Jurnal Ners

Volume 21 Issue 1, February 2026, p. 3-10
http://dx.doi.org/10.20473/jn.v21i1.78907

Original Article

Open Access

Effectiveness of virtual reality positive self-talk on changes in brain wave activity among patients with breast cancer undergoing chemotherapy: a randomized controlled trial

Ikhsanuddin Ahmad Harahap[1], Azizah Nasution[2]*, Urip Harahap[2], and Dedi Ardinata[3]

[1] Faculty of Nursing, Universitas Sumatera Utara, Medan, Indonesia

[2] Faculty of Pharmacy, Universitas Sumatera Utara, Medan, Indonesia

[3] Faculty of Medicine, Universitas Sumatera Utara, Medan, Indonesia

*Correspondence: Azizah Nasution. Address: Faculty of Pharmacy, Universitas Sumatera Utara, Medan, Indonesia. Email: azizah@usu.ac.id

Responsible Editor: Retnayu Pradanie

Received: 15 September 2025○ Revised: 20 November 2025 ○ Accepted: 3 Desember 2025

ABSTRACT

Introduction: Patients with breast cancer undergoing chemotherapy often experience pain, cognitive impairments, and changes in brainwave activity. This study evaluated the efficacy of Virtual Reality Positive Self-Talk (VR-PST) on changes in brain wave activity in breast cancer patients undergoing chemotherapy.

Methods: A single-blind randomized controlled clinical trial was conducted involving 92 patients with breast cancer undergoing chemotherapy, who were randomly assigned to the VR-PST intervention group (n = 46) and the control group (n = 46). Participants in the VR-PST group received five intervention sessions conducted over a two-week period, consisting of structured cognitive self-talk presented in a virtual reality environment (VR-PST), while the control group received standard care. Brain wave activities in both groups were measured using the Muse 2 electroencephalographic (EEG) device before and after the intervention.

Results: There were shifts in brain waves from delta to alpha waves in both groups, indicating relaxation; however, the VR-PST group showed a more dominant increase in beta waves. The VR-PST group demonstrated a trend toward greater cognitive activation; however, Fisher's Exact Test showed that the difference between the groups was not statistically significant (p = 0.052).

Conclusions: Although the difference was not statistically significant, the observed trend of increased beta-wave activity in the VR-PST group suggests a possible enhancement of cognitive activation. However, this finding should be interpreted with caution, and further studies are required to confirm this effect.

Keywords: affirmations, brain waves, breast neoplasms, chemotherapy, virtual reality

Introduction

Breast cancer is the most common type of cancer in women, and remains a major cause of morbidity and mortality worldwide. In Indonesia, breast cancer accounts for the highest number of new cases among all cancer types, with a prevalence rate of 16.7% and mortality rate of 11.0% (WHO, 2022).

Pain is one of the most feared symptoms in patients with cancer. Cancer pain typically increases with cancer stage. Previous studies have shown that 60% of patients with metastatic or advanced cancer experience severe pain (European Society for Medical Oncology (ESMO), 2019). Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage (IASP 2022). Pain can be caused by inflammation, nerve compression, and injury to normal tissues by the expansion of tumor cells, which overstimulates nociceptive C-fibers. The condition is also aggravated by decreased descending inhibition from the prefrontal cortex and periaqueductal gray, which keeps these gates open and enhances pain perception (central

sensitization). Thus, breast cancer pain is not just an outcome of problems within the spinal cord (gate control mechanism), but also due to changes in brain wave activity. Because the tumor transmits pain signals persistently, it changes neural oscillation patterns in the brain, which is the rhythmic and regular activity of a population of neurons, particularly increased theta waves (4–8 Hz) in the anterior cingulate cortex (ACC) and gamma waves (>30 Hz) in the somatosensory cortex (Fallon *et al.*, 2018). Pathological theta waves are associated with increased pain sensitivity (hyperalgesia), and gamma waves with sensory-emotional integration of pain (Ploner, Sorg and Gross, 2017).

From a nursing perspective, pain management in oncology practice requires an integrated and holistic approach. Nurses play a central role in providing interventions that not only address physical discomfort, but also help manage psychological and neurocognitive responses to pain. Recently, non-pharmacological interventions that target central nervous system activity have gained recognition as essential complements to conventional therapy (Haywood et al., 2025).

