Daily vs. weekly data collection in VR interventions: Implications from a pilot study of patient-reported outcomes among adults with cancer

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Abstract

Background: Virtual reality (VR) interventions are increasingly used in healthcare settings to improve patient-reported outcomes (PROs). Measuring PROs are commonly evaluated at weekly intervals with data collected via digital surveys. While weekly assessments have benefits, VR devices enable more frequent in-device data collection. It remains unclear whether PROs collected more frequently provide more information on these interventions than PROs collected more infrequently.

Objective: We examined PROs collected daily versus weekly in a VR intervention with nature imagery designed to reduce pain, anxiety and depression and improve well-being among cancer patients. We also evaluated whether guided imagery accompanying the nature imagery improved PROs.

Methods: Patients with cancer were randomly assigned to one of four conditions: [1] VR assisted guided imagery (“VRAGI”); [2] VR without guided imagery, [3] “Desktop VR” on a laptop with guided imagery; and [4] Desktop VR without guided imagery. Devices were mailed to patients' homes. Patients engaged with their assigned intervention for 15-20 minutes daily for three weeks. Weekly levels of pain, anxiety, depression and well-being were measured using items from the Edmonton Symptom Assessment Scale. Daily outcomes were collected in-device before and after each VR session. Descriptive analyses and visual pattern comparisons were used to explore trends and answer our research objectives.

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Conclusions: Daily collection of PROs may be more informative than less frequent data collection. Additional research is needed to confirm these study findings with larger sample sizes. Clinical Trial: Clinicaltrials.gov, NCT05348174

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Daily vs. weekly data collection in VR interventions: Implications from a pilot study of patient-reported outcomes among adults with cancer

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Abstract

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Trial Registration: Clinicaltrials.gov, NCT05348174

Keywords: virtual reality; guided imagery; survey administration; pain management; research design

Introduction

Healthcare interventions using virtual reality (VR) are often evaluated by testing their efficacy at weekly intervals [1,2]. Data can be collected via digital surveys, paper questionnaires, text messages, or physician notes on medication use and psychological outcomes (i.e., pain, anxiety, depressive symptoms) and compared with these same measures weeks later [3,4]. Collecting data relatively infrequently (i.e., weekly) has benefits. For instance, using weekly push notifications from the Research Electronic Data Capture (REDCap) system, patients can complete HIPAA-compliant surveys with minimal burden [5]. Additionally, patients may be more likely to complete surveys if assessments are spaced further apart [6].

Interventions with VR devices allow for more frequent data collection than weekly assessments. One potential benefit of frequent, in-device data collection is the ability to measure changes in outcomes on the VR device each time patients engage with the intervention. Another advantage is that in-device surveys can use approaches such as visual analog scales [7] asking participants how they feel in the moment to collect data with minimal recall bias. These data can be collected and stored on VR devices for retrieval when devices are returned to the research team.

What is relatively unknown is whether more frequent data collection (i.e., daily pre-post surveys) is more informative for measuring patient-reported outcomes (PROs) than less frequent data collection (i.e., weekly surveys). Comparisons of PROs suggest weekly scores tend to be more severe than daily scores [6]. How these findings translate to digital health interventions is largely unknown. Determining the impact of the frequency with which data is collected on PRO measurement would have major implications. If daily surveys showed that the effects of VR plateaus after a certain number of days, then intervention costs and participant burden could be lowered without impacting the intervention efficacy. If daily surveys showed that the impacts of VR were cumulative across time, interventions could continue for many weeks with greater impacts.

In the current study, we examined weekly and daily data from a VR intervention on PROs among patients with varying stages of cancer diagnoses. Our intervention consisted of a virtual computer-generated natural environment similar to other virtual environments that distract and induce relaxation [8,9]. We additionally examined how adding guided imagery to our intervention influenced PROs. Guided imagery is audio narration meant to invoke one or more of the senses and guide an individual to mentally visualize experiences to reduce pain, anxiety and depression and to improve well-being [10]. To generalize to more types of digital health interventions, we provided the intervention at two immersion levels: delivery in a head-mounted display (HMD) and in “desktop VR”—where patients interact with a three-dimensional multimedia environment on a computer screen [11,12]. Our primary research question was: **Is collecting data at weekly intervals sufficient to predict trends in PROs, or is daily data collection more informative?** Additionally, while VR interventions and guided imagery in isolation have been shown to improve PROs among patients with cancer [13–22], we are unaware of published research on how VR with guided imagery improves PROs. Therefore, we included a secondary research question: **Does VR tend to improve PROs when it includes guided imagery?**

Methods

Study Context

This study was part of a larger project examining the impact of virtual reality-assisted guided imagery (VRAGI) dimensions on cancer pain in the home setting [23]. The original intent was to assess the efficacy and safety of VRAGI on opioid use, anxiety, depression, and fatigue and compare those effects with a VR program absent of guided imagery and laptop versions of these two interventions (with and without guided imagery). The results reported here are limited to outcomes available from data collected at both daily and weekly intervals. Only these specific data and outcomes could answer the primary research question for the current study.

