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Review article

Using virtual reality to prepare patients for radiotherapy: A systematic review of interventional studies with educational sessions

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ABSTRACT

Purpose: To understand the impact of radiotherapy educational sessions with virtual reality on oncologic adult patients' psychological and cognitive outcomes related to the treatment experience.
Methods: This review was performed according to the Preferred Reporting Items for Systematic Reviews guidelines. A systematic electronic search in three databases, MEDLINE, Scopus, and Web of Science, was conducted in December 2021 to find interventional studies with adult patients undergoing external radiotherapy who received an educational session with virtual reality before or during the treatment. The studies that provided qualitative or quantitative information about the impact of educational sessions on patients' psychological and cognitive dimensions related to RT experience were retained for analysis.
Results: Of the 25 records found, eight articles about seven studies were analysed that involved 376 patients with different oncological pathologies. Most studies evaluated knowledge and treatment-related anxiety, mainly through self-reported questionnaires. The analysis showed a significant improvement in patients' knowledge and comprehension of radiotherapy treatment. Anxiety levels also decreased with virtual reality educational sessions and throughout the treatment in almost all the studies, although with less homogeneous results.
Conclusion: Virtual reality methods in standard educational sessions can enhance cancer patients' preparation for radiation therapy by increasing their understanding of treatment and reducing anxiety.

Introduction

Technology advancements have made it possible to transform two-dimensional (2D) images into three-dimensional (3D) images, enabling the construction of fictionalised computer realities. This interactive tool is a cutting-edge technology that uses computer programs to manipulate the virtual environment and combine information from multiple sources transforming it into virtual reality (VR). Introducing a new dynamic and interactive virtual learning environment makes learning more "real", facilitating the entire education process [1,2]. Several definitions of VR can be found in the literature; however, they can be divided into two categories: immersive virtual reality, where the user is transported into a virtual environment, losing the perception of the physical circumstances around him; and non-immersive virtual reality, where the projected VR is presented to the individual on a computer, preserving the connection with the external environment [3,4].

VR has been applied in several healthcare fields: medical education [5–7], patient rehabilitation [8,9], patient emotional control [10] and patient education [11–13]. One of the first applications of VR in medical education was related to surgical training [6]. The authors developed an interactive stereoscopy virtual reality that creates an active learning experience of anatomy and surgical techniques [6]. More recently, immersive VR has shown significantly better results in empathic clinical communication than traditional role-playing training in radiographer students [14]. Considering patient rehabilitation, Feyzioğlu et al. [9] investigated the potential effects of a VR-based physiotherapy programme (XBOX 360 Kinect) on upper limb rehabilitation in patients

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undergoing breast cancer surgery. The adapted video games stimulate arm movement by the patient, and the system monitors the movement aspect. The results were comparable to those obtained under face-to-face physiotherapy exercises. Besides, VR programmes increase patients' motivation and could complement standard physiotherapy without the patient having to leave home [9]. VR technology also demonstrated promising results in modulating emotional processes and reducing pain-related brain activity and anxiety associated with painful cancer procedures and treatments, such as chemotherapy, lumbar puncture, and surgery. It gives the patient a subjective immersive experience and physical placement in the virtual world while reducing the impact of the environment around him [15,16]. VR has been used in mental health hospitals, where adult hospitalised patients receive sessions to induce joy or relaxation through virtual environment navigation [17].

Finally, VR has been adapted for patient education regarding radiotherapy (RT) [18,19]. It is estimated that approximately 50 % of patients diagnosed with cancer will receive RT treatments during their illness [20]. This therapy involves complex and highly specialised concepts and procedures that may be difficult to understand, making the patient more apprehensive and anxious about the treatment [19,21]. Several studies have shown that approximately 50 % of RT patients suffer from anxiety and fear due to a lack of information about treatment [21–25]. Overall, patients generally have higher information needs before planning computerised tomography (CT) scans and treatment and on the first session of RT [23,24].

Educational sessions have been delivered before the first session in some radiation departmentsto better prepare patients for their RT treatments [26–30]. These sessions aim to reduce anxiety, improve treatment effectiveness, and respond to the patient's needs, both emotional and informational, during treatment sessions. During educational sessions, several topics regarding different phases of the treatment course, side effects, and recommendations are explained; simultaneously, patients can clarify their doubts [19,31,32]. Educational sessions often employ traditional methods such as face-to-face communication [26,27,30], print materials [26,30], and slides [33]. Video materials have also been included in these sessions, achieving better patient knowledge outcomes, improving patient satisfaction regarding healthcare [34–36] and decreased anxiety after the first consultation [28] However, understanding the RT treatment's technical aspects (e.g., the treatment procedure, location, and shape of the tumour) only through two-dimensional images, can be complex for several patients [23,37]. VR technology adds benefits that other teaching methods cannot provide in this context. Recently, Kelly et al. highlighted the impact of the low health literacy of patients undergoing radiotherapy [38]. Patients are unfamiliar with radiotherapy equipment and environment and struggle to understand the radiation process and the intangible outcomes of the treatment [39]. VR applied to educational sessions can address patients' information needs regarding the RT treatment process [40], allowing the patient to have a realistic treatment experience with access to spacial and acoustic conditions during the radiation time [19,40,41]. The patient will be able to interact with the room, know the RT equipment, and visualize what will happen during the therapy due to virtual reality [42].