VR-PST combines immersive virtual reality with structured positive affirmation. Virtual reality (VR) provides a multisensory environment that diverts attention away from pain through visual and auditory distractions (Wong, Tse and Qin, 2022), whereas Positive Self-Talk (PST) helps improve cognitive control and emotional regulation by guiding individuals to repeat adaptive statements. VR has been shown to influence brain-wave patterns by modifying attentional processes and sensory integration. VR immersion is associated with increased alpha activity, which indicates relaxation, and increased beta wave activity during tasks involving cognition (Magosso *et al.*, 2019; Kakimoto *et al.*, 2025). PST can improve cognitive control and attention by strengthening adaptive internal self-dialogue, which can modulate neural activity (Kim *et al.*, 2021). By combining these two approaches, sensory distraction and cognitive reframing occur simultaneously, which may affect the brain pathways involved in attention, coping, and pain perception. This approach is also relevant because both VR and self-talk have been shown to modulate central nervous system activity through the attention, emotion, and cognitive control pathways. Thus, VR and PST separately show effects on cognitive and neural processes; yet, no studies have examined the combined use of the two, making this intervention a novel approach developed and tested in this study. However, no studies have directly tested their combined effects on brain-wave modulation.

Brain wave activity is an objective indicator of relaxation, mental activation, and pain processing. Understanding how VR-PST affects brain oscillations can provide important scientific support for its use as a complementary nursing intervention in both hospital- and home-care settings. Therefore, this study aimed to examine the effectiveness of VR-PST in inducing changes in brain wave activity in patients with breast cancer undergoing chemotherapy. These findings are expected to strengthen the evidence base for integrating VR-PST as a non-pharmacological, technology-supported approach in nursing practice.

Materials and Methods

Study Design

This single-blind, randomized controlled clinical trial examined the effectiveness of Virtual Reality-Based Positive Self-Talk (VR-PST) in modifying brainwave activity in patients with breast cancer undergoing chemotherapy. The results presented in this article are part of a larger randomized controlled clinical trial conducted between December 2024 and April 2025. The primary objective of the parent clinical trial was to evaluate the effects of VR-PST on pain intensity, pain interference, quality of life, and EEG-derived brain wave activity in this patient population.

Population

The participants were breast cancer patients undergoing chemotherapy at the Cancer One Day Care (ODC) unit of Adam Malik Hospital and the chemotherapy ward of Prof. Dr. Chairuddin P. Lubis Hospital, University of North Sumatra, Medan, Indonesia.

Subjects and Sampling

Ninety-two participants were recruited using a consecutive sampling technique. The inclusion criteria were as follows: women over 20 years of age, undergoing chemotherapy cycles 1 to 5, experiencing pain of a certain intensity, having the cognitive ability to follow instructions, not currently using sedatives or narcotics, and willing to participate in five therapy sessions with a 2-day interval. Exclusion criteria included patients reporting vertigo or nausea, experiencing worsening clinical conditions, having mental/physical disorders during VRS-PST sessions, or using sedatives or other neuroactive medications. The minimum sample size was calculated using G*Power with an effect size of 0.80 based on previous studies (Téllez, Juárez-garcía and Jaime-bernal, 2017; Razak, Chung and Ahmad, 2019; Sirait, Purba and Harahap, 2022). The minimum sample size required for each group was 42. To compensate for possible participant dropouts, the sample size of each group was increased by 10% to 46 participants. All participants lived within the city, and monitoring of the intervention was conducted through home visits to reduce the possibility of dropout.

Randomization Procedure

The allocation sequence was generated automatically using a computer-based randomization software (Research Randomizer, www.randomizer.org). The sequence was neither created nor altered by the principal investigator or the research assistant. The randomization list consisted of an unpredictable series of group codes produced by the software, rather than a set alternating pattern (e.g., ABAB). This pre-generated random list was then used to assign participants to the VR-PST or control group based on the order in which they enrolled and completed the initial EEG evaluation.

Blinding

Participants were not informed of the research hypothesis and the research outcome assessors did not know the group allocation through the use of numerically coded EEG files. Researchers who administered the VR-PST intervention could not be blinded because of the nature of the treatment and were not involved in the randomization process, thereby minimizing potential allocation bias.

Intervention

Participants in the intervention group received VR-PST treatment, which was conducted over five sessions. Each session lasted approximately 15 minutes and was held every other day for ten consecutive days. The VR-PST therapy used a Shinecon 6.0 VR Box headset connected to a smartphone to display videos of positive self-talk. Before the first session, all participants underwent baseline EEG measurements. The principal investigator created the video specifically for this study. To ensure therapeutic accuracy and conceptual appropriateness, the investigator revised the script, which consisted of 55 positive self-talk affirmations organized into four phases (pre-talk, relaxation, positive self-talk, and closing) after consulting with three hypnotherapy experts. An information technology specialist provided technical assistance in the production of the audio and visual elements. The VR environment presented a standardized natural scenery accompanied by low-intensity instrumental audio to support immersive engagement. Participants were asked to verbally repeat each affirmation throughout the session to promote cognitive involvement. Post-test EEG measurements were taken after the completion of the fifth VR-PST session. The participants in the control group received standard care per hospital protocol and did not participate in any VR sessions. The VR-PST schedule is presented in Table 1 to clarify the intervention protocol.