Ethical Considerations and Incentives

The study was approved by the Prisma Health IRB (Pro00114598) and published on ClinicalTrials.gov (NCT05348174). The Prisma Health Cancer Institute in Greenville, SC, outpatient oncology and palliative care clinics were the sites of recruitment. Recruitment took place through flyers and word-of-mouth by the clinical and research staff. All patients provided verbal or written informed consent, which occurred 2-3 weeks before the intervention start date. Patients earned a $25 e-gift card at the end of weeks 1 and 2 if they completed ≥75% of the surveys during each of those weeks, a third $25 e-gift card if they completed ≥75% of surveys and initiated the device return after week 3; and a fourth $25 e-gift card if they completed ≥75% of the survey at week 6.

Eligibility and Preliminary Screening

Verification of eligibility relied on electronic health records (EHRs) and follow-up phone conversations with the study coordinator. Inclusion criteria included patients >18 years of age; baseline pain score Edmonton Symptom Assessment Scale (ESAS [24]) ≥ 4 (mean score at 7-day screening); able to provide consent and willing to comply with all study procedures; and able to comprehend spoken and written English. We initially set the inclusion criteria to also include an advanced cancer diagnosis—defined as incurable cancer, including locally advanced and metastatic cancers with no plan for resection during the study period—but broadened this criterion to a cancer diagnosis to expand the eligible sample pool. Exclusion criteria included patients >65 years of age; having a condition that interfered with VR such as a history of seizures, facial injury precluding safe placement of an HMD, or other visual or hearing impairment; previously participated in a VR clinical trial; underwent a surgical procedure within eight weeks; diagnosed with serious mental illness; have brain metastases; have a neurocognitive disorder according to past medical history; have a prognosis of <3 months from the time of enrollment per treating oncologist; experience current substance abuse; or experienced complex childhood trauma.

All eligible patients completed a 4-day screening, which evaluated their adherence to complete surveys. The screening survey used the same instruments as the weekly surveys in the actual study. Patients who completed fewer than 50% of the surveys provided during the screening were dismissed before the randomization process and intervention.

Intervention

Patients were randomly assigned while considering gender to one of four conditions: VRAGI, VR-NG, Laptop-AGI, and Laptop-NG. VR meant the intervention was delivered via an HMD, specifically a Meta Quest 2 (1832 x 1920 resolution per eye; 106° horizontal and 90° vertical

field of view; ≤120 Hz refresh rate), while the Laptop meant it was delivered on a Windows laptop (13” or 15” screen with 1080p resolution). AGI meant the intervention included guided imagery. NG meant the content included no guided imagery and presented simply the nature-based imagery and soundscape.

All four conditions were experienced at the patients’ home while seated. During the study, patients were asked to engage in the intervention daily (15-20 minutes/day) for three consecutive weeks. During the intervention, patients were allowed to undergo any cancer treatments outside the exclusion criteria, as prescribed by their healthcare provider.

All devices and accessories were packaged, shipped to patients’ homes, and ready to be used once unpacked. Virtual content was pre-loaded as an offline app, so no internet was needed, and patients navigated to the app with the provided instructions. Patients in the VR conditions were trained on using the HMD through a printed color manual. Patients in the laptop conditions were provided with a similar manual. To align with the audio experience of the HMD’s near-ear speaker, we provided headphones for patients in the laptop conditions to wear during the intervention. Patients could receive help from researchers by email and a telephone hotline for technical support.

Virtual Content

The virtual content consisted of a computer-generated immersive virtual landscape with nature-based imagery (i.e., trees, birds, mountains, water, and birds) aligned with the landscape preferences and perceived restorative outcomes of past virtual nature scenery [9,25,26]. All conditions also had a nature-based soundscape (i.e., water flowing and birds chirping). Additionally, the AGI conditions included an omnipresent vocal narration that overlapped with the imagery in the virtual scene and steered users through mental escape, redirection of attention, anxiety alleviation, and a non-judgmental acceptance psychological process [23]. Patients were asked to complete the intervention in calendar order (i.e., week 1 was the spring season, week 2 was the summer and week 3 was the fall) (Figure 1).

Figure 1. Seasons available in the virtual environments.

The virtual content was developed across 14 months (December 2020 to February 2022) by an interdisciplinary collaboration of physicians, mental health counselors, human systems engineers, and VR content experts. Patients in all four conditions saw the same virtual content and could look around from all angles by moving their head in the HMD or laptop cursor. No intervention allowed for “walking” within the virtual world.

Measures

Patient Characteristics

Demographic data were provided from the patient’s EHR. These data included date of birth,

age, sex, marital status, education, household income, employment status, insurance status, and place of birth. An EHR review was also used to collect patients' medical record numbers (MRN), type of cancer and other health status measures.

Weekly Data Collection of Patient-Reported Outcomes

Weekly outcomes of pain, anxiety, depression, and well-being were measured with the Edmonton Symptom Assessment Scale (ESAS) [24]. The ESAS is a nine-item patient-rated symptom instrument developed for use with patients receiving palliative care. In the current analysis, we used the individual items measuring patient-reported anxiety, depression, pain and well-being on an 11-point VAS (i.e., 0=none to 10=worst possible). The ESAS has been extensively validated for assessing symptom intensity, including among patients with cancer [27].