Several review studies have recently addressed the impact of VR technology as a distraction tool in medical treatments [43] in specific populations [44], including the effectiveness of such interventions in reducing physical and emotional symptoms imposed by medical procedures [45]. Other reviews concentrate on applying VR as an educational tool for patient and radiotherapy training [46–48]. Although some studies have focused on the impact of prior patient preparation for radiotherapy treatments, there is no specific review on the effects of VR in educational sessions to prepare adult patients for radiotherapy treatments [49,50]. The current systematic review attempted to answer the following question: What are the effects of RT educational sessions using VR on adult patients' psychological and cognitive variables related to treatment experience?

Methods

The search protocol for the systematic literature review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and meta-Analysis) statement [51]. The completed PRISMA checklist is available in Supplementary file S1.

Search strategy and selection criteria

Articles were screened for inclusion or exclusion based on PICOS criteria detailed in Table 1. A comprehensive search was run for titles, abstracts, and keywords, considering articles published from 2000 onwards. Keywords used in the search were "Radiotherapy", "Virtual reality", "Cancer", "Patient experience", "Patient knowledge", "Patient subjective perception", "Patient information needs", "Anxiety", and "Stress" and were combined simultaneously with the Boolean operator "AND" on the first three keywords and "OR" on the remaining. The universal language of the terms (MeSH) was chosen to achieve better results. The electronic database search was performed in February 2021 and updated in December 2021 on three databases (MEDLINE, Scopus, and Web of Science); grey literature was also considered.

The records were exported to a Word® document and examined independently by two authors to remove duplicates and confirm the inclusion/exclusion criteria considering the title and abstract information. The same authors performed a second-step screening of the retained full articles; other two authors were consulted when disagreements occurred to reach a final decision.

Quality assessment of the studies

Two authors independently appraised the selected studies using the *Appraising the Evidence: Reviewing Disparate Data Systematically* tool, developed by Hawker et al. [52]. This assessment tool evaluated each study in nine components (abstract and title; introduction and aims; method and data, sampling, data analysis, ethics and bias, findings/

Table 1
PICOS inclusion and exclusion criteria.

Parameter	Inclusion Criteria	Exclusion Criteria
Population	- Adult patients undergoing external RT All cancer pathologies	- Pediatric patients (under 18 years old) Patients undergoing brachytherapy Students' and health professionals training
Intervention	- RT educational session and similar interventions to prepare patients for treatment, with VR (immersive and non-immersive systems) as learning tool.	- Patients positioning training/simulation Brachytherapy educational session with VR VR as a distraction tool for cancer patients during RT treatment.
Comparator	- Control group (treatment as usual, usual care, waiting list, attention control, active comparator)	
Outcomes	- Patient knowledge Patient experience Patient subjective perception Patient information needs Anxiety Stress	- Quality of life Depression
Study design	- Interventional study Qualitative study Quantitative study Randomized controlled trial Quasi-experimental Single-arm study	- Review Meta-analysis Study protocol Oral communication and poster abstracts

results, and transferability/generalizability), with a quality score ranging from 4 (Good) to 1 (Very Poor), to obtain a final quality score that could differ from 9 to 36 points [52]. Independent scores were cross-checked for consistency, and discrepancies were resolved with the other two authors.

Data extraction and synthesis

After reading the full-text articles, two authors extracted data from the eligible articles in Word forms. Extracted information included: study identification (authorship, publication date, country); study purpose(s); target population (oncological pathology; sample size); intervention design (control and experimental conditions, timing of educational session); assessment of cognitive and psychological variables (data collection, type of instruments and evaluated outcomes), and main results of the studies. Data findings were presented as a narrative synthesis and organised according to measured cognitive and/or psychological dimensions.

Results

Of the 25 articles (Fig. 1), eight [53–60] regarding seven studies complied with the inclusion criteria. The articles' quality scores ranged from 26 [56] to 33 points [59]. The information regarding the articles retained for review is described in Table 2. The articles' quality assessment information is available in Supplementary file S2.

