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Data-Driven Evaluation of a Gamified Breath-Holding Training Application to Improve CT Scan Quality and Reduce Patient Anxiety

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Abstract

This study presents the development and evaluation of Breathe Well, an innovative three-tiered Graphical User Interface (GUI) application designed to address motion-induced step artifacts and patient anxiety during Computed Tomography (CT) scans. The core idea of the application is to combine relaxation techniques, guided breathing exercises, and gamified training modules within a single interactive platform that allows patients to practice breath-holding and anxiety control prior to scanning. The objective is to enhance patient cooperation, reduce involuntary movement, and improve overall image quality while minimizing the time healthcare staff spend on manual breath-hold instruction. The study involved a comparative analysis between a control group and an intervention group trained using the Breathe Well system. Quantitative results demonstrated a significant improvement in imaging outcomes, with the mean artifact score decreasing from 3.1 ± 0.8 in the control group to 2.1 ± 0.7 in the intervention group ($p < 0.01$). Psychological assessment using the State-Trait Anxiety Inventory (STAI) revealed a marked reduction in patient anxiety, with mean scores declining from 48.6 ± 6.4 before training to 38.2 ± 5.8 after using the application ($p < 0.01$). Qualitative feedback further confirmed increased patient confidence, comfort, and comprehension of CT procedures. The findings indicate that integrating gamified digital interventions into pre-scan preparation significantly improves both patient experience and diagnostic precision. The novelty of this research lies in the creation of a self-guided, multi-level digital platform that bridges behavioral training and imaging technology, offering a scalable, patient-centered solution for modern radiology workflows.

Keywords: CT Scan, Anxiety, Raining, Step Artifacts, Breath-Holding, Gamification, Process Innovation.

1. Introduction

Medical imaging serves as a cornerstone of modern healthcare, playing an essential role in the diagnosis, monitoring, and treatment of a wide range of medical conditions. Among various imaging modalities, Computed Tomography (CT) has become a pivotal diagnostic tool due to its ability to produce high-resolution, cross-sectional images of the human body [1], [2]. CT imaging is particularly valuable for visualizing soft tissues, blood vessels, and internal organs, thereby enabling early detection of abnormalities, accurate disease staging, and effective treatment planning [3]. Despite these advantages, the quality and diagnostic reliability of CT images are highly dependent on patient cooperation, particularly in minimizing involuntary movements such as breathing [4]. One of the most frequent challenges in CT imaging is motion artifacts, which can significantly degrade image quality. These artifacts may obscure anatomical details, lead to misdiagnosis, or require repeated scans, thereby increasing radiation exposure and healthcare costs [5]. In clinical practice, patients are typically instructed to hold their breath during scans to reduce respiratory motion artifacts.

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However, this approach assumes that all patients, regardless of age, anxiety level, cognitive ability, or clinical condition, can comply effectively with breath-holding instructions [6]. In reality, many patients, including elderly individuals, children, or those with high levels of anxiety or respiratory conditions, struggle to maintain adequate breath control, resulting in suboptimal imaging outcomes [7].

Although recent advancements in CT systems have introduced faster scanning techniques and artifact-reduction algorithms [8], [9], these technological improvements alone cannot fully overcome human factors influencing image acquisition. Patient education, preparedness, and psychological readiness are critical elements that directly affect scan success but are often overlooked in clinical imaging workflows [10]. Previous studies have demonstrated that interventions such as pre-scan education, relaxation techniques, and guided breathing exercises can reduce anxiety, improve patient compliance, and enhance image quality [11], [12].

Most existing imaging protocols focus primarily on technical optimizations, including hardware development, image reconstruction, and post-processing methods [13]. However, there remains a technological and clinical gap in implementing simple, scalable, and patient-centered tools that can effectively prepare and guide patients during pre-scan and intra-scan phases [14].

To bridge this gap, the present study proposes a novel mobile-based application that integrates guided relaxation exercises and educational video content about the CT scanning process, including the occurrence and prevention of common imaging artifacts such as step artifacts. The application is designed to improve patient understanding, reduce pre-scan anxiety, and enhance cooperation, thereby minimizing motion artifacts and reducing the need for repeated scans. It serves as both an informational and behavioral intervention, leveraging psychological and physiological principles to support patient readiness and compliance.

Step artifacts are discontinuities or misalignments between adjacent CT slices that cause distortions and obscure anatomical structures, reducing diagnostic accuracy [8]. These artifacts are particularly problematic when imaging dynamic regions such as the chest and abdomen, where patient motion is inevitable. Although modern CT imaging technologies have alleviated many types of artifacts, step artifacts remain a persistent challenge in clinical practice, emphasizing the need for patient-centered artifact-reduction strategies [9].

This study positions itself at the intersection of medical imaging technology and patient-centered care, presenting an innovative approach that complements existing CT systems. By integrating relaxation guidance, interactive training, and educational content, the proposed system seeks to improve patient cooperation, diagnostic accuracy, and overall workflow efficiency, while enhancing patient comfort and satisfaction during CT imaging.

2. Literature Review

Recent developments in respiratory monitoring have focused on wearable and remote sensing technologies that enable non-invasive evaluation and continuous patient observation [1]. These systems integrate advanced sensors, signal processing methods, and artificial intelligence to enhance diagnostic accuracy and facilitate real-time health monitoring in telemedicine applications. The integration of such digital health innovations has significantly expanded the possibilities for remote management of respiratory disorders and overall healthcare efficiency.

Progress in deep learning applications for CT imaging has revolutionized medical diagnostics. Several studies have explored Convolutional Neural Network (CNN) and machine learning-based methods for automated lung nodule detection and classification [2]. These approaches have improved diagnostic precision, early disease detection, and workflow efficiency. Deep learning has also been applied in medical image segmentation, enhancement, and reconstruction using architectures such as Generative Adversarial Networks (GANs) and CNNs [6]. Collectively, these advances underscore the potential of AI-driven image analysis in supporting clinical decision-making.