Data Collection

Brain wave data were recorded using the Muse 2 Brain Sensing Headband, which captures four-channel EEG signals from AF7, AF8, TP9, and TP10, following the 10–20 system. The validity of Muse 2 has been demonstrated by its ability to reliably detect standard ERP components (N200 and P300) with high accuracy (Krigolson *et al.*, 2017). The data were streamed via the MindMonitor application and exported. csv format for the offline analysis. The spectral band power for the gamma, beta, alpha, theta, and delta frequencies was computed using a MATLAB script that applied fast Fourier transform (FFT)-based power spectral density estimation. The mean band power was averaged across the four channels and the dominant frequency band for each participant was identified as the band with the highest mean power.

Potential confounders related to chemotherapy were recorded, including the cycle, regimen, and cycle interval (Table 2). To minimize variability due to acute chemotherapy effects such as fatigue or medication exposure, all baseline EEG measurements were collected at a standardized time point immediately following each participant's chemotherapy session. The remaining uncontrolled factors were assumed evenly distributed through randomization.

Data Analysis

Data were analyzed using IBM SPSS Statistics Version 25. Normality tests for all types of brain waves (gamma, beta, alpha, theta, and delta), both before and after the intervention, were performed using the Shapiro-Wilk test. The uniformity of the wave category distribution was tested using the Chi-Square Test of Homogeneity. The findings indicate that not all brain wave frequencies are normally distributed; therefore, non-parametric statistics were used, and descriptive data were reported as the median and interquartile range (IQR). Fisher's Exact Test was used to compare brainwave distribution between groups. Statistical significance was set at $P < 0.05$. Data analysis was performed using a per-protocol approach, because all participants in both groups completed five VR-PST intervention sessions according to the protocol. None of the participants dropped out or

Table 1. VR-PST Intervention Schedule and Implementation Procedures

Components	Description
Total sessions	5 VR-PST sessions
Duration per session	15 minutes
Frequency	Every 2 days
Overall duration	±10 days
Pre-test EEG	Before first VR-PST session
Post-test EEG	After fifth VR-PST session
Mode of delivery	VR headset (Shinecon 6.0) + smartphone
Intervention content	Structured 4-phase positive self-talk video (55 affirmations)
Setting	Baseline EEG at hospital; Session 1 at hospital; Sessions 2–5 conducted during home visits

Table 2. Characteristics of the study participants

Characteristics	VR-PST group n (%)	Control group n (%)
n	46	46
Age (years)	49 (42.3-56.8)*	52.5 (46-59.8)*
19–39 years (Young adult)	6 (13)	4 (8.7)
40–59 years (Middle-aged adult)	33 (71.7)	30 (65.2)
60–69 years (Young elderly)	6 (13.0)	12 (26.1)
70–79 years (Old-elderly)	1 (2.2)	-
Occupation		
Employer	8 (17.4)	5 (10.9)
Farmer	6 (13.0)	3 (6.5)
Self-employed	4 (8.7)	5 (10.9)
Homemaker	28 (60.9)	33 (71.7)
Surgical history		
Non-Mastectomy	31 (67.4)	33 (71.7)
Post-Mastectomy	15 (32.6)	13 (28.3)
Chemotherapy Cycle		
Cycle 1	26 (56.5)	20 (43.5)
Cycle 2	10 (21.7)	4 (8.7)
Cycle 3	4 (8.7)	8 (17.4)
Cycle 4	4 (8.7)	14 (30.4)
Cycle 5	2 (4.3)	-
Chemotherapy interval		
21 days	40 (87.0)	35 (76.1)
30 days	6 (13.0)	11 (23.9)
Chemotherapy regimens		
Taxane and Anthracycline combination	11 (23.9)	14 (30.4)
Taxane and HER2-targeted combination	13 (28.3)	8 (17.4)
Taxane-based	9 (19.6)	7 (15.2)
Anthracycline-based	4 (8.7)	4 (8.7)
HER2-targeted	3 (6.5)	1 (2.2)
Others	6 (13.0)	12 (26.1)
Brain wave (pre intervention)		
Gamma (γ): 25-100 Hz	4 (9.0)	4 (9.0)
Beta (β): 12-25 Hz	-	7 (15.0)
Alpha (α): 8-12 Hz	2 (4.0)	8 (17.0)
Theta (θ): 4-8 Hz	4 (9.0)	9 (20.0)
Delta (δ): 0.1-4 Hz	36 (78.0)	18 (39.0)
Brain wave (post intervention)		
Gamma (γ): 25-100 Hz	-	-
Beta (β): 12-25 Hz	18 (39.0)	9 (20.0)
Alpha (α): 8-12 Hz	21 (46.0)	27 (59.0)
Theta (θ): 4-8 Hz	5 (11.0)	10 (21.0)
Delta (δ): 0.1-4 Hz	2 (4.0)	-

*median (IQR)

were lost to follow-up, so all participants were included in the analysis, and no imputation was performed.