The selected studies were developed in several countries (i.e., Australia, Canada, China, the United Kingdom, and the United States of America). The studies used different research methods to fulfil their aims. Six studies had a one-arm design [55–60]; the remaining two studies [53,54] had a two-arm design with a treatment and a control group (i.e., the hospital's standard education). The studies involved 376 patients, with a sample size ranging from 7 [56] to 150 [59]. The study samples included patients with different types of cancer [53,56,59,60] or patients with only a specific cancer type, such as breast [54,55] and prostate [57,58].

The VR educational session was delivered through a computer educational program, the Virtual Environment for Radiotherapy Treatment (VERT) [53–55,57–59], navigated by the patient or by the session's facilitator, or through VR glasses, using technological solutions explicitly adapted for the study [56,60]. VR components of the sessions included an immersive experience through which patients could visualize the RT environment and the equipment display, the linear accelerator functioning (e.g., sounds, rotation of the equipment, laser's appearance), and a virtual demonstration of the RT treatment itself (e.g., patient's positioning in the table, patient's body area being irradiated by the beam). All educational sessions [53–60] included a complimentary informational component, delivered before, during, or after the VR experience [53–60], Some technical components of the treatment or the images displayed in the VR session were explained. The VR session's duration ranged between 30 min [53,59,60] and one hour [54,55,57,58] (one of the articles did not mention the time frame of the session [56]). The educational session was delivered before the CT scan in three studies [54,55], prior to the treatment in four studies [53,57,59,60], and

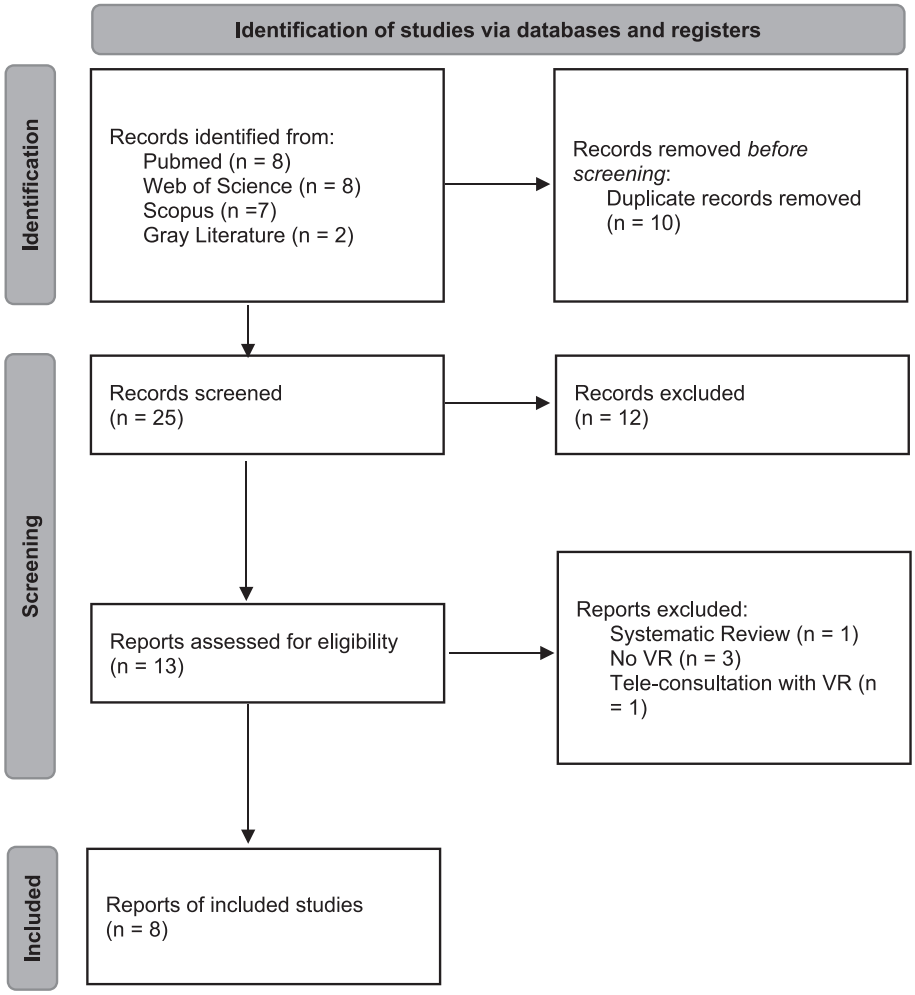

Fig. 1. PRISMA flow diagram about the selection process of the articles [37].

Table 2
Study characteristics of the selected studies.

