Redesigning cardiovascular healthcare: patient and professional perspectives on value

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CHAPTER VIII

A PREOPERATIVE VIRTUAL REALITY APP FOR PATIENTS SCHEDULED FOR CARDIAC CATHETERIZATION: PRE-POST QUESTIONNAIRE STUDY EXAMINING THE FEASIBILITY, USABILITY AND ACCEPTABILITY

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Abstract

Background

Pre- and post-operative anxiety is a common phenomenon and is associated with negative post-operative outcomes. Symptoms of post-traumatic stress disorder, such as fear, nightmares, and sleep deprivation, are prevalent in roughly 30-50% of patients following discharge from intensive care units after (cardiac) surgery. Preliminary evidence suggests a promising role of Virtual Reality (VR) in preventing of stress-related reactions using Stress Inoculation Training. Such training enables cognitive preparation of individuals for stressful situations, such as medical emergencies or treatments, thereby becoming more tolerant and resistant to stress, subsequently reducing the risk for potential negative psychological consequences. This study investigated a pre-operative VR-application ('Pre-View') in the context of better informing and preparing patients for cardiac catheterization.

Objective

To assess the feasibility, usability and acceptability of Pre-View in patients undergoing cardiac catheterization.

Methods

Eligible participants were adults scheduled for elective cardiac catheterization. Pre-View comprised an interactive virtual representation of the whole care process related to cardiac catheterization; from entering the hospital for admission to post-procedural stay and discharge. These processes were represented through 360° videos- and interactive photos. Self-report questionnaires were completed at baseline (i.e., pre-catheterization, after undergoing the VR-experience) and after cardiac catheterization. Outcome measures included user experience and satisfaction, VR-presence and immersive tendencies, and user-friendliness. Perceived effectiveness was exploratively assessed.

Results

Eight individuals with a mean age of 67 participated. Half of them underwent the VR-experience in the hospital, the other half at home. Participants reported high levels of presence in the virtual environment (Presence Questionnaire; M = 129.1, SD = 13.4). The usability of Pre-View was well evaluated (System Usability Score; M = 89.1, SD = 12.0), and patient satisfaction was high (Client Satisfaction Questionnaire; M = 27.1, SD = 3.2). Usability and satisfaction scores were higher for participants who underwent Pre-View at home versus those who underwent Pre-View in the hospital, although the latter group was significantly older; 72.8 versus 61.3 respectively. All participants reported Pre-View to be effective in terms of feeling better informed about the care process of cardiac catheterization.

Furthermore, most of participants (87.5%) reported Pre-View to be effective in terms of feeling better prepared for the cardiac catheterization, acknowledging the potential of Pre-View in reducing negative psychological consequences after catheterization.

Conclusions

The results provide initial support for the feasibility and acceptability of a pre-operative VR-application, creating a virtual environment that supports patient education and preparation for upcoming coronary catheterization. More studies are needed to further investigate the effects of VR as a tool to better prepare patients for medical procedures, its effectiveness in terms of reducing negative patient outcomes (e.g., anxiety, stress, post-operative recovery outcomes), and the generalizability of effects across different settings and patient populations.

Abbreviations

AAA:	Abdominal aortic aneurysm
CSQ-8:	Client satisfaction questionnaire
ITQ:	Immersive tendencies questionnaire
LUMC:	Leiden University Medical Centre
PQ:	Presence questionnaire
PTSD:	Post-traumatic stress disorder
SIT:	Stress inoculation training
SUS:	System usability scale
VR:	Virtual reality

Introduction

Coronary artery disease is one of three most common cardiovascular pathologies, playing a major role in mortality and morbidity worldwide (1). The occlusion of coronary vessels can lead to myocardial infarction and eventually death. Cardiac catheterization has evolved over many decades, decreasing the amount of deaths after acute myocardial infarction drastically as well as relieving anginal complaints in the elective setting (2). Overall, the clinical admission for such a procedure is short, however, psychological complaints regularly arise afterwards. Roughly 30 to 50% of patients has been found to suffer from depression and symptoms of Post-Traumatic Stress Disorder (PTSD), such as fear, nightmares, and sleep deprivation, following post-cardiac surgery (3-6). Such negative psychological outcomes can adversely impact patients' recovery (3, 7, 8). More specifically, studies have shown depression to be a strong risk factor for cardiac events, cardiac complications, and cardiac mortality following bypass surgery (3, 9, 10). Furthermore, lower levels of quality of life and psychological functioning in general have been demonstrated for subgroups of patients reporting symptoms of PTSD after bypass surgery (5).

