

Evaluating a Remote Monitoring Sleep Interface in Long Term Care Using a Combined

Heuristics Approach

by

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BSc, University of Nairobi, Kenya, 2012

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Abstract

Usability is defined as the ease with which an individual can use a product in specific circumstances. In healthcare technology, usability plays a crucial role in improving workflow efficiency, patient safety, and decision-making. This study evaluates the general usability and visualization design of Sleep Sense, a remote sleep monitoring solution used in long-term care (LTC) facilities. A heuristic evaluation was conducted using Nielsen's usability heuristics and Zuk & Carpendale's visualization heuristics to assess system interaction, interface design, and data visualization quality. A total of 77 usability questions were applied across 18 heuristic categories, identifying 58 general usability violations and 12 visualization-related issues. The metric scores of 0-4 were assigned to each violation. A Multi-Criteria Decision Analysis (MCDA) approach was used to quantify usability violations, revealing that most issues fell within medium severity, with no catastrophic violations detected. Most violations were rated at 2 (moderate changes needed). Key areas of concern included poor visibility of system status, misalignment with real-world clinical expectations, and insufficient user control and freedom. The study also identified significant gaps in alert prioritization, menu hierarchy, and filtering functionalities, impacting workflow efficiency. Challenges in data visualization (inadequate contrast, insufficient white space, limited dynamic filtering) were identified. Recommendations include redesigning the dashboard to highlight critical alerts, improving menu customization, enhancing contrast and text integration in visual displays, and incorporating dynamic filtering

and clustering tools. The study underscores the importance of integrating usability and visualization principles in healthcare software to optimize clinician experience and patient care. Future research could explore multi-modal evaluation approaches to further improve system functionality and user trust. Additionally, AI-driven usability enhancements should be considered to meet current usability and visual demands of clinicians.

Keywords: usability evaluation, heuristic analysis, healthcare technology, interface design, visualization heuristics, long-term care, sleep monitoring systems, clinical decision support

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Background and Significance

A remote sleep monitoring solution (Sleep Sense) displays sleep and out-of-bed activities for residents in long term care (LTC), thus rendering it valuable for providing insight into their sleep behaviours and for supporting clinicians by shortening clinician reaction time.

Additionally, the information received from sleep monitoring can support medication management in treating insomnia and other sleep related illnesses in LTC facilities (Miller, 2004).

Data on the Sleep Web App Interface

Sleep Sense is a palm-sized pad placed under one leg of the resident's bed. The pad tracks sleep characteristics, body movements, bed-in-and-out instances, and transmits the results to the clinician in real-time. The remote bed sensor is combined with proprietary software that generates reports containing data on sleep, in- and out-of-bed activities, and evidence-based information on sleep quality, which are displayed on the system dashboard for clinicians to utilize in clinical decision making (Maxwell, 2022).

The content of the sleep interface showcases some of the key features demonstrated in the consensus sleep diary (Carney et al., 2012) which help answer the following questions: What time did you get to bed? What time did you try to go to sleep? How long did it take to fall asleep? How many times did you wake up, not counting your final awakening? How long did this awakening last? What time was your final awakening? What time did you get you get out of bed for the day? How would you rate the quality of sleep? Other key metrics on the dashboard and the reports include items identified by the National Sleep Foundation (NSF), which clinicians were more likely to focus on during the process of evaluating sleep health in older adults (Schütz et al., 2021). These items include quality-of-sleep metrics, such as sleep

efficiency, latency, number of awakenings, REM, deep sleep, and light sleep. Summaries of the generated data are displayed on the dashboard to support clinicians' daily decision-making. The optimization of interface design and visualization for a sleep monitoring solution in LTC facilities is a vital endeavour towards guaranteeing resident safety, well-being, and interface usability. Like other systems in hospital facilities, the sleep interface dashboard and its reports support clinical decisions and improve patient safety (Sutton et al., 2020).

While the dashboards and patient reports are important for software solutions in LTC facilities, the workforce in these environments have varying levels of digital literacy and health literacy. Thus, the dashboards and report platforms should ideally be designed to support all perspective stakeholders in LTC facilities to meet the needs of older adults (defined as individuals aged 65 years and older) in care, their families, as well as the workforce (Siette et al., 2023). It is also unclear how different types of data presentation on LTC dashboards and reports may affect the comprehension and decision-making of the users (Siette et al., 2023). Software interface design can affect usability in clinical settings. As the demand for efficient and user-friendly interfaces is on the rise, rigorous methodologies are imperative to evaluate the usability and efficacy of these technological innovations (Kumar et al., 2014).