All patients were prompted via an email through REDCap and asked to fill out the ESAS at the start and end of each intervention week (days 1, 7, 8, 14, 15, 21). They also received an email reminder through REDCap if they did not complete the ESAS before the end of that day. The weekly response was recorded and stored in REDCap alongside other instruments collected weekly [23].

Daily Data Collection of Patient-Reported Outcomes

Daily outcomes of pain, anxiety, depression, and well-being were measured with an in-device survey instrument designed for this study that was administered before and after each VR session on an 11-point VAS (Figure 2). Patients were required to answer all the survey items before starting the VR intervention and again before quitting the VR application. The order of the survey items was randomized each time they were shown. The daily responses were recorded and stored on the study device (HMD or laptop) and retrieved by the researchers once the patients returned the device.

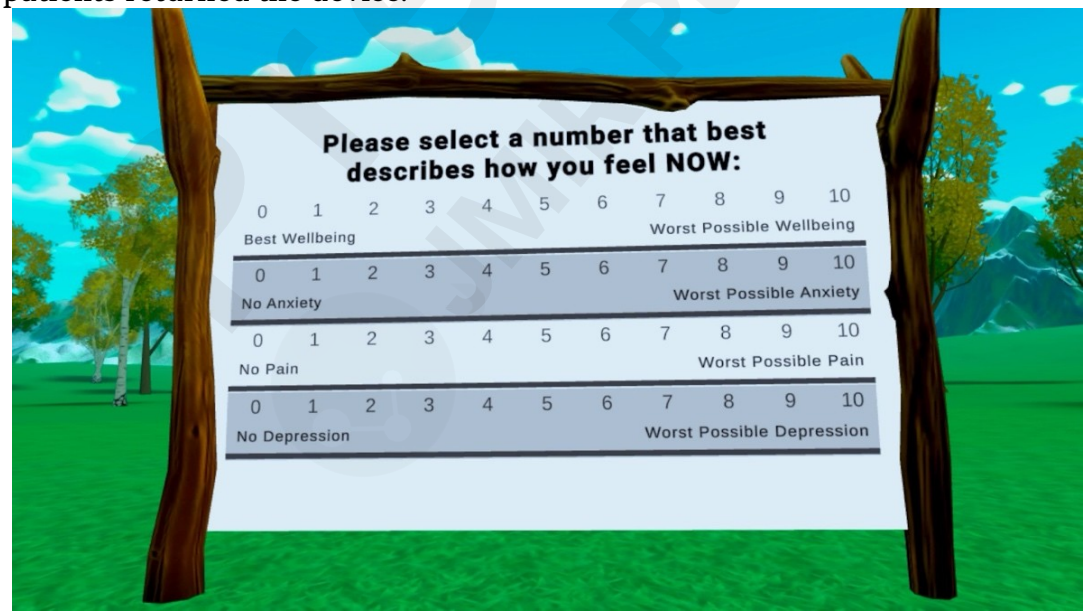

Figure 2. In-device survey for daily data collection of PROs.

Data Availability and Analysis

We faced considerable challenges in recruiting, consenting, and retaining our sample of patients with cancer. Across 17 months of recruitment (February 2023 to January 2024), we collected usable daily and weekly data from eight patients. This sample size was too small to

support powered, inferential statistical analyses. Instead, we treated this as a pilot study, using visual patterns of average scores over time to explore trends in PROs. To compare weekly and daily data, we used the raw values from the ESAS instruments and the differences (post minus pre) values from the in-device survey instruments. The visual patterns were then examined to answer our research questions.

Results

Patient Recruitment and Characteristics

We consented 41 eligible patients, but only 11 passed the screening week criteria (Figure 3). Nine patients were then randomized to VRAGI (N=3), VR-NG (N=1), Laptop-AGI (N=3), and Laptop-NG (N=2), but one patient in the Laptop-AGI condition did not provide daily in-device data. Therefore, our final sample size for analysis was eight.

shows the characteristics of the patients. One-quarter were male, and the average age was 49.1 (range = 30 to 60). All patients were Non-Hispanic White.