Previous research has demonstrated pre-operative education to be a promising method to improve post-(cardiac)surgical outcomes, such as decreasing levels of anxiety and depression, improving recovery, and increasing patient satisfaction (11-15). Pre-operative patient education can be provided through verbal advice and written information. By informing and educating patients about the care process such as surgery- and hospital admission procedures, patients might feel more at ease and prepared for hospital admission and surgery accordingly.

The incorporation of multimedia tools has been suggested beneficial in terms of increasing patient satisfaction and perceived benefits and understanding treatments (16-18). New technology such as Virtual Reality (VR) (19) is a successful tool in the education of patients (16-18). Furthermore, VR could be used to desensitize patients for stressful events. Virtual Reality-exposure therapy is being increasingly used to treat PTSD and anxiety disorders (20-24). Furthermore, preliminary evidence suggests that VR can be successfully used to prevent stress-related reactions, such as PTSD, by means of Stress Inoculation Training (SIT). Such a training can help prepare individuals for stressful situations, such as combat or battlefield stressors, or medical emergencies or treatments, to reduce the risk for potential negative psychological consequences. When using VR during SIT, individuals can be pre-exposed to a stressor in a gradual and controlled manner. This is theorized to enable individuals to prepare themselves for the actual stressful event, thereby becoming more tolerant and resistant towards stress. Indeed, using VR in the context of SIT has for example been shown a promising approach to prepare military personnel for combat situations (25-28), enhancing resilience and potentially preventing PTSD-related symptoms.

In the current study, a VR-application ('Pre-View') was used to investigate whether VR can be a useful medium in the pre-operative management of cardiac patients undergoing elective cardiac catheterization. 'Pre-View' combines pre-operational education with virtually experiencing the care process for elective cardiac catheterization in a Dutch university medical center. By means of Pre-View, participants could virtually experience the whole process; from entering the hospital for admission until the moment of elective catheterization without showing the procedure itself, and to the post-procedural stay and discharge. The benefit of the VR-experience over written or verbal information only, is that the patient is in control of the information he or she receives. The patient decides where to look and where to go to, and the application adjusts to that correspondingly.

This increases the feeling of "being present" in the virtual environment, with presence referring to the subjective experience of being in a digital environment, while physically being in another (29). The sense and quality of this presence are considered an important factor for Virtual Reality Exposure Therapy to be effective (30). The quantification of presence can furthermore be used as an evaluative measure for the virtual experience (31).

The current pilot study aimed to assess the feasibility and acceptability of using VR-application 'Pre-View' as a medium to inform and prepare patients for their upcoming elective cardiac catheterization.

Methods

Participant Recruitment and Eligibility Criteria

Participants were recruited from the Cardiology department of the Leiden University Medical Centre (LUMC), where they were listed for elective cardiac catheterization. Patients were eligible to participate if 1) aged 18 years or older, 2) able to speak and understand the Dutch language, 3) scheduled for elective cardiac catheterization, 4) able to undergo a VR-experience, that is, not having impaired eyesight and a known history of epilepsy, and 5) not having underwent a previous cardiac catheterization. The study was approved by a local medical ethics committee of the LUMC (protocol number P19-068), and subsequently a declaration of no objection was obtained from a Medical Ethics Review Committee. Recruitment and enrollment of participants took place between January 6th and February 27th of 2020.