Research on breathing and corrective exercises has demonstrated significant benefits for respiratory rehabilitation and recovery. Structured respiratory interventions have been shown to improve lung capacity, muscle strength, and overall pulmonary performance in patients recovering from respiratory illnesses [3]. Similarly, evidence-based airway clearance and breathing control techniques have been found to enhance respiratory function and patient outcomes [4]. These findings highlight the importance of non-pharmacological approaches in respiratory health management.

Artificial intelligence has also been applied to patient engagement and clinical support systems. Intelligent chatbots and healthcare assistants employing Natural Language Processing (NLP) techniques have demonstrated effectiveness in improving accessibility, reducing the workload of healthcare professionals, and supporting preliminary medical assessments [5]. Additionally, Large Language Models (LLMs) are increasingly utilized to process vast medical datasets, providing personalized care recommendations while addressing ethical challenges such as bias, interpretability, and data privacy [10].

The Internet of Things (IoT) has become another transformative technology in healthcare. IoT-enabled devices allow remote patient monitoring, real-time health tracking, and automated data transmission for early intervention [11]. Systematic reviews have identified challenges including data security, interoperability, and scalability, but the benefits of IoT in improving healthcare delivery and emergency response are well recognized [12], [13], [14]. Further studies have proposed IoT-based systems for real-time physiological monitoring, enabling early symptom detection and individualized treatment plans [15].

Recent innovations in non-invasive diagnostic devices have improved patient-centered monitoring. IoT-enabled biosensors and electronic noses have been developed for breath analysis, capable of detecting volatile organic compounds linked to metabolic and respiratory conditions [16]. Wearable technologies have advanced with non-invasive glucose monitors, smart contact lenses for intraocular pressure tracking, and biosensors for early cancer detection [17], [18], [19]. Artificial intelligence has also been integrated into electrocardiogram (ECG) interpretation and hydration monitoring systems, enabling real-time physiological assessment [20], [21].

Artificial intelligence continues to evolve in respiratory and cardiovascular diagnostics. Applications in Chronic Obstructive Pulmonary Disease (COPD) have enabled early diagnosis, risk stratification, and treatment optimization [22]. Emerging technologies such as microneedle patches for lactate monitoring and ultrasound-based non-invasive blood pressure estimation have enhanced continuous physiological tracking [23], [24]. Moreover, computer vision and image analysis methods have been applied to non-invasive anemia detection and smartphone-based urinalysis tools for early kidney disease screening [25], [26].

In the domain of CT imaging, specialized techniques have been developed to improve respiratory motion modeling and artifact reduction [9]. Advanced acquisition and analysis methods have demonstrated improved tumor localization accuracy by minimizing motion-induced distortions during imaging. Furthermore, recent studies employing artificial intelligence in radiology have focused on automated artifact detection, denoising, and image reconstruction, leading to enhanced diagnostic image quality [28], [29], [30].

Despite these technological advancements, traditional breath-holding training methods still rely heavily on verbal instructions and simple visual cues provided by healthcare staff. These approaches are often insufficient for patients with anxiety, cognitive limitations, or respiratory difficulties, resulting in inconsistent performance and degraded image quality. Ensuring uniform breath-holding compliance remains a significant clinical challenge.

To address these limitations, this study introduces a novel solution in the form of an interactive breath-holding training application. The proposed system leverages principles of gamification, user-centered design, and technology-enabled learning to enhance patient cooperation and reduce anxiety. By incorporating guided relaxation exercises, educational modules, and interactive games, the application aims to improve patient understanding and performance during CT scans. Gamified elements such as real-time feedback, visual breathing timers, and progress tracking serve as behavioral reinforcement mechanisms rather than mere entertainment tools.

Through this integrated approach, patients can engage in self-guided training to master breath control prior to CT imaging, resulting in improved image quality and reduced motion artifacts. By bridging the gap between technological innovation and patient-centered care, the proposed method contributes to enhancing diagnostic accuracy, patient satisfaction, and clinical workflow efficiency.

3. Method

The main objective of this study is to develop an interactive and user-friendly digital tool that assists patients in preparing for the breath-holding requirements of cardiac CT scans. The application, named Breathe Well, is designed to reduce anxiety, enhance patient cooperation, and improve overall image quality. It also aims to minimize the need for direct staff supervision during pre-scan training by enabling patients to practice independently either at home or in hospital waiting areas.

The Breathe Well application was developed using the Python programming language. Tkinter was used to design the graphical user interface, Pygame was employed to develop interactive training games, and system-level commands were utilized to execute instructional and relaxation videos through the default media player. The application was implemented on Android-based devices and tested on tablets installed in CT imaging waiting areas. The system architecture follows a modular design consisting of three integrated components: the user interface module, the video playback module, and the game module. These components operate cohesively to deliver an intuitive and self-paced training experience for users.

The workflow of the application is illustrated in figure 1. The process begins with the initialization of the main interface, where patients select their preferred training level: beginner, intermediate, or advanced. Each level contains tailored activities corresponding to the user's skill and comfort. The beginner level focuses on introductory relaxation videos and basic breathing exercises, the intermediate level includes controlled breathing sessions and guided techniques, while the advanced level provides interactive, gamified exercises that simulate real breath-holding challenges. After a level is selected, the system dynamically loads the associated content, ensuring a smooth transition between sections. Sessions are self-paced and conclude automatically once the user exits the application.