Interface design allows the user to manipulate a system's input and to display the effects of the manipulation in the output. A well-designed interface significantly enhances the system's functionality and capability, allowing healthcare professionals to allocate more time to patient care, ultimately improving patient outcomes (Sittig et al., 2008).

Due to the vast amount of information needed for decision-making in healthcare, data output competes for space on the screen, which if not well planned, the design output can be overwhelming for clinicians (Turchioe et al., 2019). Hence, software designers need to

understand clinicians' issues when interacting with interface design and should make improvements where necessary.

Aside from improving the general design, data visualization also plays an essential role in supporting data display and cognition. Some avenues of data visualization include information display with raw data, graphical representations, tables, visual icons, and the use of different colours to display different sets of information (Li, 2020). Clinicians can miss vital information without the proper balance between interactive displays and information views; therefore, enhancing the quality of the information display can improve clinicians' overall feel, content engagement, and information retention (Reese et al., 2021).

Another major issue in the design process and visualization techniques in healthcare is the lack of established design standards, as every vendor designs unique interfaces, trusting that they will fit the clinicians. As emphasized by Perry et al. (2021), the healthcare environment is dynamic in nature, containing several stakeholders, and the involved parties' goals and values may only sometimes align. The conflict between goals, profitability, and attempting to align with patient-centeredness can lead to diverse approaches in designing healthcare solutions and may hinder performance improvements (Shadlyn, 2022). As such, the design output is varied, and there is a need to understand whether the current innovative interface design and data visualization for the sleep information system can meet the clinicians' expectations.

One method for evaluating usability includes using Nielsen heuristics to evaluate system interfaces (Nielsen & Landauer, 1993). Nielsen's method is guided by ten principles that help an expert walk through a system and find any issues that violate its principles. Nielsen heuristics have been widely used to evaluate system interactivity, but there are certain gaps which arise when analyzing interface design and visualization using Nielsen's heuristics alone. In a study by

Santos et al., (2015) the authors point to the fact that Nielsen heuristics are better principles for evaluating human-computer interaction (HCI) but may not be utilized for information visualization (Info Vis) to a greater extent.

Another study by Dowding and Merrill (2018) showed that combining various heuristics can provide a better perspective on interaction usability and data visualization in evaluating the system interface. Hence, the addition of another method i.e., Zuk and Carpendale's heuristics (Zuk et al., 2006) in this study provides more depth of the interface evaluation.

Zuk and Carpendale's principles of visual heuristics emphasize the critical role of effective visualization design in enhancing comprehension and decision-making processes (Zuk et al., 2006). Their framework advocates for the reduction of unnecessary visual complexity, ensuring that graphical elements remain intuitive and informative to users. By aligning the design of visualizations with human perceptual processes, their principles promote the use of familiar visual descriptions to support users in recognizing patterns and relationships efficiently. Additionally, Zuk and Carpendale prioritize clarity and simplicity to ensure that visualizations communicate insights in a way that is both clear and actionable, ultimately improving the overall effectiveness of data interpretation (Zuk et al., 2006).

This study investigates the interactive and visual features of the sleep interface, commenting on how this information is designed, and provided recommendations for improvements based on the heuristic questions used for evaluation. This study used Zuk and Carpendale's heuristics (Zuk et al., 2006) and Nielsen's heuristic principles (Nielsen & Landauer, 1993). The combined approach provides a greater perspective in evaluating the general design and visualization of the remote sleep monitoring dashboard and report in the LTC setting.

Literature Review

What is Usability?

In its simplest terms, usability is the ease with which an individual can use a product in specific circumstances (Keenan et al., 2022). It is also formally defined by the International Organization for Standardization (ISO) as the extent to which specified users can use a product to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (Chaniaud et al., 2020). Usability is the basis of HCI, thus setting the tone for clinicians before and during system utilization. General design and visualization heuristics were considered to evaluate the interface layout in detail. The difference between the two items is defined as follows:

General usability design heuristics is defined as the ease of use, navigation or functionality, summarized as user interface design. Interface design addresses issues primarily related to interaction mechanisms, including the appearance, layout, and functionality of on-screen elements like buttons and menus (Diehl et al., 2022). This design approach makes it easier for users to complete tasks while ensuring the interface is visually appealing. General heuristics supports the evaluation of the interaction aspect of the interface and, to some extent, the visualization, but not at a depth (Dal et al., 2002). Therefore, additional methods are needed for a complete interface evaluation.