Procedure

Potentially eligible patients (i.e., aged 18 years or older and not having underwent previous cardiac catheterization) were approached and informed by e-mail and/or telephone by a research intern (author TW). When interested, patients received written information about the study and provided informed consent accordingly. Subsequently, the VR-experience was planned one or two weeks prior to the scheduled elective cardiac catheterization. Participants could choose to either undergo the VR-experience at home or in the hospital. In the hospital, participants were welcomed at the outpatient clinic for heart diseases in the LUMC. When participants chose to undergo the experience at home, the research assistant would visit the patient at home. Other than the location, the process of undergoing the VR-experience was identical. Patients were informed on how to use the VR-application, whereafter they could independently undergo the experience. The research assistant was present to assist in case of any technical difficulties. Directly after completion of the VR-experience, participants were asked to fill out a set of paper questionnaires assessing socio-demographic characteristics (i.e., age, gender), presence, immersive tendencies, and questions related to satisfaction and usability (for more details, see 'measures'). Patients' perceived effectiveness of Pre-View was assessed by means of a telephone call after the cardiac catheterization to enable patients to reflect on whether and how Pre-View may have supported them during the process of preparation for the surgery, as well as during and after the catheterization.

VR-experience 'Pre-View'

Patients underwent the VR-experience via a head-mounted display: the Oculus Rift Go™ device (figure 1). The headset was individually adjustable, even for participants wearing glasses. Within the VR-environment, patients were provided with an interactive representation of the whole care process related to the cardiac catheterization; they could experience, in general, the day of the heart catheterization. This encompassed the patient journey from entering the hospital for admission, to post-procedural stay. The procedure of the heart catheterization itself was not presented. However related processes were; patients were virtually being transferred in a hospital bed with wheels to the operating room, where the cardiologist would shortly explain the procedure. The experience was represented through both video and interactive photos, which had been captured and recorded during the development process of the VR-application. Topics like "What will happen on the ward? What clothing do I need? Which people are allowed to stay?", as well as topics like "What medication is given after the procedure?", "Can I eat before the surgery?" were addressed during the experience. The experience was fully interactive ; patients could to choose select objects or persons (e.g., nurse, cardiologist) to gain more information on relevant topics related to the care process at every stage of the stay. In order to do so, patients simply had to gaze a few seconds at the object or person to select it. Hence, there was no need to press a button on a controller physically.

For example, patients could gaze at the personnel around them when virtually lying in the hospital bed, after which an explanation would be given about the type of personnel (e.g., nurse, cardiologist) and what their role during the stay or catheterization would be (e.g., to perform the procedure, to assist, etc.).

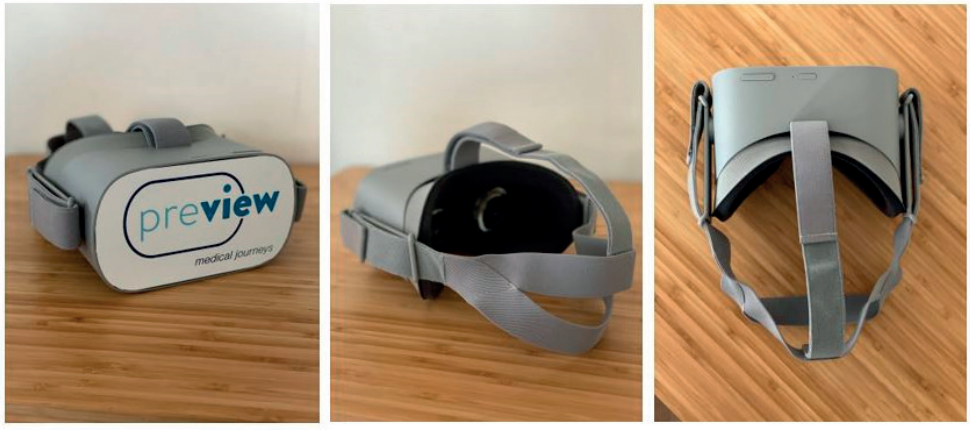

Figure 1. Occulus Rift Go™ device.

