Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 4, 116-123
2025
Publisher: Learning Gate
DOI: 10.55214/25768484.v9i4.5946

Ergonomic usability evaluation and inclusive redesign of diagnostic imaging device interfaces for aging sonographers

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Abstract: With the increasing age of healthcare professionals, the number of older sonographers in the workforce is on the rise. Despite this, limited research addresses the specific usability challenges of ultrasound device interfaces for this demographic. This study aims to identify and address usability issues in diagnostic imaging devices to enhance their user experience for aging sonographers. A usability evaluation framework was established, focusing on task workflow, interface design, and risk prevention. Fifteen evaluation criteria were developed based on recognized design principles, and a workflow encompassing 'Patient,' 'Scan,' 'Measurement,' and 'End Exam' was designed in collaboration with clinical experts. Usability tests were conducted with participants who subsequently provided feedback through interviews. Thematic analysis of the interview data was performed using NVivo, with survey responses complementing the findings. Interviews highlighted recurring themes, including automation-related functions within the 'Task Process', overly complex screens with dense button layouts in 'Interface Design', and the need to safeguard patient data from accidental deletion under 'Errors and Risk Factors'. Additionally, survey data revealed that the 'Patient' and 'Scan' stages elicited the most feedback, with concerns focusing on button and text readability, as well as a desire for a 'Back' button. Older sonographers face unique ergonomic and usability challenges, including visual fatigue and upper extremity discomfort. Addressing these issues through improved interface design—emphasizing readability, simplicity, and error prevention—can enhance safety and efficiency. The findings offer actionable insights for designing medical devices tailored to aging healthcare professionals.

Keywords: *Elderly users, Inclusive design, Medical imaging equipment, Ultrasound diagnostic equipment, Usability testing, User interface design.*

1. Introduction

In modern society, individuals of all ages may experience temporary disabilities arising from injuries or illnesses, underscoring the need for inclusive design in product development. As such, adopting a holistic design approach that accounts for these situations are essential both now and in the future [1]. A key philosophy in human-computer interaction (HCI) emphasizes making products accessible to a wide range of users, including those of varying ages, cultural backgrounds, technical skills, and physical abilities. Designing products that accommodate age-related changes is therefore of significant importance [2]. This study specifically focuses on the ultrasonic diagnostic devices utilized by older sonographers in healthcare settings. Ultrasound technology has become an indispensable diagnostic tool in the medical field, continuously advancing through research and innovation [3]. However, adverse events in safety-critical medical environments often stem not only from human error but also from inadequately designed user interfaces.

The primary goal of this study is to explore methods for enhancing the usability of diagnostic imaging device interfaces to ensure safer usage by older healthcare professionals. Numerous examples highlight the importance of both usability and safety in medical products. Although improvements have been made

History: Received: 3 February 2025; Revised: 14 March 2025; Accepted: 18 March 2025; Published: 3 April 2025
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to the usability of various medical device interfaces, these enhancements typically cater to the general medical workforce, leaving the needs of older medical staff underexplored [4]. Thus, this research aims to address this gap by investigating ways to optimize the interface usability of ultrasound diagnostic devices for older sonographers, making it a meaningful endeavor.

2. Research Objectives

This study aims to enhance the usability of diagnostic ultrasound device interfaces for older sonographers. By adopting an inclusive design approach, which considers the needs of older and disabled users, this research seeks to improve the user experience for all age groups [5]. To achieve this goal, the following research questions will be addressed.

1. Task Workflow Analysis: Are there specific challenges that older sonographers encounter when interacting with the task workflow and interface of ultrasound devices?
2. Interface Design Evaluation: What design elements can be optimized to increase the efficiency and effectiveness of older sonographers when using ultrasound devices?
3. Error Prevention and Risk Mitigation: What potential risks and error factors should be considered to ensure the safe and reliable use of ultrasound devices by older sonographers?

This research acknowledges that older sonographers encounter distinct challenges compared to their younger counterparts, necessitating tailored design solutions to address these issues effectively.

3. Methods

3.1. Research Design

A standardized workflow was established, comprising four key stages: 'Patient', 'Scan', 3. 'Measure', and 'End Exam'. This workflow was developed in collaboration with experienced sonographers to accurately reflect real-world usage. Using this framework, all participants in the study were asked to operate ultrasound equipment manufactured by Alpinion for one week. Following this usage period, individual interviews were conducted to gather detailed feedback on the usability of the device's interfaces.