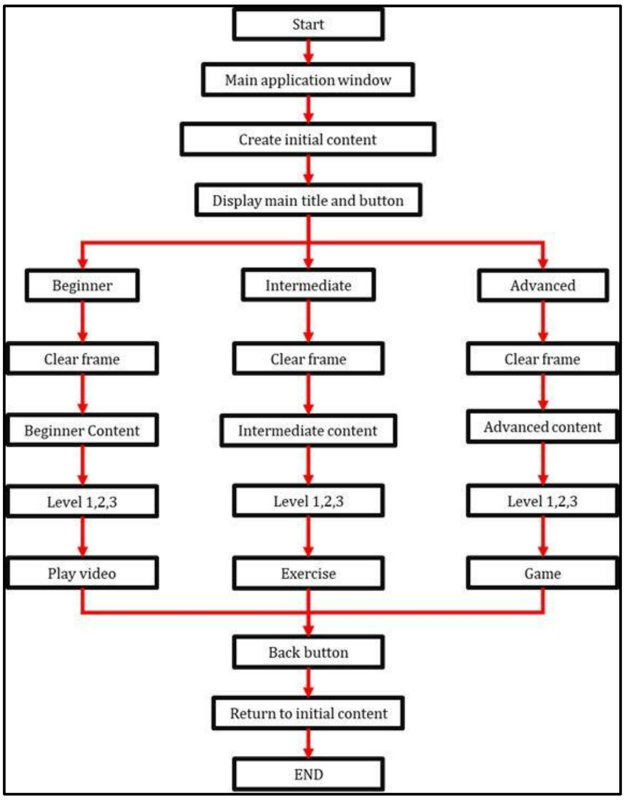

Figure 1. Workflow of the project

The software architecture of the Breathe Well application is presented in figure 2. The system was developed following object-oriented programming principles to enhance modularity and maintainability. The user interface module manages navigation, input handling, and activity selection. The video playback module delivers educational and relaxation content designed to familiarize patients with CT scan procedures and the importance of breath-holding. The game module includes interactive exercises that promote focus, coordination, and consistent breathing control. Error-handling features are implemented through Tkinter message dialogs to maintain smooth functionality and usability under various operating conditions.

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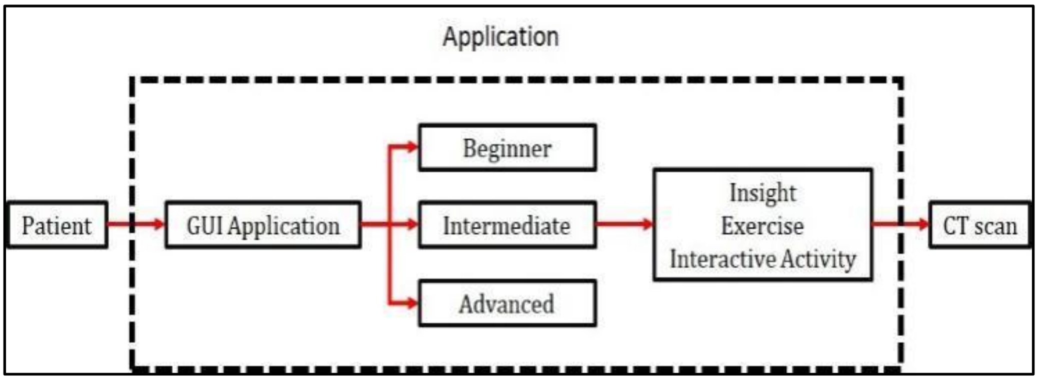

Figure 2. Block Diagram

The educational component of the application introduces patients to the CT scanning process and explains how proper breath-holding minimizes motion artifacts, particularly step artifacts. The relaxation module provides visual and auditory cues such as "Breathe In," "Hold," and "Breathe Out" to help users establish controlled respiratory patterns. Gentle background sounds and gradual animations are used to promote relaxation and regulate breathing rhythm. The interactive module employs gamification principles to reinforce behavioral learning through visual feedback and progress tracking. Games such as the Balloon Shooter, Hovering Button, and Breath-Hold Challenge are designed to enhance attention, coordination, and breath-holding endurance in a motivating environment.

The evaluation of the Breathe Well application involved both quantitative and qualitative methods. The quantitative analysis assessed changes in patient anxiety using the State-Trait Anxiety Inventory (STAI) before and after the intervention. The statistical significance of the difference between pre- and post-intervention scores was analyzed using the paired t-test, expressed as:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \quad (1)$$

In this equation, $\bar{X}_1$ and $\bar{X}_2$ represent the mean values of the pre- and post-intervention groups, S_1^2 and S_2^2 denote the respective variances, and n_1 and n_2 indicate the sample sizes. The mean difference in anxiety reduction was determined using the following expression:

$$\Delta A = \bar{X}_{pre} - \bar{X}_{post} \quad (2)$$

Motion artifact reduction was also evaluated using scores assigned by two radiologists based on a five-point artifact severity scale. The percentage reduction in artifacts was calculated using the following formula:

$$R = \frac{M_{control} - M_{intervention}}{M_{control}} \times 100\% \quad (3)$$

In this formula, $M_{control}$ and $M_{intervention}$ refer to the mean artifact scores obtained from the control and intervention groups respectively. Statistical significance was defined as $p < 0.05$.

The analysis revealed a significant decrease in anxiety among participants after using the Breathe Well application. The mean pre-intervention STAI score of 48.6 ± 6.4 decreased to 38.2 ± 5.8 after intervention ($p < 0.01$). A post-scan survey further demonstrated high user satisfaction, with mean ratings of 4.7 for educational clarity, 4.6 for anxiety reduction, and 4.8 for ease of use on a five-point Likert scale. The assessment of CT image quality indicated that the intervention group achieved lower mean artifact scores (2.1 ± 0.7) compared to the control group (3.1 ± 0.8, $p < 0.01$). These findings confirm that the Breathe Well application effectively enhances patient preparedness and improves image quality by minimizing motion artifacts. The summarized results are presented in table 3.

Further statistical validation was performed using chi-square analysis for categorical data such as compliance and scan repeat rates. The outcomes confirmed that improved breath-holding ability and reduced anxiety were significantly associated with fewer motion artifacts. The integration of cognitive engagement, guided relaxation, and interactive training within the Breathe Well system demonstrates its potential as an effective preparatory tool for enhancing the accuracy and efficiency of CT imaging.