Further interaction took place through short quizzes, for example, choosing the right floor in the virtual elevator when patients' need to find their way through the hospital towards the cardiology. A detailed overview of the total experience is presented in Table 1. An example of a 360° photo can be found in Multimedia Appendix 1. All shown images and videos were context-specific, meaning that they were captured and recorded in the LUMC, with actual LUMC-staff in order to enhance feelings of relevance and realism. The VR-experience took approximately 20 minutes, depending on the time a patient spend in each module.

Measures

Presence

Participants' degree of presence and immersion in the virtual environment was assessed with the Presence Questionnaire (PQ) (29). The PQ quantifies the amount of focus a person experiences on objects or tasks generated by a digital application, in this case the VR-application. The PQ is the most prevalent used questionnaire to measure presence (32). It was developed based on factors widely believed to underlie presence, and was found to be highly reliable and internally consistent with the ITQ (see next paragraph) (29). It consists of 22 questions covering different elements relating to the level of presence, such as the degree of realism and immersion, the degree of involvement, how compelling the sense of moving around was inside the virtual environment, and the degree of control over the virtual environment. All questions are answered on 7-point Likert scales, with answers ranging from 'not at all' till 'completely'. Total scores can vary between 22 and 154.

Immersive Tendencies

Immersion refers to a state in which an individual experiences an environment as an integral part of it, thus being enveloped in it and interacting with it naturally. Immersive tendencies relate to the tendencies to get immersed or involved easily in virtual or 'make-believe' situations, quantifying a person's tendency to become immersed and focused in digital environments.

In the current study, the Immersive Tendencies Questionnaire (ITQ) was used to quantify participants' immersive tendencies (29). The ITQ consists of 18 questions, mostly assessing the degree of involvement and focus in common activities ('Do you ever become so involved in a movie that you are not aware of things happening around you?', or 'When playing sports, do you become so involved in the game that you lose track of time?'). Answers were rated on a 7-point Likert scale ranging from 'never/not very well' to 'always/very well'. Higher cumulative scores (range total score 18 and 126) represented a higher immersive tendency to get immersed or involved easily in the virtual situation.

Table 1. Overview of the virtual reality (VR) experience.

Virtual locations	Means[a]	Description
Part 1: Hospital admission		
- Hospital entrance	P, I, A	The hospital's main entrance is shown and the main menu and gaze-function of the VR-experience are explained.
- Route to elevators	P, I, A	The hospital's main hall is shown with the route to the hospital elevators being explained.
- Elevator entrance & ride	P, I, A	The elevator entrance is shown and the choice of floor leading to the nursing ward is explained.
- Entrance cardiology ward	P, I, A	The entrance of the cardiology ward is shown.
Part 2: Admission to cardiology ward, pre-catheterization		
- Cardiology ward counter	V	The user virtually walks towards the counter of the cardiology ward, where the desk clerk welcomes him/her. The desk clerk asks for a hospital card and personal identification. Hereafter, the user walks towards the entrance of the patient room.
- Patient-room: photo	P, A, I	An interactive photo of the patient room is shown. Users need to collect items they will need to bring to the hospital (e.g., clothing, phone-charger). After all items are found, the user is placed in a hospital bed.
- Patient-room: videos	V	Two short videos are shown of a nurse and physician respectively, explaining the upcoming procedures.
- Transfer to operating room	V	The user is virtually being transferred in a hospital bed with wheels from the cardiology nursing ward to the operating room.
Part 3: Operating room		
- Operating room	P, V, I	A photo is shown of the interior of the operating room containing explanations of specific devices (e.g., radiology equipment). After this exploration the patient can start a video of the scrub-nurse and attending interventional cardiologist. They explain the upcoming procedure in general, including what they will do during the procedure and what is to be expected of the procedure (e.g., duration).
Part 4: Post-catheterization at the cardiology nursing ward		
- Patient-room: inside hospital bed	V, P	A video is shown where the nurse and physician explain important aftercare issues and procedures. When the video is finished, the user can freely look around in the room and choose to be discharged when finished.
Discharge		
- Exit cardiology ward	V, P	A short exit-video shows all personnel and wishes the patient the best of luck and a healthy recovery. Hereafter, the VR-experience is finished and the user is placed outside in front of the hospital.