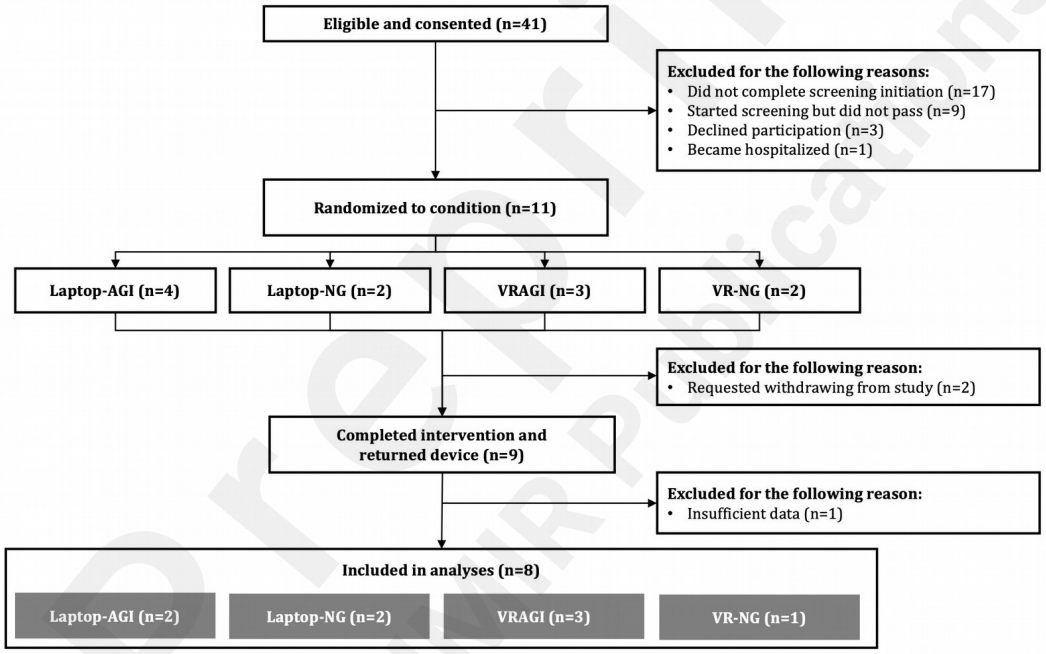

Figure 3. Study flow chart of patient recruitment and available data

Table 1. Characteristics of patients

Characteristic	Total	Laptop-AGI	Laptop-NG	VRAGI	VR-NG
N	8	2	2	3	1
Mean Age	49.1 (10.0)	58.5 (2.1)	50.5 (7.8)	44.3 (12.9)	42.0 (NA)
Sex	Male: 2 (25.0) Female: 6 (75.0)	Female: 2 (100.0)	Male: 1 (50.0) Female: 1 (50.0)	Male: 1 (33.3) Female: 2 (66.7)	Female: 1 (100.0)
Race	White: 8 (100.0)	White: 2 (100.0)	White: 2 (100.0)	White: 3 (100.0)	White: 1 (100.0)
Ethnicity	Not Hispanic: 8 (100.0)	Not Hispanic: 2 (100.0)	Not Hispanic: 2 (100.0)	Not Hispanic: 3 (100.0)	Not Hispanic: 1 (100.0)
Marital Status	Single: 1 (12.5) Married: 6 (75.0) NA: 1 (12.5)	Married: 2 (100.0)	Married: 2 (100.0)	Married: 2 (66.7) NA: 1 (33.3)	Single: 1 (100.0)

Note: Values are presented as mean (SD) for age and n (%) for categorical variables.

Weekly vs. Daily Data on Pain

Weekly pain score data showed no consistent patterns (Figure 4). In contrast, daily data from the laptop-NG and VR-NG conditions revealed double-bottom patterns, with patients reporting the greatest benefits within the first few days of the intervention and again one to two weeks afterward. While these results showed differences in PROs between conditions with and without guided imagery, there was insufficient evidence to suggest that the addition of guided imagery improved PROs.