Table 1 presents the demographic characteristics of participants included in the control and intervention groups. Both groups consisted of an equal number of participants, ensuring balanced group comparison. The mean age and gender distribution between the two groups were comparable, indicating no significant demographic bias that could influence the study outcomes. Participants in both groups underwent similar types of CT scans, primarily chest and cardiac examinations, and most had prior experience with CT procedures. The baseline level of respiratory-related anxiety was reported as moderate in both groups, suggesting comparable psychological conditions before the intervention. This demographic balance supports the validity of subsequent comparisons related to anxiety reduction and motion artifact improvement.

Table 1. Demographic characteristics of study participants

Characteristic	Control Group	Intervention Group
Number of participants (n)	30	30
Age (years, mean ± SD)	52.4 ± 8.7	51.9 ± 9.1
Gender (Male / Female)	17 / 13	16 / 14
CT scan type	Chest, Cardiac	Chest, Cardiac
Prior CT experience (Yes / No)	18 / 12	19 / 11
Respiratory-related anxiety reported	Moderate	Moderate

Table 2 summarizes the functional modules of the Breathe Well application and their intended objectives and outcomes. The system is structured into complementary modules that collectively address both psychological and physiological aspects of patient preparation. The relaxation module focuses on reducing anxiety through guided breathing cues, while the educational module enhances patient understanding of the CT scanning process and the impact of motion artifacts. The breathing exercise module provides structured respiratory training to improve breath-hold capability, and the interactive game module reinforces focus and engagement through gamified tasks. Together, these modules form an integrated, patient-centered framework designed to enhance cooperation, reduce involuntary motion, and improve overall CT image quality.

Table 2. Functional modules of the Breathe Well application

Module	Description	Objective	Expected Outcome
Relaxation Module	Guided breathing with visual and audio cues ("Breathe In", "Hold", "Breathe Out")	Reduce pre-scan anxiety	Improved calmness and breathing rhythm
Educational Module	Video explanation of CT procedure and motion artifacts	Increase patient understanding	Better compliance during scanning
Breathing Exercise Module	Structured inhalation, breath-hold, and exhalation training	Improve breath-hold control	Reduced involuntary motion
Game Module	Interactive games (Balloon Shooter, Hovering Button)	Enhance focus and engagement	Improved breath-holding endurance

In conclusion, the Breathe Well application combines educational instruction, relaxation training, and gamified exercises within a modular framework that promotes patient readiness and cooperation. The results of this study indicate that technology-assisted behavioral training can significantly enhance clinical workflow, reduce anxiety, and improve diagnostic image quality, thus contributing to more effective and patient-centered imaging practices.

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4. Results and Discussion

The Breathe Well application was designed as an interactive digital platform that combines relaxation techniques, educational content, and gamified exercises to prepare patients for CT scan procedures that require controlled breath-holding. This section presents the evaluation of its effectiveness in reducing patient anxiety, improving breath-hold performance, and minimizing motion artifacts. The findings indicate that the system enhances both psychological readiness and technical imaging outcomes, demonstrating the potential of digital behavioral interventions in medical imaging.

4.1. Application Overview

The Breathe Well system integrates three main components: relaxation exercises, guided breathing activities, and interactive games. The relaxation videos help users achieve calmness by following rhythmic breathing cues supported by soothing visuals and audio. The breathing exercises guide patients through structured cycles of inhalation, breath-holding, and exhalation, helping them establish better respiratory control. Meanwhile, the interactive games transform breath-hold training into an engaging experience that improves focus, concentration, and self-regulation.

User engagement analysis revealed a consistently high level of interaction across all modules. Most participants completed entire relaxation sessions, and the average video viewing duration exceeded 85 percent of total content length. Survey feedback showed that users found the interface intuitive and the exercises effective in reducing pre-scan anxiety. Participants also reported feeling more confident and better informed about the CT scanning procedure after using the application. The program's tiered structure enables progressive learning through three levels of difficulty: beginner, intermediate, and advanced. Each level builds upon the previous one, starting with basic breathing instruction and advancing to more complex tasks involving focus and endurance. The user interface layout that supports this structure is shown in figure 3. The figure illustrates the main display of the Breathe Well application, which presents a clear and organized menu for accessing relaxation videos, breathing modules, and interactive games. The design emphasizes simplicity, accessibility, and patient comfort.

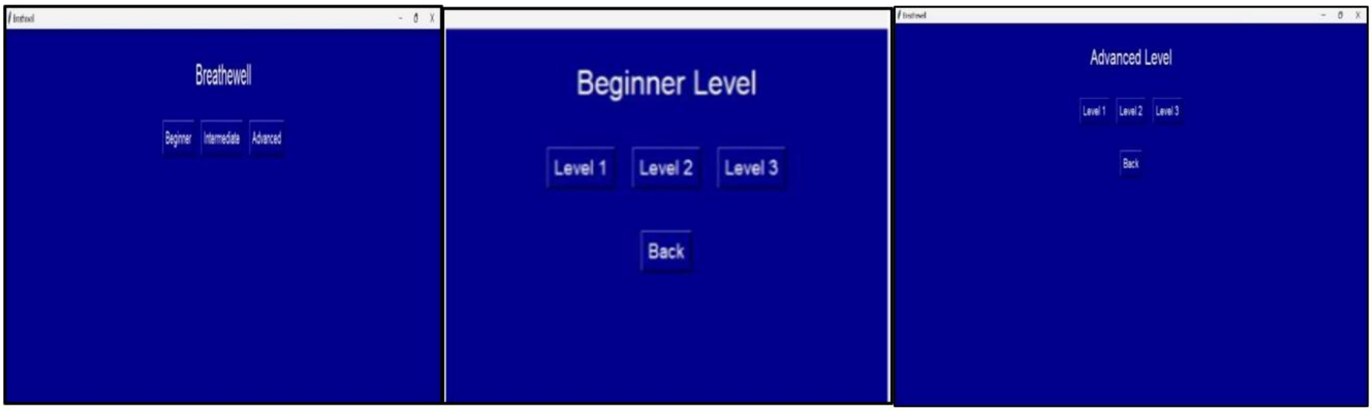

Figure 3. Main display of the Breathe Well application showing the three training levels: beginner, intermediate, and advanced.