VR = Virtual reality

[a] P = Photo, I = Interactive feature, A = Audio, V = Video

Satisfaction

Patient satisfaction was assessed by the Client Satisfaction Questionnaire (CSQ-8) (33). The CSQ-8 is a short 8-item standardized global satisfaction measure, and each of items can be scored on a scale from 1 to 4, with total scores ranging from 8 to 32. Mean satisfaction levels were computed for each individual. The CSQ-8 is widely used across healthcare studies with good reliability and validity (34, 35).

Several questions were asked to further assess satisfaction levels. First, participants were asked to rate their satisfaction with Pre-View on a scale of 1 (extremely dissatisfied) to 10 (extremely satisfied), and to shortly summarize and clarify their score subsequently. Second, participants were asked to what extent Pre-View met their need in terms of received information on a 5-point Likert scale (1 'definitely not' to 5 'definitely'), and to shortly summarize and clarify their score subsequently. Third, participants were asked whether they experienced any discomfort or side-effects when undergoing the VR experience (yes/no), and if yes, to shortly elaborate on these.

Usability

In order to assess the usability of Pre-View, participants were asked to complete the System Usability Scale (SUS) (36). The SUS provides a quick and reliable tool for measuring the usability of a wide variety of products and services. It comprises a 10-item questionnaire with 5-point Likert scales ranging from 'strongly agree' to 'strongly disagree'. Total SUS scores can range from 0 to 100. The SUS is reliable and robust tool in assessing usability (37).

Perceived Effectiveness

Participants were asked to what extent they agreed with several statements assessing their perceived effectiveness of Pre-View in terms of 1) feeling better informed about the care process of cardiac catheterization, 2) feeling better prepared for the care process of cardiac catheterization, and 3) reduction or prevention of potential negative psychological consequences (e.g., nightmares, anxiety, symptoms of depression) after cardiac catheterization. Answer scales ranged from 1 'totally do not agree' to 5 'totally agree'.

Statistical Analysis

All data was processed by means of SPSS™ version 25. Descriptive analyses (i.e., means, standard deviations, frequencies, percentages) were used to describe the socio-demographic characteristics of participants of the study population, as well as to summarize the questionnaire data in terms of the measures described in the section 'measures'.

Results

Study Population

A total of 27 patients were approached to participate in this study, of whom twelve patients were interested to participate. One patient dropped out of the study before undergoing the Pre-View due to a fear of motion sickness symptoms. Furthermore, three patients were not included in the study because of cancellation of the VR-appointment due to the start of the Covid-19 pandemic and preventative measures which forced an early termination of study enrollment. This resulted in a total of eight patients participating in the current pilot study. Socio-demographic characters of the study population can be found in Table 2. The average age of the study population was 67 years, including six males and two females. Half of the participants chose to undergo the VR experience in the hospital, the other half at home.

Presence and Immersive Tendencies

Patients reported high levels of presence in the virtual environment with an average PQ-score of approximately 129 (Table 2). At an individual item level, items that were scored lowest related to how much one was able to control events (*M* = 4.3), the extent to which the visual display quality interfered or distracted one from performing assigned tasks or required activities (*M* = 4.6), and how much delay one experienced between their actions and expected outcomes (*M* = 4.9). Items that were scored highest related to how well one could concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities (*M* 6.8), how involved one was in the virtual environment experience (*M* = 6.5), how well one could actively survey or search the virtual environment (*M* = 6.5).