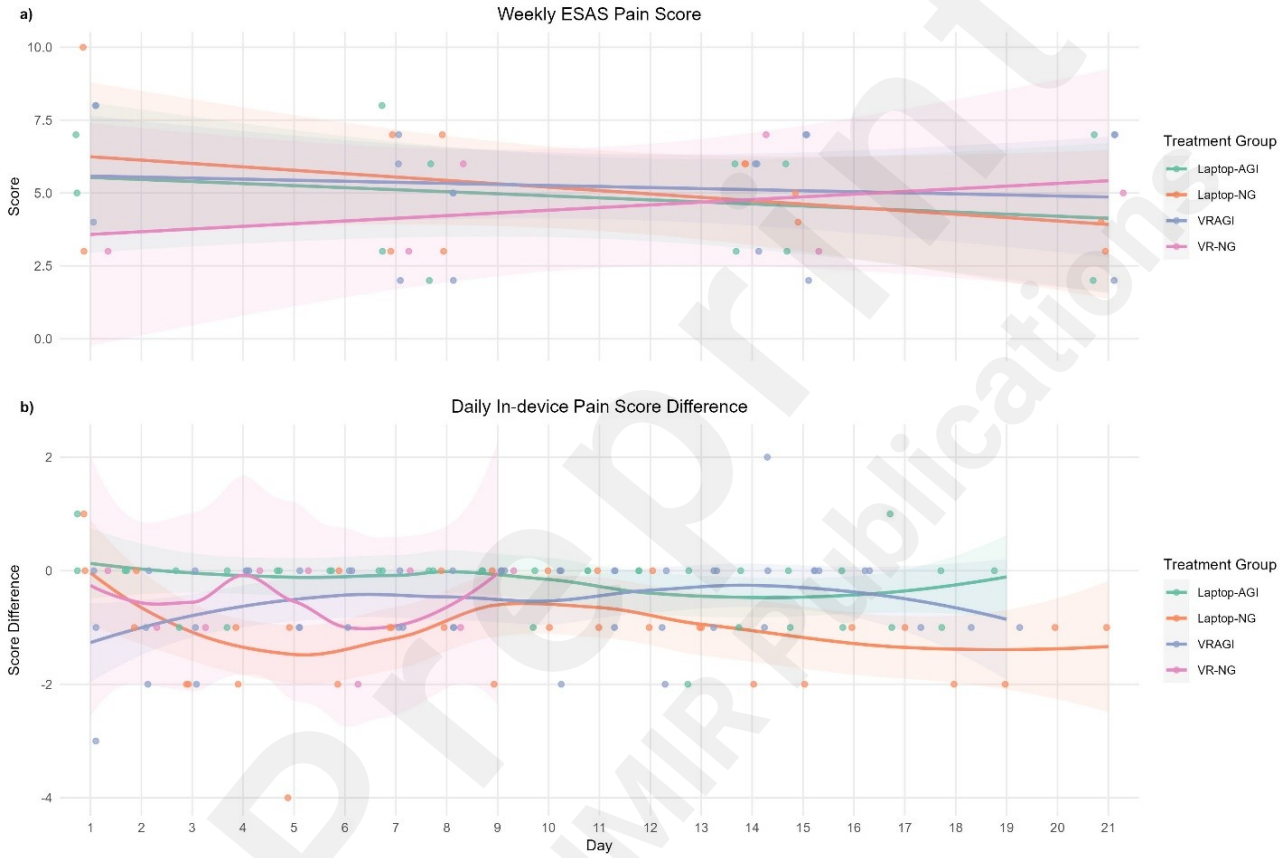

Figure 4. Changes in pain scores based on data collected at weekly vs. daily intervals. (a) Weekly ESAS pain scores. (b) Daily in-device pain score differences.

Weekly vs. Daily Data on Anxiety

Weekly data from the intervention showed no strong effects on anxiety (Figure 5). The laptop-NG condition exhibited the greatest decrease in anxiety over time, while the VR-NG condition showed the greatest increase, though both effects were modest. In contrast, daily data revealed clearer trends for the VR-NG and VRAGI conditions, with anxiety levels plateauing over time. Initial benefits were observed within the first two days of the VR-NG intervention and within the first week of VRAGI. However, these effects did not continue to increase with prolonged use of the intervention. These results also provided insufficient evidence that the addition of guided imagery assisted with PROs.

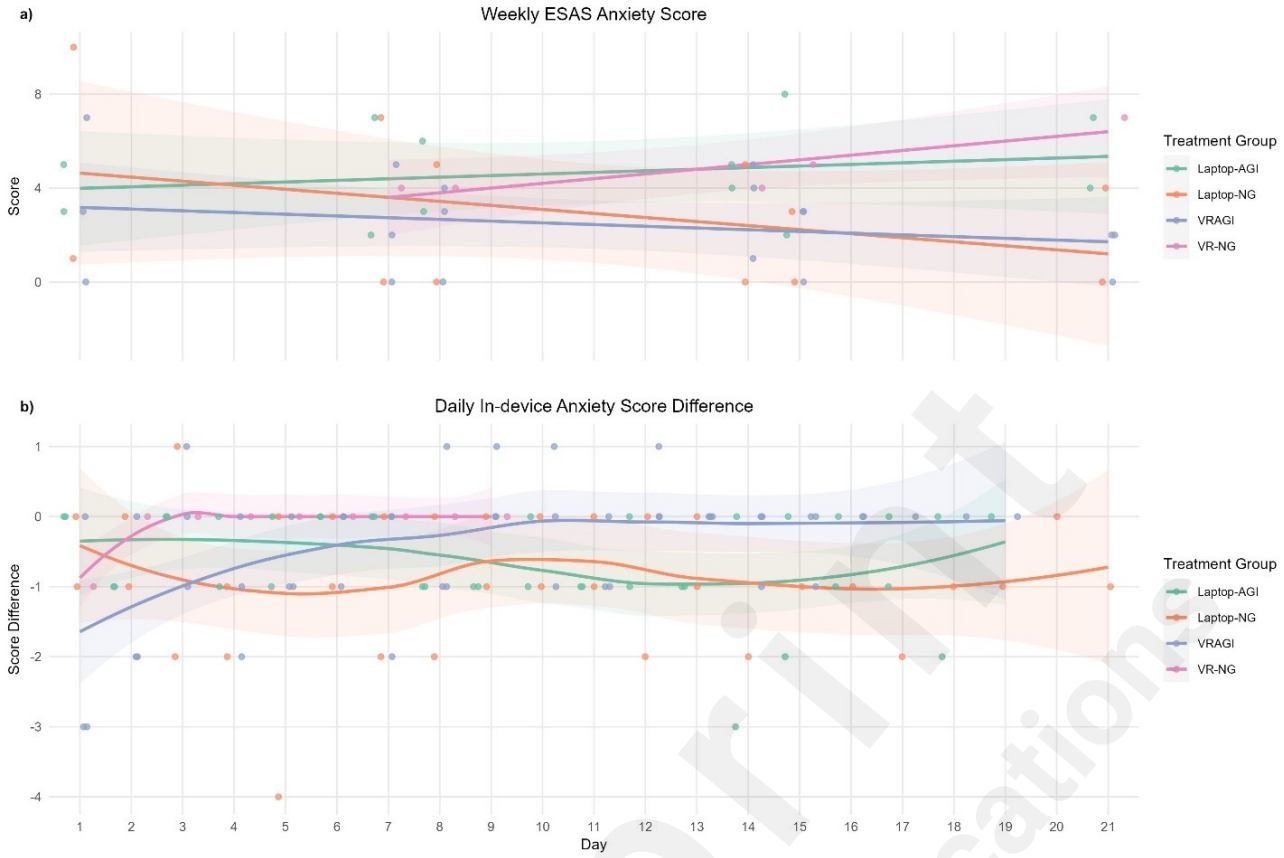

Figure 5. Changes in anxiety scores based on data collected at weekly vs. daily intervals. (a) Weekly ESAS pain scores. (b) Daily in-device pain score differences.