Primary Outcomes

Following these methods, the primary outcome of the study was the change in EEG brain wave distribution (gamma, beta, alpha, theta, and delta) before and after the five VR-PST sessions.

Ethical Consideration

The Health Research Ethics Committee of Universitas Sumatera Utara granted ethical permission for Health Research Implementation (Number 311/KEPK/USU/2024). All the participants signed an informed consent form after providing verbal and written consent. They were informed of the study methods, potential risks, and benefits. Participants were free to withdraw from the study at any time without penalties. All personal data were kept confidential and analyzed anonymously. As part of the ethical practice, participants in the control group were informed that they could receive the VR-PST intervention after completing all study procedures. The VR-PST sessions were made available to control participants who expressed interest and provided their consent.

Results

In total, 145 participants were evaluated for eligibility. Fifty-three were disqualified because they refused to participate, resided in remote locations, or did not meet the inclusion criteria. The remaining 92 individuals were randomly divided into two groups: the control group (n = 46) and VR-PST intervention group (n = 46). There were no missing data for any outcome variable because every participant received their assigned intervention or normal care and completed all planned follow-up evaluations. No participants were eliminated from the analysis or lost to follow-up. A CONSORT flow diagram is shown in Fig. 1.

The Shapiro–Wilk normality test indicated that all brain wave activity variables, both before and after the intervention, were not normally distributed ($p < 0.05$). Furthermore, the homogeneity test indicated that the data before the intervention were not homogeneous ($\chi^2 = 18.523$; $p = 0.001$). In contrast, the data after the

Table 3. Median of brain wave and IQR before and after VR-PST intervention in both groups

Brain wave	VR-PST group		Control group	
	Median	IQR	Median	IQR
Brain waves (pre)				
Gamma (γ): 25-100 Hz	1.00×10^{-4}	$5.00\times10^{-5} – 1.87\times10^{-3}$	1.98×10^{-3}	$1.89\times10^{-3} – 2.05\times10^{-3}$
Beta (β): 12-25 Hz	2.88×10^{-4}	$1.75\times10^{-4} – 1.69\times10^{-3}$	1.98×10^{-3}	$1.81\times10^{-3} – 2.20\times10^{-3}$
Alpha (α): 8-12 Hz	5.50×10^{-4}	$2.94\times10^{-4} – 1.74\times10^{-3}$	1.90×10^{-3}	$1.63\times10^{-3} – 2.16\times10^{-3}$
Theta (θ): 4-8 Hz	9.88×10^{-4}	$4.94\times10^{-4} – 1.71\times10^{-3}$	1.98×10^{-3}	$1.79\times10^{-3} – 2.23\times10^{-3}$
Delta (δ): 0.1-4 Hz	2.48×10^{-3}	$1.95\times10^{-3} – 5.36\times10^{-3}$	2.12×10^{-3}	$1.84\times10^{-3} – 2.12\times10^{-4}$
Brain waves (post)				
Gamma (γ): 25-100 Hz	3.00×10^{-4}	$3.00\times10^{-4} – 3.25\times10^{-4}$	3.00×10^{-4}	3.00×10^{-4} - 3.00×10^{-4}
Beta (β): 12-25 Hz	3.25×10^{-4}	$3.25\times10^{-4} – 3.50\times10^{-4}$	3.25×10^{-4}	$3.00\times10^{-4} – 3.50\times10^{-4}$
Alpha (α): 8-12 Hz	3.50×10^{-4}	$3.50\times10^{-4} – 3.75\times10^{-4}$	3.50×10^{-4}	$3.25\times10^{-4} – 3.50\times10^{-4}$
Theta (θ): 4-8 Hz	3.25×10^{-4}	$3.25\times10^{-4} – 3.50\times10^{-4}$	3.25×10^{-4}	$3.19\times10^{-4} – 3.50\times10^{-4}$
Delta (δ): 0.1-4 Hz	3.25×10^{-4}	$3.25\times10^{-4} – 3.31\times10^{-4}$	3.25×10^{-4}	3.00×10^{-4} - 3.25×10^{-4}

Table 4. Differences in Post-VR-PST Brainwave Types Between Groups

Statistical Test	Exact Sig. (2-sided)	Cramer's V
Fisher-Freeman-Halton Exact Test	$p = 0.052$	0.28

Cramer's V = 0.28 indicates a medium effect size.

intervention were homogeneous ($\chi^2 = 7.417$, p = 0.060), although some cells showed low expected cell counts. Based on these findings, further analyses were conducted using nonparametric methods.