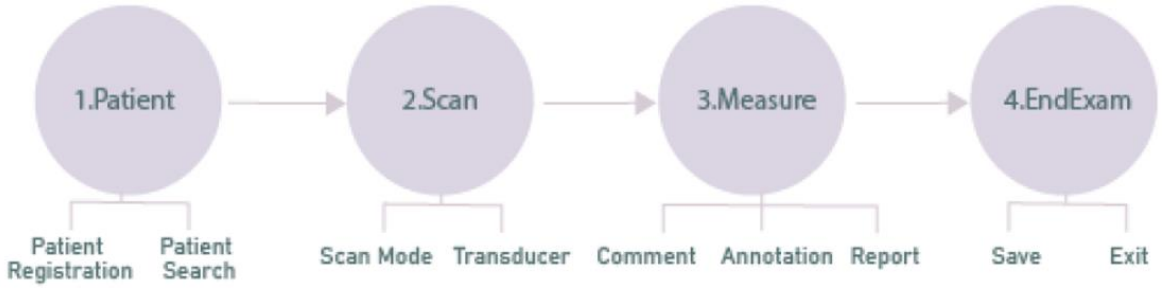

Figure 1.
Task Process Diagram.

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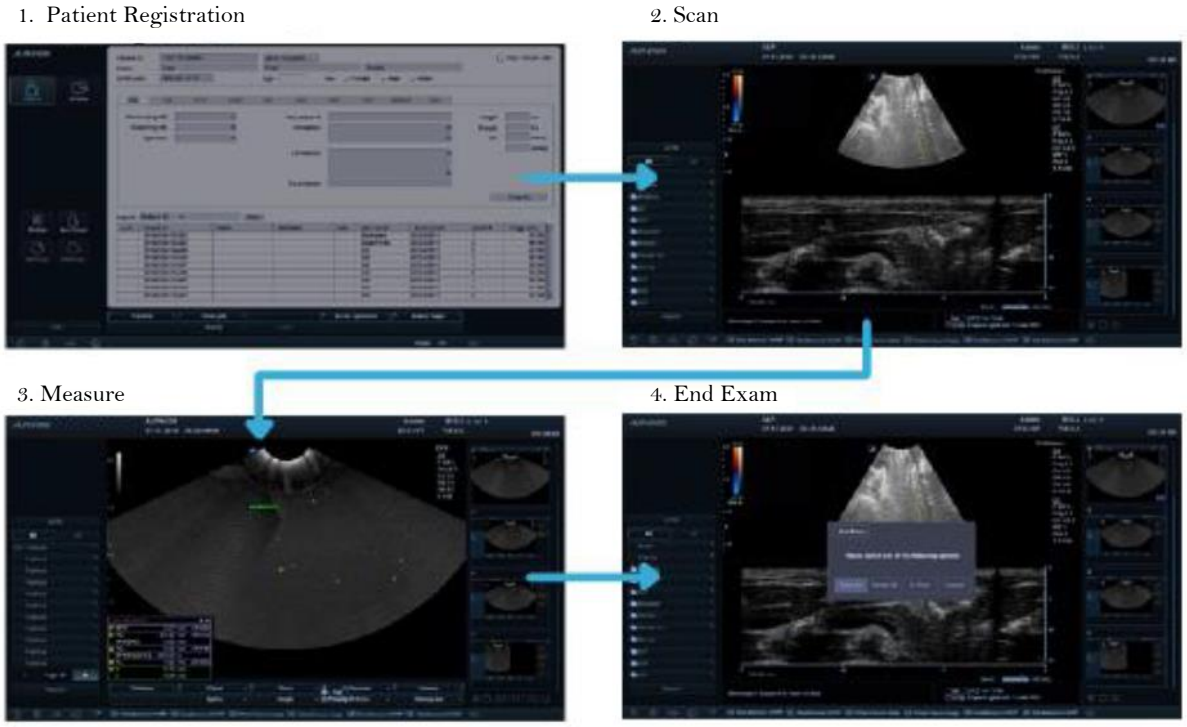

Figure 2.
Task Process – Alpinion ECUBE Interface.