Author, Year and Country	Pathology	Study purpose	Sample	Intervention design	Timing of educational session	Data collection, Type of instruments and Outcomes	Main results	Quality score
Gao et al, 2020 China [53]	Breast, lung, oesophageal, other	Explore the effectiveness of VR educational intervention on patients' RT understanding and anxiety	IG: n = 30 and relatives CG: n = 30	IG: 30-min individual educational VR session CG: Standard educational session	Prior to initiating RT treatment	Pre- and post-intervention evaluation (prior to simulation, and prior to treatment) with self-reported questionnaires. *Outcome(s):* patient's comprehension about RT treatment (simulation, planning and treatment); state-trait anxiety (State-Trait Anxiety Inventory-S, State-Trait Anxiety Inventory-T); psychological state regarding RT (VAS); anxiety-related physiological measures (heart rate, HR; respiration rate, RR; systolic blood pressure, SBP; and diastolic blood pressure, DBP).	IG and CG did not significantly differ regarding variables in study at baseline (STAI-T: $t = 0.448$, $p = 0.656$; STAI-S: $t = 1.248$, $p = 0.217$; VAS: $t = 0.462$, $p = 0.646$; RT comprehension: $t = -0.215$, $p = 0.831$; SBP: $t = -0.164$, $p = 0.870$; DBP: $t = -0.255$, $p = 0.799$; HR: $t = 0.050$, $p = 0.960$; RR: $t = -0.227$, $p = 0.831$). When comparing IG and CG scores at post-intervention assessment: *i)* RT comprehension scores was significantly higher in the IG ($t = 11.806$, $p < 0.001$); *ii)* STAI-S score ($t = -3.622$, $p = 0.001$), SBP ($t = -3.150$, $p = 0.003$), and HR ($t = -2.185$, $p = 0.033$) were significantly lower in the IG.VAS ($t = -1.747$, $p = 0.086$), RR ($t = -1.140$, $p = 0.259$), and DBP ($t = 0.230$, $p = 0.819$) also decreased after the VR educational session, but without significant differences comparing with CG.	30
Jimenez et al, 2018 Australia [54]	Breast	To investigate the impact of a newly developed education tool using VERT system on patients' RT knowledge, anxiety, and experience.	IG: n = 19 and relatives CG: n = 18	IG: 1-hour individual or group educational VR session CG: Written and verbal standard educational session	Prior to the simulation appointment	Pre- and post-intervention evaluation (at the time of clinic consultation, T1; on the day of simulation but prior to simulation, T2 for CG, or following the VERT education session, T2 for IG; first week of treatment, T3, and the last week of treatment, T4) with self-reported questionnaires. *Outcome(s):* patient's knowledge about RT treatment; state-trait anxiety (State-Trait Anxiety Inventory-S, State-Trait Anxiety Inventory-T); patient's RT experience (confidence regarding treatment).	IG and CG did not significantly differ regarding variables in study at baseline (RT knowledge regarding *Simulation*, *Preparation* and *Treatment*, combined scores $U = 131.5$, $p = 0.230$; STAI-S: $U = 162.5$, $p = 0.804$), except for STAI-T ($U = 53.00$, $p < 0.001$). When comparing IG and CG scores at post-intervention assessment: *i)* RT knowledge combined scores were significantly higher in IG at T2 ($U = 30.5$; $p < 0.001$), T3 ($U = 63.5$; $p < 0.001$) and T4 ($U = 80.5$; $p = 0.006$); *ii)* there were no significant differences between groups regarding STAI-S after the intervention (all time	28

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Table 2 (*continued*)

Author, Year and Country	Pathology	Study purpose	Sample	Intervention design	Timing of educational session	Data collection, Type of instruments and Outcomes	Main results	Quality score
							points) (T2: U = 121.5, p = 0.135; T3: U = 125.0, p = 0.166; T4: U = 130.0, p = 0.217), *iii)* IG patient's confidence mean values regarding RT treatment experience were higher (for all items) comparing with CG patients scores, at T3 and T4.	
Jimenez et al, 2017 Australia [55]	Breast	Report on the patient evaluation of the newly developed education using VERT.	IG: n = 19 and relatives	30-min individual or group educational VR session with oral explanations and pre-selected VERT images	Prior the planning CT scan	Post-intervention evaluation (after the VR session) with a self-reported questionnaire. *Outcome(s):* patient's agreement regarding aspects of the VERT educationprogram (structure, content, venue and images) ; patient's perception about VERT system support on RT concepts visualization; patient's perception about the most and least useful about the educational session (open-ended question).	Patients stated that VR education session improved their overall knowledge about the RT treatment from beginning to end, and specific understanding about the RT process at various steps.	27
Johnson et al, 2020 Canada [56]	Gastrointestinal, genitourinary, gynaecologic	Create and evaluate a prototype VR video as a supplement to traditional educational methods	IG: n = 7	Group educational VR session	First day of treatment	Post-intervention (after the VR session) focus group discussion. *Outcome(s):* patient's thoughts and feedback about the VR session.	After VR educational session, all patients reported an increased understanding of the treatment process and 57 % considered that VR has the potential to decrease RT-related anxiety.	26
Marquess et al, 2017 USA [57]	Prostate	Evaluates the impact of VR on anxiety and comprehension in patients undergoing RT	IG: n = 22 and relatives	1-hour individual educational VR session	After the planning CT scan, prior the RT treatment	Pre- and post-intervention evaluation (before and after the VR session) with a self-reported survey. *Outcome(s):* patient's RT comprehension; treatment-related anxiety (modified version of the Amsterdam Preoperative Anxiety and Information Scale).	Patients significantly improved their RT comprehension (all items, $p < 0.001$; effect size from 1.84,*"What I will feel during the treatment"*, to 3.30, *"What I need to do if I need the treatment to be interrupted."*). Patients also significantly decreased treatment-related anxiety in five of the eight items of the instrument (p-value from 0.001 to 0.026; effect size from 0.83 *"Getting radiation to my prostate."* to 1.51 *"How precise my treatment will be."*), from pre- to post-intervention evaluation.	27
Stewart-Lord et al, 2016 United Kingdom [58]	Prostate	Explore patients' perceptions of VR in RT as an information giving resource prior to the treatment	IG: n = 38	1-hour individual or group educational VR session	4 weeks prior to the planning CT scan	Post-intervention evaluation (2nd week of treatment) with a self-reported questionnaire. *Outcome(s):* patient's knowledge about RT, benefits and limitations of using VR as a pre-	All patients felt that the session improved their understanding about RT and what to expect during treatment. The session also increased understanding about	28