Regarding immersive tendencies, participants showed a mean score of approximately 76, indicative of above-average tendency to get immersed or involved in virtual or 'make-believe' situations. Higher levels of immersive tendencies and presence were found for those who underwent the VR experience at home (PQ *M* = 139.8, ITQ *M* = 80.8) in comparison to those who underwent it at the hospital (PQ *M* = 118.5, and ITQ *M* = 53.8), although patients in the hospital-group were on average roughly ten years older in comparison the home-group; 73 versus 61 respectively.

Satisfaction and Usability

As shown in Table 2, the usability of the Pre-View application was well evaluated by all participants with a SUS mean score of approximately 89 on a scale of 0 to 100. Patient satisfaction as assessed by the CSQ-8 was high, with an average score of approximately 27 on a scale of 8 to 32. The results of the additional assessment of participants' satisfaction are shown in Table 3.

Table 2. Socio-demographic characteristics of the study population, as well as outcome descriptives.

Gender	Age	Location	PQ	ITQ	CSQ-8	SUS
Individual participants						
Male	73	Hospital	115.0	42.0	21.0	70.0
Male	77	Hospital	114.0	52.0	27.0	72.5
Female	73	Hospital	129.0	70.0	29.0	87.5
Male	68	Hospital	137.0	67.0	24.0	90.0
Male	60	Home	116.0	51.0	28.0	92.5
Male	69	Home	130.0	105.0	28.0	100.0
Female	59	Home	142.0	69.0	31.0	100.0
Male	57	Home	150.0	82.0	29.0	100.0
Total study population[a]						
Male 6 (75)	67.0 (7.5)	Hospital: 4 (50)	129.1 (13.4)	76.3 (20.0)	27.1 (3.2)	89.1 (12.0)
Female 2 (25)		Home: 4 (50)				

PQ = Presence Questionnaire; ITQ = Immersive Tendencies Questionnaire; CSQ-8 = Client Satisfaction Questionnaire – 8; SUS = System Usability Score

[a] As provided in means (*SD*) and *N* (%) where appropriate.

These results demonstrated acceptable to good satisfaction with Pre-View. Positive remarks were mostly about the clear explanation and visualization of the procedure day. One patient elaborated on his score of 6 on the item 'Overall, how satisfied are you with Pre-View?' (Table 3); he was not able to see all of the videos during the experience because of a technical error resulting in a black screen.

Also, there were two remarks identifying targets for improvements. One patient indicated having missed seeing the actual catheterization. Another patient indicated that the cardiologist in the VR-experience could perhaps be a little more elaborate about the diversity of complaints that one could experience, as now only chest pain was stated as the reason for visiting the cardiologist. Finally, none of the participants reported side-effects during or after the VR-experience.

Table 3. Result in terms of satisfaction and perceived effectiveness of the VR-application.

	Answer scale	*N* (%)	Mean (*SD*)
Satisfaction items			
Overall, how satisfied are you with Pre-View?	1 = extremely dissatisfied	0 (0.0)	8.6 (1.3)
	2	0 (0.0)	
	3	0 (0.0)	
	4	0 (0.0)	
	5	0 (0.0)	
	6	1 (12.5)	
	7	0 (0.0)	
	8	2 (25.0)	
	9	3 (37.5)	
	10 = extremely satisfied	2 (25.0)	
To what extent did Pre-View fulfill your need in terms of information received prior to the cardiac catheterization?	1 = Not at all	0 (0.0)	4.5 (0.5)
	2 = Not really	0 (0.0)	
	3 = Neutral / Do not know	0 (0.0)	
	4 = Fairly well	4 (50.0)	
	5 = Really well	4 (50.0)	
Have any side effects occurred while undergoing Pre-View (e.g., nausea, dizziness, headache, etc.)?	1 = Yes	0 (0.0)	2 (0.0)
	2 = No	8 (100.0)	
Perceived effectiveness items			
Pre-View was effective in terms of feeling better informed about the cardiac catheterization care process	1 = Totally disagree	0 (0.0)	4.5 (0.5)
	2 = Disagree	0 (0.0)	
	3 = Neutral / Do not know	0 (0.0)	
	4 = Agree	4 (50.0)	
	5 = Totally agree	4 (50.0)	
Pre-View was effective in terms of feeling better prepared for the care process of cardiac catheterization	1 = Totally disagree	0 (0.0)	4.3 (0.7)
	2 = Disagree	0 (0.0)	
	3 = Neutral / Do not know	1 (12.5)	
	4 = Agree	4 (50.0)	
	5 = Totally agree	3 (37.5)	
Pre-View was effective, or could potentially be effective, in terms of reducing or preventing negative psychological consequences (e.g., anxiety, nightmares, symptoms of depression) after cardiac catheterization	1 = Totally disagree	0 (0.0)	4.0 (0.9)
	2 = Disagree	0 (0.0)	
	3 = Neutral / Do not know	1 (12.5)	
	4 = Agree	5 (62.5)	
	5 = Totally agree	2 (25.0)	