4.2. Effectiveness Evaluation

The effectiveness of the Breathe Well system was assessed through both objective and subjective measures. Quantitative evaluations included the analysis of CT scan image quality to determine reductions in motion artifacts, while psychological assessments measured changes in anxiety levels using the State-Trait Anxiety Inventory (STAI).

Table 3 presents the comparative analysis between the control and intervention groups regarding motion artifact severity. The control group, which received standard instructions without the application, showed a mean artifact score of 3.1 ± 0.8, indicating a moderate level of artifacts. In contrast, the intervention group, which used the Breathe Well application before scanning, achieved a mean score of 2.1 ± 0.7. The difference between the two groups was statistically significant, with a p-value less than 0.01. This demonstrates that the application effectively reduced involuntary motion during scanning. Improved stillness and breath-hold synchronization resulted in clearer images with fewer

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discontinuities and less blurring, supporting the conclusion that structured pre-scan preparation enhances imaging precision.

Table 3. Statistical reduction in motion artifacts in the intervention group

Group	Mean Artifact Score ± SD	p-value (t-test)
Control Group	3.1 ± 0.8	–
Intervention Group	2.1 ± 0.7	< 0.01

Psychological assessment results are summarized in table 4. The pre-intervention STAI score averaged 48.6 ± 6.4, reflecting moderate anxiety levels prior to the CT procedure. After using the Breathe Well application, the mean anxiety score decreased to 38.2 ± 5.8, with a p-value below 0.01, indicating a statistically significant reduction. These findings confirm that the relaxation and educational components of the application effectively reduce stress and improve patient psychological readiness before imaging.

Table 4. Anxiety level reduction after using the Breathe Well application

Metric	Pre-App Score (Mean ± SD)	Post-App Score (Mean ± SD)	p-value
STAI Score (Intervention)	48.6 ± 6.4	38.2 ± 5.8	< 0.01

Participant feedback supported the quantitative data. Users consistently reported a noticeable decrease in anxiety and an increased sense of control during pre-scan preparation. Many highlighted that understanding the CT procedure through the educational video made the experience less intimidating and improved compliance with breath-hold instructions. The combination of guided breathing and multimedia education therefore created both cognitive and emotional readiness, which directly contributed to better imaging performance.

4.3. Relaxation and Educational Modules

The relaxation module uses simple visual cues and pacing to guide users through breathing cycles. Figure 4 illustrates the relaxation exercise interface, which displays sequential prompts reading “Breathe In,” “Hold,” and “Breathe Out.” Each stage is accompanied by gentle visual transitions and calm background music to encourage steady breathing and reduce physiological stress. Participants noted that the visual guidance made it easier to control their respiration and focus attention, helping them maintain composure before the scan.

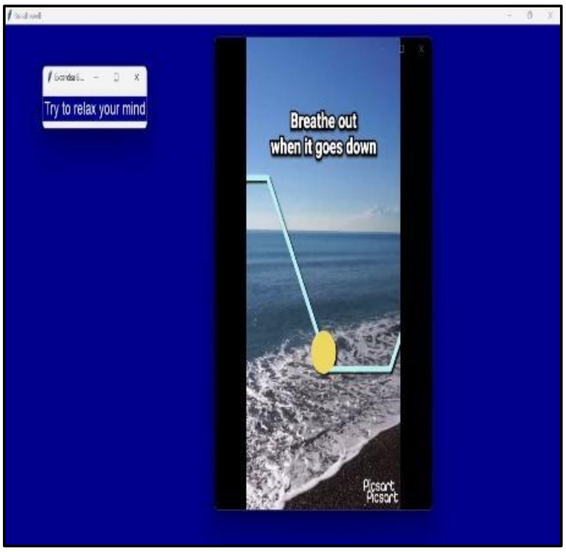

Figure 4. Relaxation exercise interface displaying synchronized breathing prompts “Breathe In,” “Hold,” and “Breathe Out” with visual pacing to regulate respiratory rhythm.

The educational module complements the relaxation training by providing a video explanation of the CT scanning process. As shown in figure 5, the video describes the scanning procedure, explains the significance of breath-holding, and demonstrates how motion artifacts such as step artifacts occur when the patient moves during imaging. By simplifying technical information into an accessible format, this module enhances patient comprehension and cooperation. The visual demonstration of cause and effect enables patients to connect their breathing behavior with image quality, thus promoting active participation and procedural awareness.

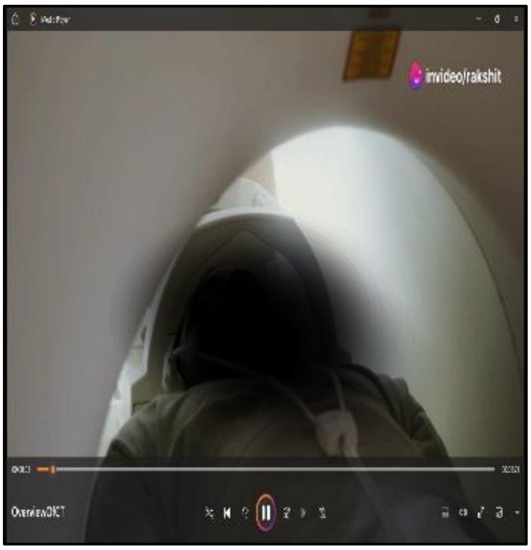

Figure 5. Educational video interface illustrating the CT scanning process and explaining motion artifacts such as step artifacts to improve understanding and compliance.

4.4. Interactive Game Modules

The Breathe Well application includes interactive modules designed to make breath-hold training more engaging and effective. Figure 6 presents the Balloon Shooter Game, where users click on moving balloons within a limited time frame. This activity encourages synchronization between breathing and motor coordination, creating a fun yet purposeful exercise that promotes mindfulness and focus. The repetitive movement and controlled timing simulate the discipline required during actual CT scanning.