Table 2 illustrates the characteristics of the study participants in both groups: VR-PST group (n = 46) and control group (n = 46). The ages of the participants in both groups were similar. The majority of participants in both groups were in the middle-aged adult with proportion: VR-PST group, 71.7%; control group, 65.2% with the median age (years): VR-PST group, 49 (IQR 42.3 – 56.8), whereas the median age of the control group was 52.5 years (IQR 46 – 59.8). Most of the participants in both groups were unemployed or homemakers in the following proportions: VR-PST group, 60.9%; control group, 71.7%; underwent non-mastectomy procedures with proportion: VR-PST group, 67.4%; control group, 71.7%; and received their first chemotherapy cycle (56.5% vs. 43.5%) at a 21-day interval (87% vs. 76.1%). Three of the most frequently administered chemotherapy regimens in the VR-PST group (in decreasing order) were Taxane and HER2-targeted (28.3%), Taxane and Anthracycline (23.9%), and taxane-based (19.6%). In the control group, three of the most frequently administered chemotherapies in decreasing order were Taxane and Anthracycline combination (30.4%), Taxane and HER2-targeted combination (17.4%), and taxane-based regimen (15.2%).

There was a difference in the brain wave distribution patterns pre- and post-intervention in both the groups. In the pre-phase, delta waves were dominant in both groups (78% in the VR-PST group vs. 39% in the control group), indicating that most participants were in a state of deep relaxation or rest before the intervention. After five sessions of VR-PST intervention, changes in brain wave activity occurred in both groups, where most participants in both groups showed a shift in brain waves to alpha waves (46% vs. 59%).

Interestingly, the greatest contrast was seen in the brain wave pattern after the intervention, especially in the VR-PST group, where more subjects had greater beta brainwaves than the control group (39% vs. 20%). This result indicates that VR-PST may influence brain waves, as reflected by the observed changes in brain wave activity.

The median and IQR values of the brain waves before and after VR-PST intervention in both groups are presented in Table 3. Based on the analysis of brainwave frequencies, the overall activity pattern was relatively similar between the VR-PST and control groups before the intervention. Prior to VR-PST, both groups demonstrated the highest median brainwave activity in the delta wave band, with median values of 2.48×10^{-3} (IQR 1.95×10^{-3}–5.05×10^{-3}) in the VR-PST group and 2.12×10^{-3} (IQR 2.44×10^{-3}–1.84×10^{-3}) in the control group, indicates a dominance of slower wave activity at baseline, reflecting a relaxed or drowsy mental state. After the VR-PST intervention, both groups exhibited an overall increase in the median values across most brainwave frequencies. However, a notable shift occurred from the delta band to alpha and beta bands. Both groups had the highest median brainwave values in the alpha band, with 3.25x10-4 (IQR 3.75x10-4 – 3.50x10-4) in the VR-PST group and 3.25x10-4 (IQR 3.50x10-4 – 3.25x10-4) in the control group, indicating enhanced alertness and cognitive engagement. Despite this upward trend, the magnitude of the change was greater in the VR-PST group, suggesting that VR-PST may have contributed to greater relaxation and focused awareness.

Table 4 shows a comparison of post-intervention brainwave distributions between the VR-PST and control groups. The difference was analyzed using Fisher's Exact Test because 25% of the cells had an expected count below 5, which violated the chi-square test assumptions. The analysis yielded a two-sided p-value of 0.052, indicating that there was no significant difference in the post-intervention brainwave distribution between the

VR-PST and control groups. Although non-significant, the effect size (Cramer's V = 0.28) indicated a moderate association.

Discussions

This study aimed to determine the effectiveness of VR-PST in influencing brain wave activity in patients with breast cancer receiving chemotherapy. Both groups displayed a change in wave direction and meaning from delta waves (low arousal) to alpha waves (relaxation), which was more obviously indicative of a calm state.

Brain wave analysis showed that during the pre-VR-PST intervention phase, participants in both groups had lower median brainwaves, with delta brainwaves being more prevalent in both groups, especially in the intervention group. Participants were recruited, and brainwaves were measured before the VR-PST intervention while receiving chemotherapy at either the One Day Care (ODC) unit of Adam Malik Hospital or the Chemotherapy Unit of Prof. Dr. Chairuddin P. Lubis Universitas Sumatera Utara Hospital. The VR-PST sessions were then followed at home and administered every other day for five sessions. This setting may have influenced the initial brainwave measurements, as participants in both groups showed low-frequency brainwave activity, predominantly in the delta range, during the preintervention stage.

With regard to chemotherapy, the most common drugs administered to both groups were taxane-based drugs, especially in combination with paclitaxel. Paclitaxel is a taxane chemotherapy and antimitotic chemotherapy that stabilizes microtubules to prevent depolymerization and interrupt cancer cell division (Weaver, 2014). Clinically, paclitaxel is administered as the first-line treatment for various types of cancers, including breast cancer (National Comprehensive Cancer Network, 2023).

Although paclitaxel is a potent suppressor of the growth of cancer cells, it also causes several side effects, such as impaired cognitive function, also referred to as "chemo-brain" (Ahles and Saykin, 2007). Paclitaxel is usually administered in 1–3 weekly cycles, with a standard dose of 175 mg/m² body surface area (BSA) every 3 weeks, or 80–100 mg/m²BSA every other week (National Comprehensive Cancer Network, 2023).