When looking at usability and satisfaction scores separately for the patients who underwent Pre-View at home versus those who underwent Pre-View in the hospital, both scores were higher for the former group: 98 versus 80 regarding usability scores, and 29 versus 25 regarding acceptability scores. These subgroups differed however not only in terms of where they underwent the VR-experience, but also in terms of age; those who underwent Pre-View in the hospital showed a higher mean age (M = 72.8, SD = 3.7) in comparison to those who underwent it at home (M = 61.3, SD = 5.3).

Perceived Effectiveness

As presented in Table 3, all patients agreed that Pre-View was effective in terms of feeling better informed about the care process of cardiac catheterization; half of the participants 'totally agreed' with this statement, and the other half 'agreed'. Furthermore, seven out of eight patients agreed or totally agreed with the statement that Pre-View was effective in terms of feeling better prepared for the care process of cardiac catheterization. Two patients who agreed elaborated: '*If you know what is going to happen, you experience less stress'*, and *'The more you know, the better'*. Finally, when asked whether Pre-View has been effective, or could potentially be effective, in terms of reducing or preventing negative psychological consequences after cardiac catheterization, two participants 'totally agreed', five participants 'agreed', and one participants 'disagreed'. The patient who disagreed elaborated '*Even though you are better prepared for what is going to happen, you still don't know exactly what they are doing during the procedure. Nor does it completely take away the anxiety about what they will find, which so there is always some uncertainty'*. Another patient who agreed also specifically remarked that even though he felt better informed and prepared, he still indicated to feel somewhat anxious and stressed before the hospital admission for his cardiac catheterization.

Discussion

The current pilot study investigated the feasibility, usability, and acceptability of a pre-operative VR-application ('Pre-View') in the context of better informing and preparing patients for cardiac catheterization. Its feasibility was demonstrated by participants reporting high levels of presence in the virtual environment, and the VR-experience being well tolerated without experiencing any side effects. Results furthermore indicated good user satisfaction and system usability. Finally, the majority of participants self-reported Pre-View to have been effective in terms of feeling better informed, feeling better prepared for the cardiac catheterization care process, and in terms of its potential to reduce or prevent negative psychological consequences after cardiac catheterization.

The current study results are promising in terms of feeling better informed about the hospital stay and corresponding elective cardiac catheterization. This is in line with previous literature suggesting that the incorporation of multimedia tools is beneficial in terms of perceived benefits and understanding of upcoming treatment(s) (16-18). Our results also adds to the body of literature underscoring the usefulness of VR as an engaging tool for patient education. For example the results of a study by Pandrangi et al. (38), showing that a VR-experience modeling an abdominal aortic aneurysm (AAA) for patients diagnosed with AAA, was perceived as beneficial in better understanding their health status and feeling more engaged in their healthcare. Another study demonstrated that patient education using a VR-training on radiotherapy increased knowledge and positive experiences of undergoing radiation therapy for breast cancer patients (39). Hence, the results of this pilot study underscore not only the acceptability and usability of using VR as a patient educational tool, but furthermore highlight the potential of using VR as a means to better inform patients on upcoming, stressful treatment processes.