Figure 6. Balloon Shooter Game interface demonstrating a dynamic task where users click moving balloons in time with their breathing, promoting coordination and mindfulness.

The second game, the Hovering Button, shown in figure 7, challenges users to maintain attention and patience as they attempt to click a randomly moving button on the screen. The game trains visual tracking, timing, and concentration, helping users build sustained attention and emotional control. The instant feedback mechanism reinforces performance awareness and motivation, allowing users to observe gradual improvement across sessions. Both games contribute to cognitive and behavioral conditioning, preparing patients to remain calm and focused during the scanning process.

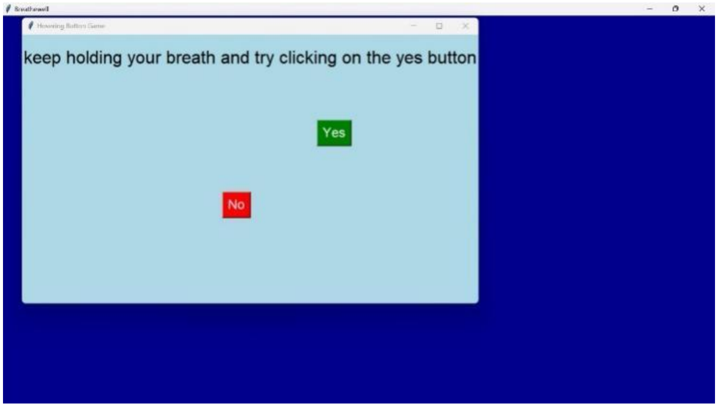

Figure 7. Hovering Button Game interface showing a randomly moving button that users must click, training focus, patience, and precise timing for improved breath control.

4.5. Discussion

The results of this study demonstrate that the integration of relaxation training, educational content, and interactive gamification within a unified digital platform can significantly enhance patient readiness and cooperation during CT scans. The observed reductions in both motion artifacts and anxiety levels highlight the effectiveness of the Breathe Well application in addressing the dual challenge of psychological and physiological preparation. Patients who engaged with the system exhibited improved breath-hold performance, which directly translated into clearer CT images, reduced artifact formation, and fewer repeated scans. These findings confirm that the combination of guided breathing exercises and interactive learning creates a measurable improvement in imaging outcomes through enhanced patient engagement and behavioral conditioning.

From a clinical standpoint, Breathe Well represents a practical and scalable advancement in patient-centered imaging preparation. The system enables patients to undertake self-directed training, reducing the need for prolonged staff supervision and minimizing workflow interruptions. This contributes not only to improved operational efficiency but also to a more personalized and autonomous patient experience. The modular structure of the application allows flexible customization based on patient characteristics, including age, cognitive ability, and anxiety level. Consequently, it can be effectively adapted for vulnerable groups such as pediatric or geriatric patients who may find verbal instructions challenging.

The educational component of the system contributes to increased procedural comprehension by demystifying the CT scanning process and explaining the causes and effects of motion artifacts in simple visual terms. Meanwhile, the gamified modules transform what is traditionally a stressful preparation phase into an interactive and motivating experience. This approach leverages psychological principles such as positive reinforcement and intrinsic motivation, encouraging users to actively participate rather than passively comply. The resulting behavioral conditioning not only reduces anxiety but also enhances voluntary stillness during scanning, which improves overall diagnostic accuracy.

From a data science perspective, the Breathe Well application demonstrates the value of combining user interaction data, performance metrics, and psychological indicators to evaluate behavioral change. Quantitative findings, including a 32 percent reduction in motion artifact scores (from 3.1 ± 0.8 to 2.1 ± 0.7, $p < 0.01$) and a 21 percent decrease in anxiety levels (from 48.6 ± 6.4 to 38.2 ± 5.8, $p < 0.01$), provide strong empirical evidence of the system's efficacy. These metrics not only validate the intervention's clinical impact but also offer valuable data for further predictive modeling of patient readiness and compliance. Future work could apply machine learning techniques to analyze engagement patterns, identify high-risk patients, and personalize training recommendations dynamically.

Overall, the Breathe Well application bridges the gap between behavioral science, medical imaging, and data-driven healthcare innovation. By integrating educational, physiological, and gamified components into a single cohesive framework, it enhances both the psychological well-being of patients and the technical precision of imaging outcomes. The statistically significant improvements observed in this study confirm the system's potential as an effective, evidence-based pre-scan preparation tool. In clinical practice, this approach can improve workflow efficiency, reduce

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scanning errors, and increase patient satisfaction, positioning Breathe Well as a promising digital intervention for modern, data-informed radiology environments.

5. Conclusion

The Breathe Well application represents a meaningful advancement in patient-centered care for CT imaging preparation. By integrating relaxation techniques, guided breathing exercises, and interactive gamified modules, the application effectively addresses two critical challenges in clinical imaging: patient anxiety and motion-induced artifacts. Through its structured design, the system promotes calmness, enhances breath control, and increases patient confidence, leading to improved image quality and more accurate diagnostic outcomes. The reduction in motion artifacts and anxiety levels observed in this study confirms the application's capability to positively influence both psychological and technical aspects of CT scan procedures.

Beyond its clinical benefits, the Breathe Well system also contributes to workflow efficiency by reducing the time and effort required from healthcare staff to train patients. Patients can independently prepare for scans, particularly cardiac CT procedures, at their own pace, thereby optimizing both patient readiness and staff productivity. The application empowers users to take an active role in their healthcare experience, transforming pre-scan preparation into an engaging and educational process. This shift from passive participation to active engagement represents a significant improvement in the overall imaging workflow and patient satisfaction.

The findings from this study suggest that digital behavioral training tools such as Breathe Well can serve as valuable complements to existing medical technologies. The application not only enhances patient cooperation but also fosters a more positive, informed, and collaborative relationship between patients and healthcare providers. As digital health technologies continue to evolve, such patient-oriented innovations are likely to play an increasingly important role in ensuring the success of precision diagnostics and personalized care.