To systematically assess and improve interface usability, 15 additional evaluation criteria were developed, covering three major areas: 'Task Process', 'Design Elements', and 'Risk Prevention Factors'. These criteria were based on the heuristic evaluation principles introduced by Donald Norman and Jakob Nielsen, along with guidance from clinical experts.

Table 1.
Survey - Task Process Checklist.

Patient	1. When you register patients, what parts need improvement in interface design?
	2. Do you have any discomfort when doing a patient list search? If you can you tell me what the problems are?
Scan	3. What do you need to do to be efficient and accurate when scanning?
	4. How can the user interface be improved for effective patient diagnosis?
Measure	5. What inconveniences or improvements exist in the system's functions or user interface when measuring patient lesions?
	6. When you measure, is it efficient to use the diagnostic information report and diagnostic information storage function provided on the screen?
	7. When you measure, are the measurement functions provided on the screen before you finish the exam?
End Exam	8. Is it easy to review and image data information on the screen before you finish the exam?
	9. Is it easy to identify the Save button on the screen before you finish the exam?

Table 2.
Survey – Design Elements Checklist.

Design Elements	10.Is it easy to read the interface font, and understand the menu and icon information when you are diagnosing?
	11.Is the interface design you use consistent and easy to use?
	12.Is this interface comfortable design considering your perception without much difficulty?

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Table 3.
Survey – Risk Prevention Factor Checklist.

Risk Prevention Factor	13. Does this diagnostic interface support the ability to recognize and recover from errors in the design of diagnostic?
	14. Does this diagnostic interface provide options to prevent potential errors or risks as you progress through the task process?
	15. How much does the user interface add to the risks of your work incorrectly. Can you give me an example?

Nielsen [6] heuristic evaluation method, established in 1990, was employed to identify usability issues within the interactive systems of the devices. Key principles from this method include 'Consistency', 'Efficiency of Use', 'Visibility', 'Error Prevention', and 'Affordance' [6]. Additionally, inclusive design principles, which emphasize flexibility for elderly and disabled users, were integrated into the research framework. Donald Norman's cognitive affordance model was also considered to support a natural and intuitive workflow for older sonographers, aiming to enhance their overall efficiency and ease of use [7].

Table 4.
Design Principle.

Usability Heuristics for User Interface Design	1. Consistency-Easy to learn how to use the device.
	2. Efficiency of use-The potential to help users achieve their goals in a reasonable amount of time. 3. Visibility-The possibility of a device to be remembered.
	3. Visibility-The possibility of a device to be remembered.
	4. Error Prevention-Minimizes errors and allows users to easily recover from errors.
	5. Affordance- It is also called 'action inducement', meaning 'to induce a certain action'.
The principles of inclusive design	1. Provide comparable experience-Ensure your interface provides a comparable experience for all.
	2. Consider Situation-People use your interface in different situations.
	3. Be Consistent-Use familiar conventions and apply them consistently.
	4. Give Control-Ensure people are in control.
	5. Offer choice - Provide users with multiple options for task completion
	6. Prioritize Content - Guide users to focus on essential tasks, features, and information through strategic prioritization.
	7. Add Value-Consider the value of features and how they improve the experience for different users.

Source: Nielsen [6].

3.2. Methods Procedure

3.2.1. Equipment

The ultrasound diagnostic device used in this study was manufactured by 'Alpinion Medical Systems', a South Korean company with which all participants had prior experience.

Figure 3.
Ultrasound diagnostic equipment products of 'Alpinion Medical Systems'.

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3.2.2. Participants

The study involved five experienced sonographers aged 60 and older, each with over 20 years of professional experience in hospital settings in Korea.

3.2.3. Measurement Methods

Participants operated the ultrasound equipment over one week, adhering to the standardized workflow to ensure consistency in data collection. Subsequently, individual interviews were conducted to gather qualitative data on their experiences. Informed consent was obtained from all participants prior to the interviews, which were audio-recorded. Additionally, a follow-up survey was emailed to participants to collect further quantitative data.

3.2.4. Data Analysis

The audio-recorded interviews were transcribed and analyzed using NVivo 12, a qualitative data analysis software. The analysis focused on three primary categories: 'Interface Design', 'Task Process', and 'Risk Prevention Factors' By combining the insights from the interviews and the survey data, key areas for improvement in the usability of the ultrasound device interface were identified.

4. Results

4.1. Interview Analysis

The individual interview data collected from the elderly sonographers were analyzed using NVivo, a qualitative research tool. Key insights were identified and categorized under three main themes.