Weekly vs. Daily Data on Depression

Weekly data from the intervention showed no strong effects on depression (Figure 6). However, daily data from VR-NG showed a plateauing pattern where the intervention's benefits were observed in the first two days of device use but not afterward. These results once again provided no evidence that the addition of guided imagery assisted with PROs.

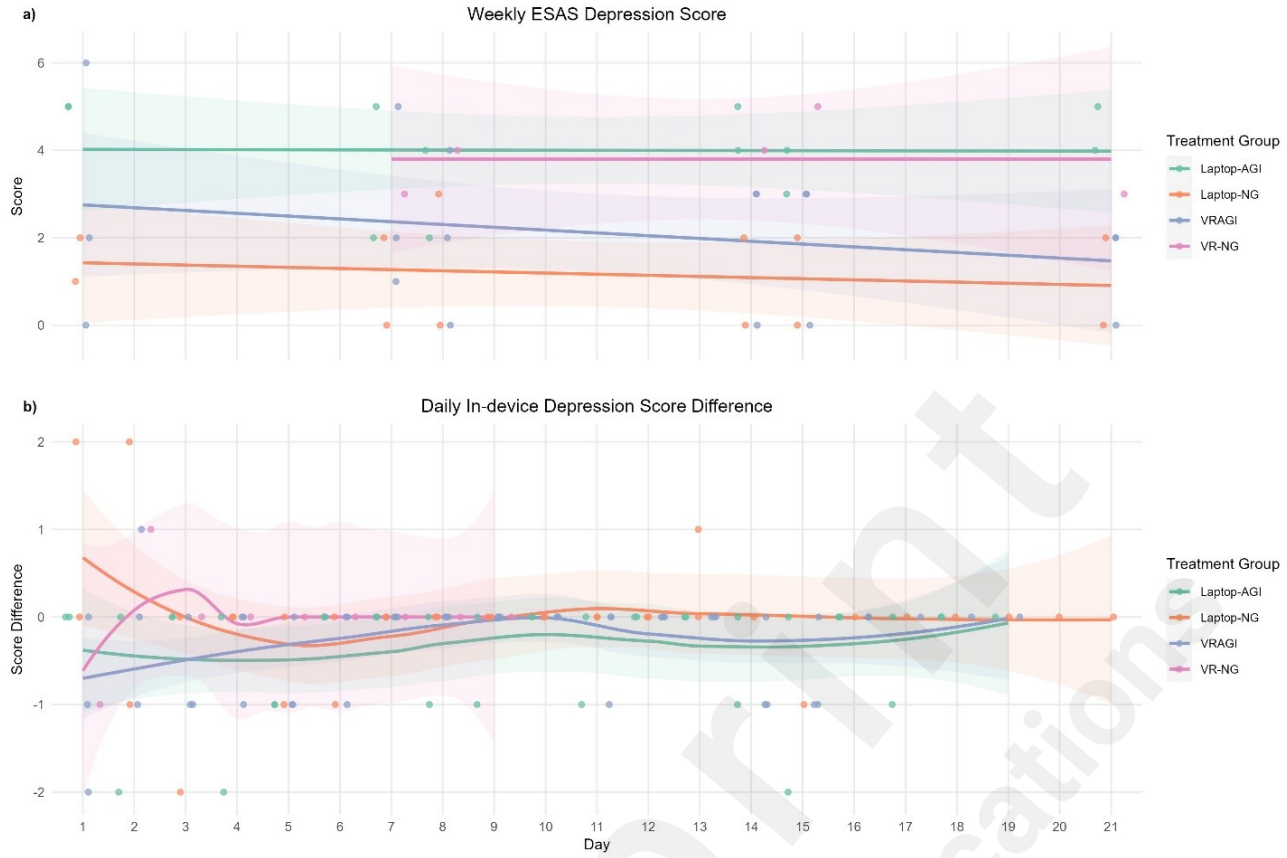

Figure 6. Changes in depression scores based on data collected at weekly vs. daily intervals. (a) Weekly ESAS pain scores. (b) Daily in-device pain score differences.

Weekly vs. Daily Data on Well-being

Weekly data from well-being scores suggested downward trends for VRAGI and VR-NG (Figure 7). Daily data from VR-NG showed a plateauing pattern similar to the depression data pattern, where the intervention's benefits were observed in the first couple of days but not afterwards. These results provided evidence that the addition of guided imagery assisted with PROs measured weekly but not daily.