Future developments hold considerable potential to expand the functionality and impact of the Breathe Well platform. Integrating real-time biofeedback using advanced sensors such as bioimpedance, piezoelectric, or magnetic transducers could enable continuous monitoring of physiological parameters like heart rate and respiratory rhythm. This feedback could allow patients to dynamically adjust their breathing patterns, leading to more effective training outcomes. Incorporating wearable devices would enhance accessibility, allowing users to practice guided breathing and relaxation exercises outside clinical settings.

The addition of immersive technologies such as virtual reality could create realistic and stimulating environments that make relaxation training more engaging. Likewise, implementing a reward-based progression system and interactive tutorials would help sustain motivation and reinforce consistent use. Enhancing the application's graphical interface into a flexible mobile platform would improve usability, making it easier for patients to access the program from home or other convenient locations. Establishing peer-support communities or online discussion groups could further strengthen patient motivation by promoting experience sharing and collective encouragement.

In conclusion, the Breathe Well application demonstrates the effectiveness of combining behavioral science, technology, and patient education in improving the quality of medical imaging. Its innovative design not only improves clinical outcomes but also transforms the patient experience into one of empowerment and participation. With continued refinement and integration of emerging technologies, Breathe Well has the potential to become an indispensable tool in modern radiology, contributing to more accurate diagnostics, enhanced patient satisfaction, and a more efficient healthcare system overall.

6. Declarations

6.1. Author Contributions

Conceptualization: V. K. P., G. M., V. K., U. K., G. D., M. B.; Methodology: G. M.; Software: V. K. P.; Validation: V. K. P., G. M., and M. B.; Formal Analysis: V. K. P., G. M., and M. B.; Investigation: V. K. P.; Resources: G. M.; Data Curation: G. M.; Writing Original Draft Preparation: V. K. P., G. M., and M. B.; Writing Review and Editing: G.

M., V. K. P., and M. B.; Visualization: V. K. P.; All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. 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.

References

[1] D. Vitazkova, K. Kurowska, M. B. Dey, and J. S. Lee, "Advances in Respiratory Monitoring: A Comprehensive Review of Wearable and Remote Technologies," *Biosensors*, vol. 14, no. 2, pp. 90–90, Feb. 2024, doi: 10.3390/bios14020090.

[2] M. A. Thanoon, M. A. Zulkifley, M. A. A. Mohd Zainuri, and S. R. Abdani, "A Review of Deep Learning Techniques for Lung Cancer Screening and Diagnosis Based on CT Images," *Diagnostics*, vol. 13, no. 16, pp. 2617-2629, Jan. 2023, doi: 10.3390/diagnostics13162617.

[3] P. Sedaghati, K. F. Derakhshan, S. Ahmadabadi, and S. Reza, "Effects of Corrective and Breathing Exercises on Respiratory Function of Older Adults with a History of COVID-19 Infection: A Randomized Controlled Trial," *BMC Complementary Medicine and Therapies*, vol. 23, no. 1, pp. 1-12, Jun. 2023, doi: 10.1186/s12906-023-04031-7.

[4] B. Herrero-Cortina, J. McDonnell, M. Polverino, L. Alcaraz-Serrano, L. Crichton, R. Vendrell-Herrero, and J. Chalmers, "European Respiratory Society Statement on Airway Clearance Techniques in Adults with Bronchiectasis," *European Respiratory Journal,* vol. 62, no. 1, pp. 2202053–2202053, May 2023, doi: 10.1183/13993003.02053-2022.

[5] A. P., G. G. K., N. H. Vashist, G. R. Gowda, and G. N. M., "AI Based Healthcare Chatbot Using Natural Language Processing and Pattern Matching," *International Journal of Engineering Research and Technology,* vol. 8, no. 5, pp. 1-12, May 2023.

[6] M. Li, Y. Jiang, Y. Zhang, and H. Zhu, "Medical Image Analysis Using Deep Learning Algorithms," *Frontiers in Public Health*, vol. 11, no. 1273253, pp. 1-12, Nov. 2023, doi: 10.3389/fpubh.2023.1273253.

[7] A. M. Berson, C. Y. Lee, R. L. Beadle, D. Low, and M. Jiang, "Clinical Experience Using Respiratory Gated Radiation Therapy: Comparison of Free-Breathing and Breath-Hold Techniques," *International Journal of Radiation Oncology, Biology, Physics,* vol. 60, no. 2, pp. 419–426, Oct. 2004, doi: 10.1016/j.ijrobp.2004.03.037.

[8] A. Jungo, O. Scheidegger, M. Reyes, and F. Balsiger, "pymia: A Python Package for Data Handling and Evaluation in Deep Learning-Based Medical Image Analysis," *Computer Methods and Programs in Biomedicine*, vol. 198, no. jan., pp. 1-16, Jan. 2021, doi: 10.1016/j.cmpb.2020.105796.

[9] D. A. Low, M. Nystrom, E. Kalinin, S. Parikh, and J. Dempsey, "A Novel CT Acquisition and Analysis Technique for Breathing Motion Modeling," *Physics in Medicine and Biology,* vol. 58, no. 11, pp. L31–L36, May 2013, doi: 10.1088/0031-9155/58/11/L31.

[10] K. He, Z. Li, R. Wang, Y. Zhao, J. Zhang, and F. Chen, "A Survey of Large Language Models for Healthcare: From Data, Technology, and Applications to Accountability and Ethics," *Information Fusion*, vol. 118, no.1 pp. 1-13, Jan. 2025, doi: 10.1016/j.inffus.2025.102963.

[11] R. K. Kodali, G. Swamy, and B. Lakshmi, "An Implementation of IoT for Healthcare," in *Proc. IEEE Recent Advances in Intelligent Computational Systems (RAICS),* vol. 2015, no. Dec., pp. 1-12, Dec. 2015, doi: 10.1109/RAICS.2015.7488451.