This study revealed that most participants in both groups underwent the first cycle of chemotherapy and had a 21-day interval between the sessions. Although paclitaxel-induced cognitive impairment generally exacerbates with cumulative exposure, neurotoxicity such as peripheral neuropathy and cognitive impairment can occur in a matter of days, as soon as 24 - 72 hours after initial paclitaxel infusion and persist for months post-treatment (Ahles, Root and Ryan, 2012; Rooker *et al.*, 2024). Early signs of neurotoxicity may interfere with normal brain function, causing slower brain activity, which appears as an increase in delta waves (0.5–4 Hz). This pattern is often linked to redness and reduced concentration. Delta wave activity was dominant during the pre-intervention period in both groups. Interestingly, the VR-PST group included a larger proportion of individuals who had received paclitaxel exposure compared to the control group, which would explain the heightened baseline delta activity prior to VR-PST intervention. This finding is consistent with the current literature showing that patients receiving paclitaxel therapy demonstrate increased delta and theta activities on EEG, reflective of neurotoxic and cognitive effects (Wu *et al.*, 2019). However, this interpretation should still be viewed as associative rather than causative in light of the non-significant statistical results.

After VR-PST intervention, both groups showed increased brain wave activity, with alpha waves being dominant. This finding supports previous studies that reported relaxation interventions with increased alpha activity (Jensen and Finnerup, 2014). Relaxation and mindfulness were associated with alpha waves. However, bivariate analysis did not detect a difference in brainwave distribution (alpha, beta, delta, and theta) between the control and intervention groups.

Interestingly, beta brain activity was mostly increased in the VR-PST group compared to the control group after the VR-PST intervention. Although no statistically significant differences were found between the groups, the increase in beta activity observed predominantly in the VR-PST group was noteworthy. Attentional engagement, executive control, and active cognitive processing are strongly associated with beta waves (Schmidt *et al.*, 2020; Lundqvist *et al.*, 2024). Higher-order cognitive systems control nociceptive input, and these cognitive processes are crucial for the top-down modulation of pain perception (Wiech, 2016). This trend aligns with the VR-PST's cognitive mechanism, which uses structured positive self-talk to trigger cognitive control mechanisms that may affect chemotherapy patients' perceptions of pain. This tendency, however exploratory in nature, implies that VR-PST may predominantly use cognitive engagement rather than just relaxation-based pathways to produce neurophysiological benefits. However, these results should be viewed as preliminary and exploratory rather than confirmed because of the borderline p-value (0.052), and they might indicate transient cognitive engagement rather than a long-term neurophysiological effect.

These findings suggest that the self-talk structure in the VR-PST intervention was less effective in inducing relaxation, as indicated by the absence of a significant increase in alpha brainwave activity in the intervention group. This result may have been influenced by the

framework and content of the positive self-talk script, "Positive Self-Talk for Pain Control and a Meaningful Life," which consisted of four phases: pre-talk, relaxation, positive self-talk, and termination.

After analyzing the content of the self-talk script, it was found that 71% of the sentences were categorized as cognitively stimulating (e.g., active awareness, explicit acknowledgment, cognitive reflection), such as: "Oh, the illness that is in my body right now," or "I'm sorry if I have been rude in rejecting your presence." Only 18% of the sentences conveyed themes of relaxation, whereas 11% were religious or expressed gratitude. These findings suggest that the VR-PST intervention is more likely to be related to cognitive processing, as seen from the increase in beta brain wave activity. This finding is consistent with recent studies showing that positive self-talk improves cognitive performance (Wallace *et al.*, 2017) by modulating brain activity (Kim *et al.*, 2021). Positive self-talk may activate frontal cognitive control processes that increase beta activity, whereas VR immersion supports relaxation-linked alpha activity. The combination of the two has the potential to modulate brain waves through cognitive and attentional mechanisms (Michelmann, Griffiths and Hanslmayr, 2022). This possible cognitive mechanism is still hypothetical, though, and needs to be confirmed by longer interventions and repeated EEG tests, given the short intervention time and non-significant statistical results.

This study has a few limitations, such as the short duration of the intervention, limited number of VR-PST sessions, and use of portable EEG devices, which are less precise than clinical-grade systems. Although EEG recordings were obtained at a standardized time point immediately after chemotherapy sessions to reduce variability, the residual effects of treatment-related fatigue, discomfort, or acute chemotherapy reactions cannot be eliminated. In addition, the VR-PST script used in this study mostly featured cognitively challenging content rather than relaxation-oriented suggestions, potentially unexpectedly affecting brainwave responses. Future enhancement of the VR-PST content, especially in balancing cognitively demanding and relaxation-oriented elements, could improve its neurophysiological effects. Crucially, the short intervention period might have prevented quantifiable neurophysiological effects from emerging, which could help explain the non-significant findings.