(*continued on next page*)

Table 2 (*continued*)

Author, Year and Country	Pathology	Study purpose	Sample	Intervention design	Timing of educational session	Data collection, Type of instruments and Outcomes	Main results	Quality score
						treatment information resource (open-ended question).	RT side effects and the importance of following correctly the radiotherapy preparation protocols (e.g., bowel and bladder preparation) for 97.4 % of the patients. A large number of patients also stated that the session reduced their treatment-related anxiety.	
Sulé-Suso et al, 2015 United Kingdom [59]	Prostate, breast, rectum, lung, thymus	To assess the patients' and relatives' knowledge of RT after provision of information using VR.	IG: n = 150 and relatives	30-min individual educational VR session	After the planning CT scan, prior the RT treatment, except when the time between the planning CT scan and the start of RT was too short	Post-intervention evaluation (after the VR session) with a self-reported survey. *Outcome(s):* patient's needs regrading tumor visualization and RT planning; comments and observations about the educational session (open-ended question).	All patients reported a better understanding about their disease and RT treatment on different levels (procedural, knowledge, technical delivery of treatment), which contributed to a reduction in anxiety and the "fear factor".	33
Wang et al, 2022 USA [60]	Breast, prostate, lung, oesophagus, rectal, endometrial cancer	Determine if VR can improve patient understanding of RT and/or reduce patient anxiety	IG: n = 43	Patient personalized 1-hour educational VR session	1 to 2 days prior to the RT treatment	Pre- and post-intervention evaluation (before and after the VR session) with self-reported questionnaires. *Outcome(s):* patient's knowledge and understanding about illness and RT treatment; RT treatment-related anxiety.	Most patients (93.7 %) agreed that VR educational session increased their knowledge and understanding about RT treatment. More than half (57 %) of the patients who expressed RT-related anxiety at baseline stated that the VR session helped decrease their anxiety about the treatment.	31

Legend: IG = Intervention group; CG = control group; VR = virtual reality; RT = radiotherapy; VERT = Virtual Environment for Radiotherapy Treatment.

on the first day of treatment in one study [56]. Sessions were attended individually [53,56,59,60], in a group [57], or both modalities [54,55,58]. In some studies [53–55,57,59], a relative or a support person was invited to educational sessions.

Assessment and impact of RT educational session using VR on adult patients' psychological and cognitive variables related to the treatment experience

Data collection regarding psychological and cognitive variables was gathered and analysed mainly through self-reported questionnaires (some rather include open-ended questions) completed pre and/or post-intervention, except in one of the studies that performed a pre and post-intervention focus group [56]. The studies frequently assessed patient's knowledge (also evaluated as patient's comprehension or understanding) about aspects of RT simulation, planning and/or treatment [53,54,57,59,60] or about specific procedures to be performed before RT sessions (e.g., bowel and bladder treatment preparation instructions for prostate patients [58]. RT knowledge was assessed through surveys and scales predominantly developed for the study. Most studies [53–58,60] also evaluated patients' perceived anxiety as a psychological state induced or related to the treatment experience. In two studies [53,54], the patient's anxiety levels were evaluated with the State-Trait Anxiety Inventory (STAI), a standardized and well-studied questionnaire; in Gao et al. [53] study, other anxiety-related physiological measures (e.g., blood pressure, heart rate, and respiration) were also considered. The remaining studies developed questions to assess anxiety and concerns related to specific aspects of the RT treatment (e.g., RT machine's movements, radiation exposure). Jimenez et al. [54] also addressed the educational session's impact on patients' confidence regarding RT treatment.