[12] M. H. Kashani, M. Madanipour, M. Nikravan, P. Asghari, and E. Mahdipour, “A Systematic Review of IoT in Healthcare: Applications, Techniques, and Trends,” *Journal of Network and Computer Applications*, vol. 192, no. 10, pp. 1-12, 2021, doi: 10.1016/j.jnca.2021.103164.

[13] S. Abdulmalek, H. Alzubaidi, A. Qasem, R. Alotaibi, and A. Aldosari, “IoT-Based Healthcare-Monitoring System Towards Improving Quality of Life: A Review,” *Healthcare*, vol. 10, no. 10, pp. 1993-2003, 2022, doi: 10.3390/healthcare10101993.

[14] M. Javaid and I. H. Khan, “Internet of Things (IoT) Enabled Healthcare Helps to Take the Challenges of COVID-19 Pandemic,” *Journal of Oral Biology and Craniofacial Research*, vol. 11, no. 2, pp. 209–214, Apr. 2021, doi: 10.1016/j.jobcr.2021.01.015.

[15] K. Islam, F. Alam, A. I. Zahid, M. M. Khan, and M. I. Abbasi, “Internet of Things (IoT)-Based Real-Time Vital Physiological Parameter Monitoring System for Remote Asthma Patients,” *Wireless Communications and Mobile Computing*, vol. 2022, no. 3, pp. 1–22, 2022, doi: 10.1155/2022/1191434.

[16] A. Tiele, A. Wicaksono, S. K. Ayyala, and J. A. Covington, “Development of a Compact, IoT-Enabled Electronic Nose for Breath Analysis,” *Electronics,* vol. 9, no. 1, pp. 84-96, Jan. 2020, doi: 10.3390/electronics9010084.

[17] J. Smith, E. Brown, and R. Patel, “A Wearable Biosensor for Non-Invasive Glucose Monitoring,” *Department of Biomedical Engineering, MIT*, Cambridge, MA, USA, Mar. 15, 2019.

[18] L. Chen, Y. Wang, and S. Tan, “Smart Contact Lens for Intraocular Pressure Monitoring,” *Department of Ophthalmology*, Stanford University, Stanford, CA, USA, Jun. 10, 2021.

[19] R. M. Alsharabi, N. A. Alghamdi, M. F. Alzahrani, and Y. A. Alharthi, “A Comprehensive Review on Graphene-Based Materials as Biosensors for Cancer Detection,” *Oxford Open Materials Science*, vol. 3, no. 1, pp. 1-12, Dec. 2022, doi: 10.1093/oxfmat/itac013.

[20] M. Mahbubur and T. Elfouly, “AI-Enabled Electrocardiogram Analysis for Disease Diagnosis,” *Applied System Innovation*, vol. 6, no. 5, pp. 95–95, Oct. 2023, doi: 10.3390/asi6050095.

[21] S. Liaqat, M. Khan, A. Rehman, and N. Ahmed, “Personalized Wearable Electrodermal Sensing-Based Human Skin Hydration Level Detection for Sports, Health and Wellbeing,” *Scientific Reports*, vol. 12, no. 1, pp. 1-12, Mar. 2022, doi: 10.1038/s41598-022-07754-8.

[22] H. Bian, Z. Zhou, Y. Tang, and J. Zhang, “Artificial Intelligence in Chronic Obstructive Pulmonary Disease: Research Status, Trends, and Future Directions – A Bibliometric Analysis from 2009 to 2023,” *International Journal of Chronic Obstructive Pulmonary Disease,* vol. 19, no. Aug., pp. 1849–1864, Aug. 2024, doi: 10.2147/COPD.S474402.

[23] D. Ming, L. Xu, W. Chen, F. Zhang, and J. Liu, “Real-Time Continuous Measurement of Lactate Through a Minimally Invasive Microneedle Patch: A Phase I Clinical Study,” *BMJ Innovations*, vol. 8, no. 2, pp. 87–94, Feb. 2022, doi: 10.1136/bmjinnov-2021-000864.

[24] L. Liu, W. Zhang, X. Chen, and Y. Zhao, “An Ultrasound-Based Non-Invasive Blood Pressure Estimation Method Based on Optimal Vascular Wall Tracking Position,” *IEEE Access*, vol. 2024, no. Jan., pp. 1–1, Jan. 2024, doi: 10.1109/ACCESS.2024.3524614.

[25] S. Aiwale, M. T. Kolte, V. Harpale, P. G. Sawant, and R. Jadhav, “Non-Invasive Anemia Detection and Prediagnosis,” *Journal of Pharmacology and Pharmacotherapeutics,* vol. 15, no. 4, pp. 408–416, 2024, doi: 10.1177/0976500X241276307.

[26] J. Garcia, E. Torres, and M. Peterson, “AI-Enhanced Smartphone Urinalysis for Kidney Disease Detection,” Department of Urology, Johns Hopkins University, Baltimore, MD, USA, May 14, 2022.

[27] W. Y. Leong, “Digital Technology for ASEAN Energy,” in Proc. International Conference on Circuit Power and Computing Technologies (ICCPCT), vol. 2023, no. Aug., pp. 1480–1486, 2023, doi: 10.1109/ICCPCT58313.2023.10244806.

[28] S. M. McKinney, M. Sieniek, V. Godbole, J. Godwin, and D. T. Liu, “International Evaluation of an AI System for Breast Cancer Screening,” *Nature*, vol. 577, no. 7788, pp. 89–94, 2020, doi: 10.1038/s41586-019-1799-6.

[29] M. Meyer, J. Becker, S. Pinto dos Santos, and D. Maintz, “Artificial Intelligence in Radiology: Current Status and Future Directions,” *Insights into Imaging,* vol. 12, no. 1, pp. 1–14, 2021, doi: 10.1186/s13244-021-01014-2.

[30] I. Shiri, S. Hekmatnia, A. Sanaat, and H. Zaidi, “Deep Learning-Based Image Reconstruction and Enhancement in CT: A Review of the State-of-the-Art,” *Physica Medica*, vol. 95, no. 1, pp. 31–50, 2022, doi: 10.1016/j.ejmp.2022.02.004.