Conclusion

This study shows that VR-PST intervention alters brain wave activity, suggesting a modulatory effect on cognitive processes in patients with breast cancer undergoing chemotherapy. Although there was no significant difference in the brain wave distribution, the VR-PST group showed a numerical increase in beta waves, indicating greater cognitive engagement than relaxation. To maximize its potential as a non-pharmacological therapeutic agent for cancer pain, especially in breast cancer patients receiving chemotherapy, future VR research needs to find a balance between cognitive stimulation and relaxation as part of technology-based nursing interventions. These results highlight the broader potential of VR-based cognitive interventions in clinical nursing practice, particularly in oncology care.

Acknowledgments

The authors would like to express their gratitude to the director and staff of Adam Malik Hospital and Prof. Dr. Chairuddin P. Lubis Universitas Sumatera Utara Hospital for their support and access to research facilities. The authors also wish to thank hypnotherapy and IT experts for offering valuable inputs in completing the VR-PST intervention. We also thank all patients with breast cancer involved in developing this technology-based non-pharmacological pain management approach.

Funding source

This study did not receive any funding from any institution, whether in the form of grants, sponsorships, or other institutional support. All research activities were independently conducted by the researchers.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the Zenodo repository, https://doi.org/10.5281/zenodo.17113330

Authors' contributions

I.A.H.: Designing the study ideas, backgrounds and theoretical frameworks, designing and consulting with experts regarding VR-PST protocols, conducting patient recruitment and randomization, providing VR-PST treatment for the breast cancer patients, observing and collecting brain wave data, following up patients, preparing draft manuscripts, journal browsing and literature studies, and taking full responsibility for the overall conduct of the study process.; A.N.: Direct the research design both methodologically and instrument validation, ensure the research complies with ethical and scientific standards, assist in the selection of appropriate statistical analysis, evaluate the interpretation of the study results, revise draft proposals, reports, and manuscripts, and provide feedback and refinement of proposals, reports, and manuscripts.; U.H. Provide input related to the mechanism of chemotherapy-induced pain and the relevance of VR-PST interventions, ensure the suitability of the protocol to the conditions of breast cancer patients, contribute to data analysis, discussion, and conclusions, and provide input on the design, methodology, and results of the study.; D.A.: Validate

relevant patient inclusion criteria e.g. cancer stage, chemotherapy history, and other clinical aspects, assess the feasibility of the intervention from a medical perspective, provide input on participant selection criteria, ensure the study is carried out in accordance with ethical standards and hospital services, provide input in the formulation of ethical clearance, interpretation of research results and discussion.

Declaration of Interest

The authors declare that there are no conflicts of interest, either financial or nonfinancial, or collaborative relationships with VR device manufacturers or other parties that could influence the conduct or results of this study. All aspects of the study, including design, data collection, analysis, interpretation, and manuscript preparation, were conducted independently and transparently.

References

Ahles, T. A., Root, J. C. and Ryan, E. L. (2012) "Cancer- and Cancer Treatment–Associated Cognitive Change: An Update on the State of the Science," *JCO*, 30(30), pp. 3675–3686. doi: https://doi.org/10.1200/JCO.2012.43.011.

Ahles, T. A. and Saykin, A. J. (2007) "Candidate mechanisms for chemotherapy-induced cognitive changes," *Nature Reviews Cancer*, 7(3), pp. 192–201. doi: 10.1038/nrc2073.

European Society for Medical Oncology (ESMO) (2019) *Cancer Pain Management guide for Patients*.

Fallon, N. *et al.* (2018) "Altered theta oscillations in resting EEG of fibromyalgia syndrome patients," *European Journal of Pain (United Kingdom)*, 22(1), pp. 49–57. doi: 10.1002/ejp.1076.

Haywood, D. *et al.* (2025). The effect of nonpharmacological interventions on cognitive function in cancer: an overview of systematic reviews. *Supportive care in cancer : official journal of the Multinational Association of Supportive Care in Cancer*, *33*(2), 151. https://doi.org/10.1007/s00520-025-09212- 3

IASP (2022) *IASP Revises Its Definition of Pain for the First Time Since 1979*.

Jensen, T. S. and Finnerup, N. B. (2014) "Allodynia and hyperalgesia in neuropathic pain: Clinical manifestations and mechanisms," *The Lancet Neurology*, 13(9), pp. 924–935. doi: 10.1016/S1474-4422(14)70102-4.

Kakimoto, A. *et al.* (2025) "Virtual reality-based training for radiopharmaceutical administration: development and educational effectiveness," *PLoS ONE*, 20(3 March), pp. 1–17. doi: 10.1371/journal.pone.0321101.