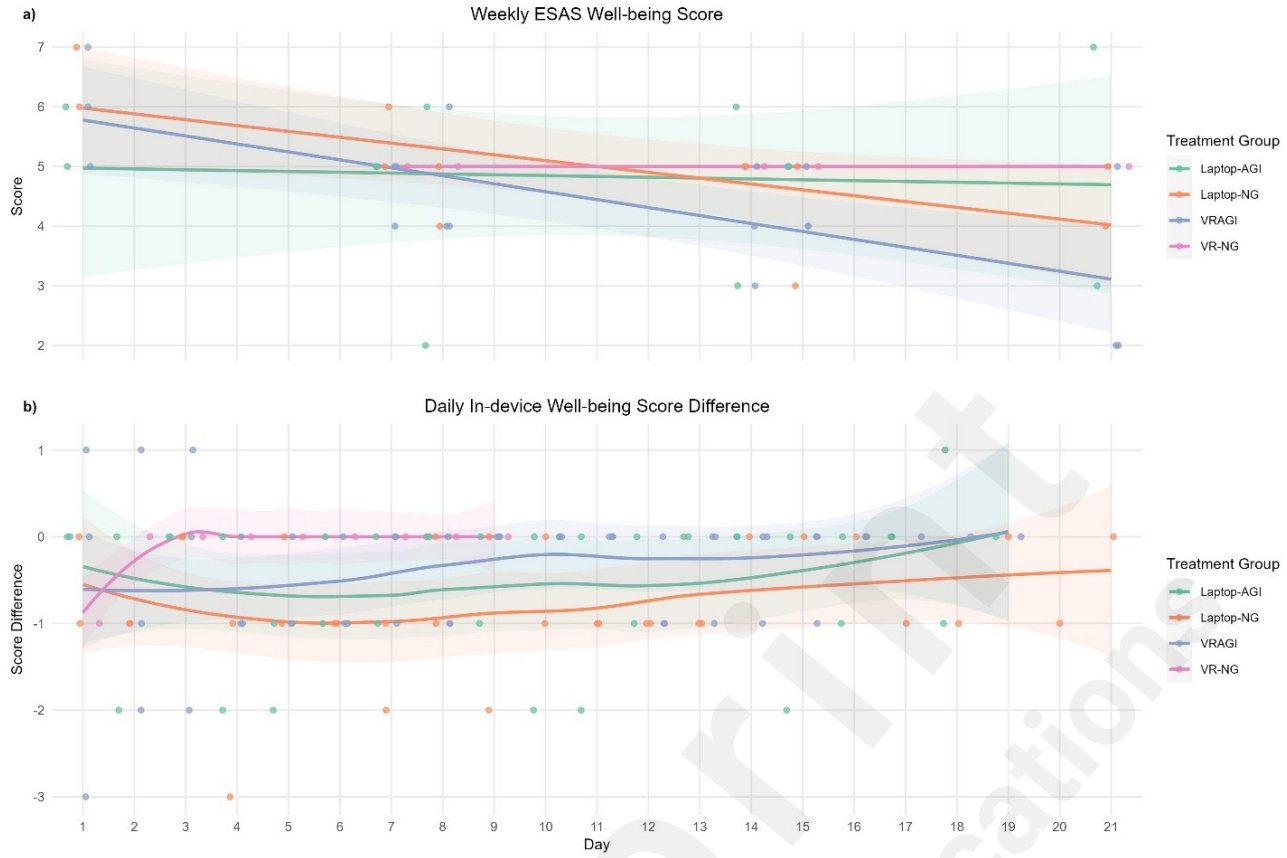

Figure 7. Changes in well-being scores based on data collected at weekly vs. daily intervals. (a) Weekly ESAS pain scores. (b) Daily in-device pain score differences.

Discussion

In summary, eight patients analyzed within this technology-based intervention provided PRO data on daily and weekly schedules. Weekly data showed inconsistent patterns, while daily data revealed more informative trends such as double-bottom patterns and plateauing effects for some outcomes and conditions.

Weekly data for pain, anxiety, and depression PROs had no consistent patterns over time. However, weekly data suggested that the laptop intervention with virtual nature imagery (and no guided imagery) had the greatest **decrease** in anxiety. The VR HMD intervention with virtual nature imagery (and again, no guided imagery) showed the greatest **increase** in anxiety over time.

Daily data showed different findings. The greatest benefit for pain was observed in the laptop and HMD interventions (without guided imagery) but only within the first few days and then one to two weeks later. Daily data also showed benefits for anxiety among the HMD conditions but only within the first few days to one week. Likewise, depression and well-being plateaued after a few days in the VR condition without guided imagery.

Comparing weekly and daily data illustrates the importance of PROs at varying time points during a digital intervention. Without daily data, for instance, there may be less insights into the trends and patterns over the course of the intervention.

Furthermore, for PROs specific to pain, anxiety, and depression, there was insufficient evidence

to suggest that guided imagery improved the benefits of VR. However, for PROs specific to well-being, guided imagery coupled with virtual nature imagery improved well-being when measured weekly but not when measured daily.