Impact of the educational session on patient's RT knowledge. Independently of the study design, all the articles reported the benefits of the VR educational sessions on increasing patients' knowledge about treatment. Two studies [53,54] assessed the effectiveness of VR educational sessions towards a treatment as usual control condition and compared, at least, the results of two repeated measures. In both cases, the experimental group samples were small ($N \leq 30$), and the conclusions about the impact of the VR were based on different statistical analyses. Gao et al. [53] found that patients that received the VR educational session had significantly improved their RT comprehension regarding simulation, planning and treatment after the intervention compared with the control group. After confirming the group equivalence at baseline, the difference between post and pre-intervention measurements in each group was computed (to eliminate the baseline effect), and the achieved scores were compared (statistical significance for *p*-values below 0.05). Jimenez et al. [54] analysed the impact of the VR educational sessions through comparisons between groups for each of the four-time points measurements separately, considering the same *p*-value for statistical significance. The authors concluded that patient's

RT knowledge (both the combined score and individual scores regarding simulation, planning, and treatment) was significantly higher in the intervention group (when compared with the control group) in all post-intervention assessments (immediately after the intervention, one week of treatment, and in the last week of treatment).

The studies [57–60] that only enrolled patients in the VR educational session (without a control group to compare) also concluded that the intervention increased patients' RT knowledge and comprehension regarding treatment. The dimensions under study were frequently evaluated with individual items and/or open-ended questions in these studies. As such, the conclusions drawn about the impact of VR technology were mainly supported by descriptive analysis; only one study [57] performed inferential statistical analyses. Also, most studies included small samples ($N < 50$), except Sulé-Suso et al. [59] work that analysed data from 150 patients. Marquess et al. [57] ran comparative statistical analyses to assess differences between the mean scores achieved by patients before and after the VR educational session considering a Bonferroni correction for p-value tests adjustment (p-value $<$ 0.05); a standardized estimate of the effect size was also calculated. The authors found that RT comprehension significantly improved from baseline to post-intervention assessment for all items, which included aspects related to the RT environment (e.g., machine movements, noises, smells that patients could feel during the treatment), the treatment procedure itself (e.g., how the RT will be conducted and how will work on the patient's tumour) and how the patient should behave during the treatment. The effect size was higher for "*What I need to do if I need the treatment to be interrupted*." ($d = 3.30$), "*What I will smell during the treatment*." ($d = 2.95$), and "*Why lasers will be used*." ($d = 2.63$) items. In Wang et al. [60] study, the proportion of patients that reported having a good understanding of RT treatment after the VR educational session increased after the session regarding the experience of being treated in the RT room (from 22 to 41 patients), side effects related to radiation (from 33 to 40 patients), and the tumour's size (from 29 to 42 patients). Patients that participated in Sulé-Suso et al. [59], Jimenez et al. [55] and Stewart-Lord et al. [58] studies reported a better understanding of how the RT treatment will be performed and what to expect after the educational session with VR. Specific aspects of the RT preparation procedures, such as the importance of following specific instructions regarding RT preparation procedures (i.e., bowel and bladder) [58], the patient positioning and dose administered in organs [55], the treatment side effects [58], or the nature of their oncological disease [59] were also better understood by patients who were exposed to this virtual reality learning environment. Finally, Johnson et al. [56] qualitative study performed a thematic analysis of a focus group discussion, where seven patients gave feedback about a prototype 360-degree VR video viewed before the RT treatment. The authors identified four main themes: *Efficacy of traditional education*, *VR benefits*, *VR challenges/limitations*, and *VR logistic*. Regarding *VR benefits*, all patients stated that the VR video delivered additional information that the earlier teaching session could not provide, and several of them referred to the potential of VR video to increase understanding of the view and sound components of the treatment.

Impact of VR educational session regarding patient's treatment-related anxiety. The findings regarding the VR education sessions impact on patients' treatment-related anxiety levels were less homogeneous than patients' RT knowledge. In Gao et al. [53] study, scores for three anxiety measures (i.e., STAI-S, systolic blood pressure, and heart rate) in the experimental condition were significantly lower than the control group after the intervention. Nevertheless, scores regarding the visual analogic scale, diastolic blood pressure, and the respiratory rate did not differ between groups compared with the baseline assessment. The analyses were run considering group equivalence at baseline for all the dimensions. In the Jimenez et al. [54] study, intervention and control groups consecutively diminished their anxiety scores across post-intervention assessments. Although the decrease in anxiety was higher for patients exposed to VR educational sessions, the results did not significantly differ from the control group. As mentioned previously, this study did not assess the interaction between condition and time on treatment-related anxiety outcomes.