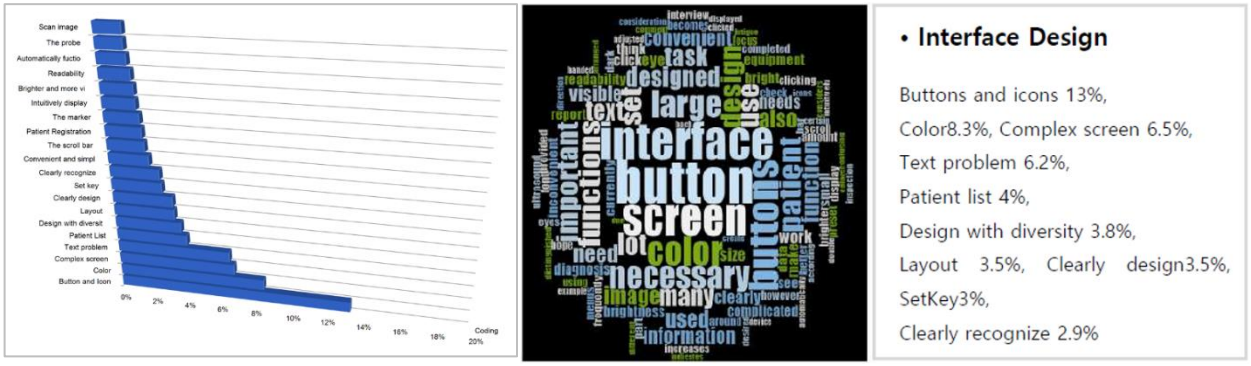

Figure 4.
Keywords of 'Interface Design'.

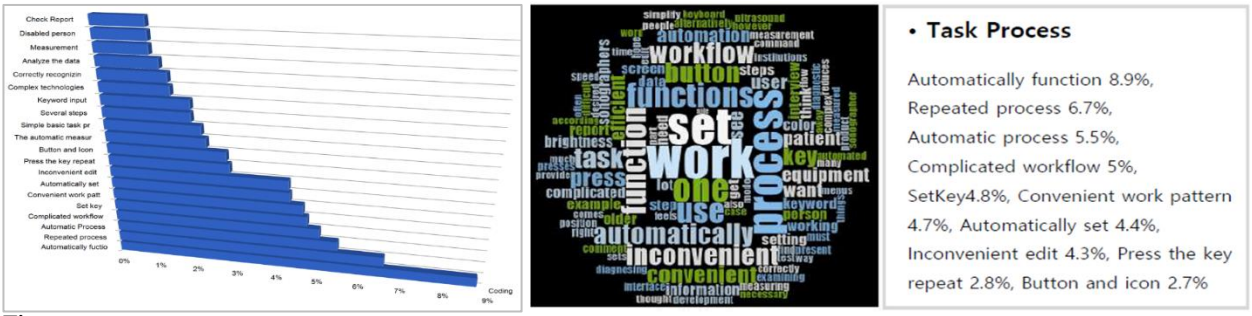

Figure 5.
Keywords of 'Task Process'.

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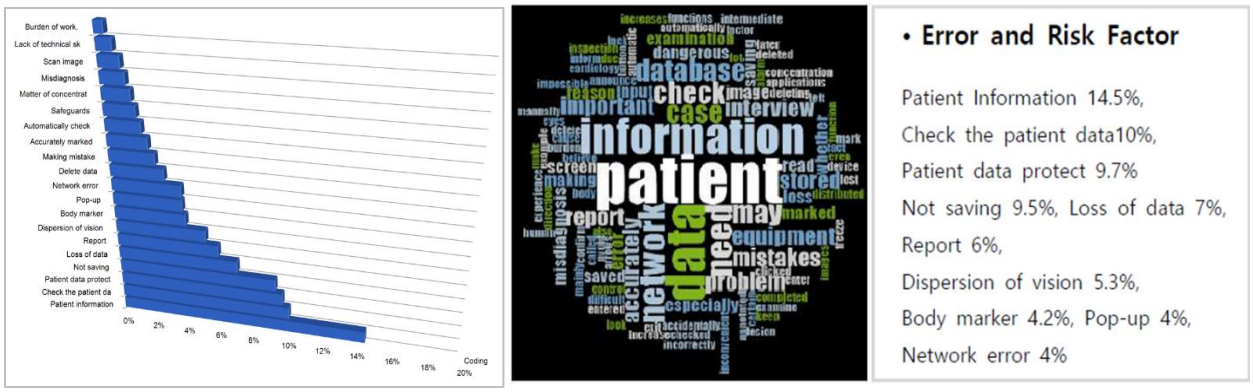

Figure 6.
Keywords of 'Error and Risk Process'.

