology", Spine (Phila Pa 1976), 2018, Vol. 43, pp. 1018-1023. 10.1097/BRS.0000000000002502.

[39] J. Gasco, A. Patel, J. Ortega-Barnett, "Virtual reality spine surgery simulation: An empirical study of its usefulness", Neurol Res, 2014, Vol. 36, pp. 968-973. 10.1179/1743132814Y.0000000388.

[40] G. Ahlberg, L. Enochsson, A. G. Gallagher, L. Hedman, C. Hogman, D. A. McClusky, S. Ramel, C. D. Smith, D. Arvidsson, "Iconography: proficiency-based virtual reality training significantly reduces the error rate for residents during their first 10 laparoscopic cholecystectomies", Am J Surg. 2007, Vol. 193, pp.797–804.

[41] A. M. Digioia, D. A. Simon, B. Jarama, M. Blackwel, E. Morgan, R. V. O'Toole, B. Colgan, E. Kischel, "HipNav: preoperative planning and intra-operative navigational guidance for acetabular implant placement in total hip replacement surgery", Proc Computer Assisted Orthopaedic Surgery Symp. 1995.

[42] N. E. Seymour, A. G. Gallagher, S. A. Roman, M. K. O'Brien, V. K. Bansal, D. K. Andersen, R. M. Satava, "Virtual reality training improves operating room performance: results of a randomized, doubleblinded study", Ann Surg., 2002, Vol. 236, pp. 458–463.

[43] B. Spiegel, G. Fuller, M. Lopez, T. Dupuy, B. Noah, A. Howard, M. Albert, V. Tashjian, R. Lam, J. Ahn, F. Dailey, B. T. Rosen, M. Vrahas, M. Little, J. Garlich, E. Dzubur, W. IsHak, I. Danovitch, "Virtual reality for management of pain in hospitalized patients: A randomized comparative effectiveness trial", PLoS One, 2019 Aug 14; Vol. 14(8):e0219115. doi: 10.1371/journal.pone.0219115. PMID: 31412029; PMCID: PMC6693733.

[44] E. Honzel, S. Murthi, B. Brawn-Cinani, G. Colloca, C. Kier, A. Varshney, L. Colloca, "Virtual reality, music, and pain: developing the premise for an interdisciplinary approach to pain management", Pain, 2019, Vol. 160(9), pp. 1909–1919. https://doi.org/10.1097/j.pain.0000000000001539.

[45] D. L. Streiner, "Figuring Out Factors: The Use and Misuse of Factor Analysis." The Canadian Journal of Psychiatry, 1994, Vol. 39(3), pp. 135–140. doi:10.1177/070674379403900303.

[46] H. F. Kaiser, & Rice, J. "Little Jiffy, Mark Iv." Educational and Psychological Measurement, 1974, Vol. 34(1), pp. 111–117. doi:10.1177/001316447403400115.

[47] A. Field, (2013). Discovering statistics using IBM SPSS statistics (4th ed.). SAGE Publications.

[48] H. F. Kaiser, "An index of factorial simplicity", Psychometrika, 1974, Vol. 39, pp. 31–36.

[49] H. B. Heywood, "On finite sequences of real numbers", Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character, 1931, Vol. 134(824), pp. 486–501

[50] R. B. Cattell, "The Scree test for the number of factors", Multivariate Behavioral Research, 1966, Vol. 1(2), pp. 245–276. doi:10.1207/s15327906mbr0102_10.

[51] H. Yurdugül, "Minimum Sample Size for Cronbach's Coefficient Alpha: A Monte-Carlo Study", Hacettepe University Journal of Education, 2008, Vol. 35, pp. 397-405.

[52] E. Guadagnoli, W. F. Velicer, "Relation of sample size to the stability of component patterns.", Psychological Bulletin, 1988, Vol. 103(2), pp. 265–275. https://doi.org/10.1037/0033-2909.103.2.265.