Marquess et al. [57] found a significant decrease in patients' concerns after the VR educational session regarding treatment precision ("*What I will feel while I am getting each radiation treatment.*"), RT machine movements ("*The treatment machine moving close to me during the treatment.*"), radiation exposure ("*Getting radiation to my prostate.*", "*Having X-rays every day*."), or what he/she will feel during RT treatment ("*What I will feel while I am getting each radiation treatment.*") items. Overall, the effect sizes were low; the item regarding treatment precision achieved the highest effect size ($d = 1.51$). On the other hand, concerns about the odors felt during the treatment, the need to wait for their turn, or being alone in the RT room did not significantly diminish after the session. The two studies [56,60] investigating patients' opinions regarding VR sessions' effect on anxiety revealed positive results. Over half (57 %) of the 21 patients who expressed any treatment-related anxiety level at baseline reported that VR sessions helped decrease those concerns [60]. Patients that participated in Jimenez et al. [55] study also highlighted how the VR session helped them to alleviate their treatment-related stress and focus on the positive effects of the RT rather than on the side effects. In Jonhson et al. [56] qualitative study, 57 % of the participants agreed that VR video had the potential to reduce anxiety related to RT treatment in new patients.

Impact of VR educational session regarding other psychological variables related to the RT experience. Jimenez et al. [54] also assessed the VR educational session impact on patient's level of confidence regarding RT treatment, asking questions about how the session helped patients to improve their RT experience, feel comfortable with the treatment machine and radiation therapist's procedures, or if the patient's initial expectations about RT were accurate. The evaluation of this dimension was accessed twice, in the first week (T3) and the last week of RT treatment (T4). Although no inferential statistical information was available regarding the significance of mean differences within or between groups, the descriptive analysis showed that the experimental groups achieved higher mean scores than the control group at T3 regarding all patient RT experience questions. Both groups' scores slightly increased or remained equal from T3 to T4.

Discussion

This systematic review aimed to assess the impact of the VR educational session on patients' psychological and cognitive outcomes related to the treatment experience. We analysed eight articles regarding seven studies, primarily quantitative, with a one-arm design and including patients with different oncological diseases. VR educational sessions also varied greatly regarding the timing of the RT treatment at which patients received the session, the timing of the treatment when the complementary informational component was delivered, and its duration. These outcomes may indicate that RT educational sessions are not sufficiently documented and protocolled. Researchers and institutions are still looking for the best way to deliver them to patients, given that VR procedures are relatively recent. It is also noticeable that the studies were carried out in a hospital setting with a sensitive population (i.e., patients undergoing cancer treatment), which may have made using more detailed study designs difficult. Regarding the quality of the studies, although the overall evaluations were relatively good, we found many instruments used to assess cognitive and psychological variables. Some questionnaires were constructed specifically for the study, and details about their development, testing, and/or psychometric features were only sometimes available in the articles. These reasons justified some of the scores given to the studies' methodological quality (i.e., two studies scored *Good* [55,59], the remaining classified as *Fair* [53,54,57,58,60] and one as *Poor* [56]. Also, particularly in studies with a two-arm design, the statistical analysis did not always allow us to understand whether there were differences regarding the effect of

experimental conditions (between-groups variability) over time (within-groups variability).

All studies assessed patients' RT knowledge and/or treatment-related anxiety as the primary cognitive and psychological dimensions to evaluate the impact of educational sessions with VR. Although these variables are usually considered in studies on procedures and treatments in oncologic patients, it would be interesting to understand the impact of VR on other variables that have also been shown to be essential for patients undergoing radiotherapy, such as self-efficacy [21]. Only one study [54] evaluated the educational session's impact on a different psychological dimension, i.e., patients' confidence regarding RT treatment.

The two-arm studies showed that, in general, patients' knowledge of RT treatment was higher after the educational session compared to usual care (without VR) [53,54]; studies with only one experimental condition also showed significant positive differences after the VR session [55–60]. Moreover, patients reported increased knowledge and understanding of the RT treatment process after the VR educational session in focus group discussion and open-ended questions [55,56,58,59]. It is possible that VR technology offers patients a virtual environment experience about the treatment of RT and how radiation will work on their bodies, which is hardly achieved through the explanations given by health professionals [19,41]. On the other hand, this technology might allow some patients autonomy in exploring the available content and meeting their distinctive information needs [31,42,61]. Although Halkett et al. [23,24] found that patients have higher information needs before treatment planning and treatment, the differences between studies regarding the timing to deliver the educational session with VR to patients did not seem to interfere negatively with the effectiveness of the intervention regarding patients' RT knowledge.