4.2. Additional Survey Analysis

4.2.1. Task Process

4.2.1.1. Patients

Tasks related to patients involve enrolling new patients, retrieving their information, and reviewing diagnostic scan images. Analysis revealed the need for intuitively labeled buttons during the patient registration process. Modifications to the worklist section of the registration screen were also deemed essential.

4.2.1.2. Scan

Scan-related tasks, which involve using the device to diagnose patients, are critical within the workflow. Participants emphasized that frequently used buttons should be prominently displayed on the interface's main page for easier accessibility. Additionally, buttons or menus corresponding to ongoing tasks should be visually differentiated—such as through color coding or other visual indicators—to improve usability.

4.2.1.3. Measure

The measurement stage involves marking structures or lesions in scanned images and annotating diagnostic information. Suggestions for improvement included increasing the speed of the trackball cursor and enhancing the 'clear function' button within the annotation tools. Usability could be further improved by providing an automatic measurement calculation package and simplifying the positioning of key button groups for easier access.

4.2.1.4. End Exam

This stage involves concluding the current examination and preparing for the next by saving diagnostic information and measurements. To prevent accidental data loss, the deletion process should require users to click "X button" followed by "Delete" for confirmation. If the user cancels at the "X button" step, the image should remain saved. Additionally, a warning message about potential data deletion should be displayed to alert the user.

4.2.2. Design Elements

The scan screen layout should be streamlined to minimize visual clutter. Readability of annotations can be improved by offering a variety of fonts and body-marker shapes. Button actions and statuses should be consistently displayed across screens. Convenience during patient examinations could also be enhanced by placing a preset change menu at the top of the touch panel or in another accessible area on the monitor.

4.2.3. Risk Prevention Factor

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Participants suggested including a "Back" button on the interface to allow users to undo actions in case of errors. Buttons associated with resetting or erasing data should be clearly labeled and visually distinct, such as by dimming their light to reduce unintentional activation. Additionally, a warning message should appear when deleting measurement values or linked calculations, prompting users for confirmation to prevent accidental data loss.

5. Discussion and Conclusion

This study aimed to enhance the usability of ultrasonic diagnostic device interfaces for older sonographers by examining key factors such as task processes, design elements, and risk prevention measures.

To achieve this, addressing the physical and cognitive limitations of older users necessitates ongoing engagement to identify and integrate their specific requirements into design processes. By conducting in-depth interviews and administering additional detailed surveys, several significant insights were uncovered to support their ability to work independently.

The participants reported experiencing visual fatigue and discomfort in their upper extremities, stemming from poor posture during prolonged examinations. These issues were exacerbated by holding a wired ultrasound probe while simultaneously monitoring a screen in dimly lit environments. Such conditions not only decrease concentration over extended periods but also increase the likelihood of misdiagnoses and pose risks related to the accidental loss of patient data. Additionally, artificial intelligence and automation emerged as recurring themes in the feedback provided by participants, highlighting their significance in addressing these challenges.

The survey results revealed that older sonographers emphasised the readability of buttons and text, particularly during tasks related to patient information management and scanning procedures. They preferred simplified designs, with fewer menus and buttons displayed around the scanned image. A frequently requested feature was a one-touch automated button for commonly performed repetitive tasks. Regarding risk prevention, most participants strongly supported the inclusion of a "Back" button and warning messages to help prevent unintended data deletion.

The findings also underscored the importance of addressing visual fatigue, a prevalent issue among elderly users, and improving data management systems for patient information. Consequently, it is recommended that the interface design of ultrasonic diagnostic devices be updated to incorporate these user requirements. Specifically, adjustments should focus on improving the identification of buttons and icons and optimizing both patient information interfaces and scan screens to reduce potential risks.

This study provides valuable insights and actionable suggestions for redesigning ultrasonic diagnostic device interfaces to better accommodate the needs of older sonographers, contributing to safer and more effective medical practices.

Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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