Kim, Junhyung *et al.* (2021) "The effects of positive or negative self-talk on the alteration of brain functional connectivity by performing cognitive tasks," *Scientific Reports*, 11(1), pp. 1–11. doi: 10.1038/s41598-021-94328-9.

Krigolson, O. E. *et al.* (2017) "Choosing MUSE: Validation of a low-cost, portable EEG system for ERP research," *Frontiers in Neuroscience*, 11(MAR), pp. 1–10. doi: 10.3389/fnins.2017.00109.

Lundqvist, M. *et al.* (2024) "Beta: bursts of cognition," *Trends in Cognitive Sciences*, 28(7), pp. 662–676. doi: 10.1016/j.tics.2024.03.010.

Magosso, E. *et al.* (2019) "EEG alpha power is modulated by attentional changes during cognitive tasks and virtual reality immersion," *Computational Intelligence and Neuroscience*, 2019. doi: 10.1155/2019/7051079.

Michelmann, S., Griffiths, B. and Hanslmayr, S. (2022) "The Role of Alpha and Beta Oscillations in the Human EEG During Perception and Memory Processes," *The Oxford Handbook of EEG Frequency*, pp. 202–219. doi: 10.1093/oxfordhb/9780192898340.013.10.

National Comprehensive Cancer Network (2023) "NCCN clinical practice guidelines in oncology.," *National Comprehensive Cancer Network*.

Ploner, M., Sorg, C. and Gross, J. (2017) "Brain Rhythms of Pain," *Trends in Cognitive Sciences*, 21(2), pp. 100–110. doi: 10.1016/j.tics.2016.12.001.

Razak, I., Chung, T. Y. and Ahmad, T. S. (2019) "A Comparative Study of Two Modalities in Pain Management of Patients Presenting with Chronic Brachial Neuralgia," *The Journal of Alternative and Complementary Medicine*, 00(00), pp. 1–7. doi: 10.1089/acm.2019.0052.

Rooker, J. *et al.* (2024) "Innovative infusion center assessments of chemotherapy-induced neurotoxicities: A pilot study supporting early and routine screenings as part of survivorship programs.," *Journal of Clinical Oncology*, 42(16_suppl), pp. e24102–e24102. doi: 10.1200/jco.2024.42.16_suppl.e24102.

Schmidt, R. *et al.* (2020) "Mini-Symposium Beta Oscillations in Working Memory , Executive Control of Movement and Thought , and Sensorimotor Function To cite this version : HAL Id : hal-02335268 Beta Oscillations in Working Memory , Executive Control of Movement and Thought , and S."

Sirait, R., Purba, J. M. and Harahap, I. A. (2022) "Positive Self-Talk on Pain Intensity and Pain Interference in Low Back Pain Patients," *Jurnal Aisyah: Jurnal Ilmu Kesehatan*, 7(3), pp. 823–830. doi: 10.30604/jika.v7i3.1088.

Téllez, A., Juárez-garcía, D. M. and Jaime-bernal, L. (2017) "The effect of hypnotherapy on the quality of life in women with breast cancer," 10(2), pp. 228–240. doi: 10.11621/pir.2017.0216.

Wallace, P. J. *et al.* (2017) "Effects of Motivational Self-Talk on Endurance and Cognitive Performance in the Heat," *Medicine and Science in Sports and Exercise*, 49(1), pp. 191–199. doi: 10.1249/MSS.0000000000001087.

Weaver, B. A. (2014) "How Taxol/paclitaxel kills cancer cells," *Molecular Biology of the Cell*, 25(18), pp. 2677–2681. doi: 10.1091/mbc.E14-04-0916.

WHO (2022) *Cancer*.

Wiech, K. (2016) "Deconstructing the Sensation of Pain: The Influence of Cognitive Processes on Pain Perception," *Science*, (354), pp. 584–587. doi: https://doi.org/10.1126/science.aaf8934.

Wong, K. P., Tse, M. M. Y. and Qin, J. (2022) "Effectiveness of Virtual Reality-Based Interventions for Managing Chronic Pain on Pain Reduction, Anxiety, Depression and Mood: A Systematic Review," *Healthcare (Switzerland)*, 10(10). doi: 10.3390/healthcare10102047.

Wu, J. *et al.* (2019) "Cannabinoid Type 2 Receptor System Modulates Paclitaxel-Induced Microglial Dysregulation and Central Sensitization in Rats," *Journal of Pain*, 20(5), pp. 501–514. doi: 10.1016/j.jpain.2018.10.007.

How to cite this article: Harahap, I. A., Nasution, A., Harahap, U., and Ardinata, D. (2026) 'Effectiveness of Virtual Reality Positive Self-Talk on Changes in Brain Wave Activity among Patients with Breast Cancer Undergoing Chemotherapy: A Randomized Controlled Trial', *Jurnal Ners*, 21(1), pp. 3-10. doi: http://dx.doi.org/10.20473/jn.v21i1.78907