The preliminary results of the current study suggests Pre-View to be potentially effective in preventing or reducing of potential negative psychological consequences after surgery, which is compatible with the existing theory and body of literature indicating the potency of using VR-technology as a means to desensitize individuals for stressful future events such as combat situations, thereby supporting resilience and prevention of negative psychological symptoms (25-28). Related to hospital settings and surgery specially, there is scarce research investigating the effects of pre-operative VR applications on patient outcomes. A single-blinded randomized controlled trial by Eijlers et al. (40) investigated the effects of a child friendly VR-exposure to the operating theatre on the day of children's' surgery, aiming to get them familiarized with the upcoming medical procedures (e.g., anesthesia procedures, transfer to operating room) and corresponding environment. The VR-exposure was not found to beneficially impact on anxiety levels during anesthesia and post-surgery, nor on levels of post-operative pain and emergence deliriums. Nevertheless, a subgroup of children who underwent the more painful surgeries (i.e., adenoidectomy and tonsillectomy) were significantly less often in need of rescue analgesia when having received the VR-exposure in comparison to those who had not. Another randomized controlled trial investigated the effects of a pre-operative VR experience in patients undergoing cranial and spinal operations (41). In comparison to usual pre-operative procedures, the VR experience was found to lead to higher patient satisfaction, as well better preparedness and lower levels of stress on the day of the surgery. Thus, based on the results of our pilot study and the limited available research as discussed above, VR seems to be an acceptable and feasible pre-operative preparation tool to use in hospital settings before medical procedures. However, further research is needed to establish its effects in terms of both physical and psychological outcomes.

Future studies could furthermore explore the effects of using pre-operative VR experiences across different contexts (e.g., type of medical procedures in different types of illnesses), and different patient demographics (e.g., age, immersive tendencies, psychological wellbeing status). Additionally, the role of presence on patients' satisfaction and outcomes may be an interesting direction for future research; is presence a necessary pre-condition or moderator of patient satisfaction and outcomes in the context of pre-operative VR interventions? Not feeling 'present' in the virtual environment has found to be associated with higher levels of drop-out in VR treatment for anxiety disorders, however the same review did not find an effect of the degree of presence on patient outcomes (30). A final interesting direction for future research is to investigate whether pre-operative VR interventions can be effectively delivered via smartphones. In the literature the feasibility of smartphone-based delivery of VR has already been demonstrated for various goals. Google's 'Cardboard' platform has for example been successfully used to deliver VR experiences for educational purposes (42) as well as in the context of a smoking cessation program (43). The Google Cardboard is a fold-out cardboard viewer that provides the structure for Head Mounted Display while the display is provided by a smartphone that can be placed inside the cardboard viewer. Such smartphone-based delivery of VR-experiences is of interest and relevance in light of its possibility for less costly and timely VR-experiences, thereby enabling more easy and broad-scale implementation as individuals would be enabled to start and walk through the experience whenever and wherever they chose or prefer to.

Limitations

The results of this pilot study should be interpreted in light of several limitations. The study sample was rather small. Due to the Covid-19 pandemic, appointments with included patients were cancelled, and elective surgeries including cardiac catheterization, were at the time of study recruitment postponed until further notice by the hospital. This led to a premature ending of patient inclusion. The study was designed to assess the feasibility, usability and acceptability of the pre-operative VR-experience. Hence, no definitive statements can be made about the effectiveness of the VR-experience in better informing and preparing patients for their upcoming hospital admission and corresponding procedures, or in reducing negative psychological consequences afterwards.

Conclusion

The current results provide initial support for the feasibility and acceptability of a pre-operative Virtual Reality application, creating a virtual experience that can support patient education and preparation for upcoming coronary catheterization. Further studies are needed to investigate the effects of VR as a tool to better prepare patients for medical procedures, its effectiveness in terms of reducing negative patient outcomes after such procedures, and its effects across different settings and patient populations.

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Conflicts of Interest

None.

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Multimedia Appendix 1