Implications for Researchers and Clinicians

This study has implications for researchers and clinicians interested in utilizing VR and XR for improving PROs. It is important to consider when designing an XR clinical trial how frequently to measure PROs. There are benefits and drawbacks to daily versus weekly survey administrations, such as patient burden or biases resulting from repeated survey instruments. Still, daily surveys may allow for in-depth, tracking of an intervention's efficacy. Daily approaches may thus allow for a more personalized approach to these interventions. Research coordinators could communicate with patients after PROs severely decrease, increase, or plateau and offer intervention support or follow-up data collection on the severe changes in PROs.

Daily PRO collection may also allow researchers and clinicians to track when a patient group or individual may discontinue an intervention. For example, a patient group may be on a standardized intervention schedule (i.e., 8 weeks) but their daily PROs may plateau in week four. This indicates that patients may not need to continue the intervention, saving resources and time and ultimately helping patient's reap benefits of PROs quicker and through a less demanding or intensive intervention process. However, it should be acknowledged that plateauing of daily PROs survey may have been due to familiarity of survey items, as patients may have defaulted to providing the same values each time they saw the in-device surveys, even when items are randomized.

Patient samples provide opportunities for applied research where VR and VR interventions benefit those in greatest need. However, we experienced challenges when utilizing patients, specifically those with cancer. Among the 41 patients who provided informed consent, we observed substantial attrition before the intervention initiation, with 42% of patients not choosing to follow-up. This rate may be attributed to multiple factors. For instance, the extended timeline between consent and screening (one week) and involvement of non-healthcare personnel (screening-intervention process was supervised by non-clinical research team members) may have introduced communication inefficiencies and spurred dropout. Streamlining recruitment-to-screening processes and integrating healthcare team members in screening processes might improve early retention rates. Embedding trusted healthcare providers as contacts for XR interventions may also ensure patients are invested throughout the study process. Trusted healthcare providers are likely positioned to build trust and address concerns throughout the study process. This trust-based approach may be crucial in studies requiring sustained patient engagement, such as daily interventions.

Despite the high pre-intervention attrition, the retention rate among patients who commenced the intervention was encouraging, with 73% of patients completing the study protocol. Patients who demonstrated higher engagement and motivation during the screening process tended to show better adherence during the intervention. This suggests that XR interventions measuring PROs may benefit from screening processes that mimic the surveys and patient responsibilities required during the intervention.

For researchers and clinicians using at-home XR interventions, there are challenges to balancing device functionality and monitoring. We ran into minor incidents, including

unauthorized device use by a minor, concerns about illegal data entry, devices malfunctioning and needing to be replaced, and packages missing before arrival. Still, we expect our challenges to have been greater if devices were connected to the internet. Future protocols can be designed to assist XR researchers and clinicians to balance competing priorities, including stable device performance, patient safety, sensitive information, and unauthorized use, while still enabling data collection of PROs and adherence.

Strengths and Limitations

This study had both strengths and limitations. One strength was the combination of immersive nature imagery in VR with guided imagery that could be self-administered at home without an internet connection. The completion rate among our intervention initiators is high (>70%), suggesting this intervention was generally feasible once patients overcame initial barriers. One weakness was our inability to determine adherence for weekly vs. daily survey items. Patients were required to complete the daily surveys to also use the intervention. Weekly surveys were optional and could be answered without using the device. Incentives were contingent on the weekly completion of survey data only, which was designed for the patients to feel encouraged to complete these email-based surveys. Such incongruencies between the requirements and incentives of daily vs. weekly data measures may have led to biases in our results. Additionally, we retrieved data from a small sample size due to recruitment constraints during recruitment, and we were unable to conduct live monitoring or biofeedback to track physiological indicators and validate PROs.

Conclusions

When designing XR interventions, it may be important to consider how often to collect PROs. This pilot study suggests that daily data collection may be more informative for researchers and clinical teams than less frequent data collection. Future research is needed to substantiate these findings and evaluate how data collection frequency and VR interventions like guided imagery impact patient-reported outcomes.

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Data Availability

De-identified data sets in this study are available from the corresponding author on reasonable request.

Author Contributions

MB contributed to conceptualization, funding acquisition, software, formal analysis, methodology, visualization, original draft writing and editing, supervision. OM contributed to conceptualization, project administration, methodology, original draft writing and editing,

supervision. FL contributed to project conceptualization, administration, investigation, software, formal analysis, methodology, visualization, original draft writing and editing, data curation, supervision. JB contributed to conceptualization, project administration, software, methodology, visualization, original draft reviewing and editing, data curation, supervision. DD contributed to investigation, software, formal analysis, methodology, original draft editing, and data curation. FM contributed to conceptualization, software, methodology, narration, original draft reviewing and editing. KM contributed to conceptualization, funding acquisition, project administration, software, methodology, visualization, original draft reviewing and editing, supervision. TG contributed to conceptualization, funding acquisition, project administration, methodology, original draft reviewing and editing, data curation, supervision. All authors approved the final version of manuscript.

Conflicts of Interest

None declared.

Abbreviations

NG: No guided imagery
PROs: Patient-reported outcomes
VR: Virtual reality
VRAGI: Virtual reality assisted guided imagery

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