Treatment-related anxiety levels were measured with standardized instruments (i.e., STAI), questions to assess concerns regarding RT treatment, and physiological data (blood pressure, heart rate, and respiration) that reflect the patient's psychological state. Although anxiety levels have decreased with VR educational sessions and throughout the treatment in almost all the studies, these outcomes were more heterogeneous and less precise than those concerning the knowledge about RT treatment. For example, in Jimenez et al. study [54], anxiety levels decreased significantly in the VR group at the T2 time point; however, there were no significant differences compared with the control group for each time point measurement. Several factors might have contributed to these results. First, patients may have high trait anxiety, a general anxiety vulnerability risk factor for adverse stress reactions. This dimension of anxiety was only considered in two studies of the present review, and its effect was not controlled when the differences between groups and repeated measures were assessed [53,54]. As early evidenced by Grilo et al., patients with trait anxiety need educational sessions with additional coping strategies training that was not the focus of these sessions [63]. VR educational sessions might impact patients' understanding of the procedure, especially the effect of RT treatment on inside tissues [58,59], not necessarily decreasing patients' emotional arousal. Second, there may be aspects related to the RT treatment experience that may generate anxiety that VR does not address. For instance, patients' overall treatment-related anxiety might be influenced by concerns about the RT's effect on the progression of the disease, which is unlikely to be reduced in educational sessions [64]. Some studies analysed anxiety levels regarding specific aspects of RT but only related to procedural features of the treatment (e.g., RT machines movement, being alone in the room) [57]. Third, in the studies in which anxiety was assessed at various times, anxiety was decreased throughout treatment, even in the control group. These results might suggest that daily exposure to treatment may have an anxiety desensitization effect [63]. Further research is needed to clarify the effect of VR on psychological processes related to RT.

On the other hand, it might be interesting to study what kind of cancer this tool could be more beneficial to improve patient understanding and adherence. Treatments that require preparation (like a bladder filling and bowel evacuation protocol) should be mainly studied, as they make the treatment experience more demanding [64]. Examining how VR impacts patients' preparation adherence would provide helpful knowledge for RT professionals. Considering patient characteristics, it is valuable to analyse the effect of VR on cognitive and psychological variables in older [65] and low-health literacy [38,48] radiotherapy patients. Finally, it could be interesting to analyse the effect of other VR systems, beyond VERT, on cancer patient radiotherapy education.

Our findings seem to point to the usefulness of VR as an additional tool to educate patients undergoing radiotherapy without requiring patients' previous or special skills [5]. Nevertheless, VR tools for patient education are still at the beginning of their development, and possible limitations to their extensive use should be addressed. Besides time and resource consumption, [67–69], which might interfere with RT departments' workflow, the cost of this technology is not negligible [70]. Systems like VERT (used in most studies retained for our review), are costly and may not be easily acquired by RT departments [19]. Additionally, some studies pointed out that VR, particularly immersive technology, can generate cybersickness, described by disorientation, nausea, and oculomotor symptoms in some patients [66,70]. Although no significant VR adverse effects were found in a recent study that used VR to relieve pain in cancer patients receiving palliative care, no significant adverse effects of VR were found, this possibility cannot be ignored. Zhou et al. [71] recommends avoiding VR use on patients that initiated RT immediately after chemotherapy due to possible increased nausea. It is also advised not to employ VR technology with patients who have vestibula or seizure history disorders [68].

Limitations

The strength of the current systematic review is the rigorous methods implemented to identify and select all studies relevant to the purpose of this study, as well as evaluate their methodological quality in agreement with PRISMA guidelines [51]. However, we should mention some limitations of the study. The search strategy was not exhaustive regarding article language and time of publication. Although these criteria might have limited access to some articles, the authors believe that the most relevant literature about educational sessions with VR was screened and retained for analysis. The authors also found some clinical and methodological diversity in the included studies, and the sample of articles is small. These limitations prevented other statistical procedures (e.g., meta-analysis or sensitivity analysis for publication bias). Nevertheless, this work contributes significantly to enlightening which psychological and cognitive variables are assessed when studying the impact of educational sessions of radiotherapy with VR and to draw preliminary conclusions about the benefits of including VR in the preparation of cancer patients for radiotherapy.

Conclusion

The studies that assessed the impact of the educational session with VR psychological and cognitive variables focused mainly on RT knowledge and treatment-related anxiety. Overall, VR educational sessions improved patients' understanding and knowledge about RT and reduced their anxiety levels, with less homogeneous results. These results specific advantages of using VR to complement the standard educational methods in preparing oncological patients who start radiation therapy. Applying this technology would imply additional human resources, costs, and time for hospitals and dedicated equipment/VR systems. Nevertheless, RT departments might benefit from integrating a VR learning environment as a complementary patient education tool. Further research is also required to develop and implement guidelines regarding educational sessions with VR (regarding procedures for specific oncological populations, session duration, or the moment during

the treatment process to deliver the session). It should also incorporate data about how VR can affect reproducibility and treatment accuracy.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tipsro.2023.100203.

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Further reading

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