Information visualization involves using tools and techniques that promote insight, understanding, and support of the user on the interface (Forsell & Johansson, 2010). This level of evaluation checks if the interaction design provides the desired level of visual satisfaction to the user as well as cognition, practical understanding, and usage of information (Santos et al., 2015).

According to Mishra (2023), the following are some key concepts in data visualization: Visual encoding, visual perception, data abstraction, visual hierarchy and information semantics, defined in Table 1 below. These concepts and principles form a robust foundation for designing information visualizations that effectively communicate complex data, support exploration and analysis, and enhance users' understanding and decision-making processes (Mishra, 2023).

Table 1

Key Concepts in Data Visualization

Principle	Description
Visual Encoding	Translates data attributes into visual properties like position, color, and size to effectively convey information.
Visual Perception Principles	Uses principles like pre-attentive processing and Gestalt principles to guide design, enhancing user understanding.
Data Abstraction	Simplifies complex data through aggregation and summarization. Interaction and exploration features (e.g., zooming and filtering) allow dynamic user engagement.
Visual Hierarchy	Structures data presentation to focus attention, ensuring a user-centered design that aligns with users' needs and cognitive abilities.
Information Semantics	Ensures meaningful representation by reducing ambiguity, applying cognitive load principles to minimize mental effort for comprehension.

Note. The table above summarizes key principles of visual information representation, focusing on effective data translation through visual encoding, perception, abstraction, hierarchy and semantics to enhance comprehension and reduce cognitive load. Information source (Mishra, 2023).

Similarly, Zuk and Carpendale have utilized some of these principles in formulating visualization heuristics (Zuk et al., 2006). Their focus on visual encoding corresponds to the translation of data attributes into visual properties such as position, color, and size, which is

central to conveying information clearly. The application of visual perception principles, including pre-attentive processing and Gestalt principles, is integral to their framework, as these design choices guide users toward faster and more accurate understanding of visual patterns.

Furthermore, data abstraction in Zuk and Carpendale's principles simplifies complex datasets, which reflects their support for dynamic user engagement through interaction techniques like zooming and filtering (Zuk et al., 2006). Visual hierarchy, another key element in their work, prioritizes the organization of data to direct attention where it is most needed, aligning with user-centered design principles that cater to cognitive needs. Lastly, information semantics and the reduction of ambiguity are critical for minimizing cognitive load, reinforcing Zuk and Carpendale's emphasis on clarity and the minimization of mental effort in data interpretation (Zuk et al., 2006). Therefore, Zuk and Carpendale embrace core visualization design principles, ensuring efficient and cognitively alignment with users' needs (Zuk et al., 2006). By understanding and applying these principles, designers can create intuitive, engaging visualizations and facilitate knowledge discovery.

Impact of Interface Design on the Users

A sleep management system's effectiveness in a complex care environment depends on its interface's ability to collect, organize, and display patient information meaningfully to users (clinicians) at the point of care, consistent with cognitive workflows. A system can be problematic and time-consuming because of poor interface design. LeBlanc et al. (2022) elaborate on usability from a user perspective, stating that users must navigate and use the system correctly to reap the benefits of the information given. The system becomes useless or has limited utility if the users cannot operate and comprehend the system. Below are a few ways that design may affect users.

A poor design can lead to increased cognition time. Insufficient information display increases the cognitive load for the users as they must go the extra mile to navigate the meaning of acronyms or words used in the display. As elaborated in works by Purnell et al. (2023), evaluating an interface for the sleep monitoring app SomnoRing (a wearable sleep monitoring ring), the study showed that consumers had difficulty interpreting sleep data due to improper definitions of some lay terms used in the app. For example, SomnoRing users were unfamiliar with abbreviations like “REM” (Rapid Eye Movement) and “PR” (Pulse Rate), despite the availability of icons like ‘?’ which users could use to search for the meaning of these abbreviations, however, the users required additional context to understand the meaning behind these abbreviations and available icons for knowledge seeking. In this example, the words and icons used did not match the users’ cognitive level of understanding, which should have been accounted for from the beginning. This violates the expectation of the user for using simple language, hence the mismatch between the system and the real world. The display should have provided the full name for easier understanding.

Furthermore, the users required the analytics provided by the web app to be clear and concise. The web app analytics scored sleep in percentages, but the consumers wanted simpler analytics on the display i.e., to know if their sleep was getting better or worse. Using percentages may not provide better recognition or recall of information; hence, summarizing it using terminology such as ‘better’ or ‘poor’ supports the user's comprehension ability. Overall, due to needing help understanding the web app metrics and reports, the participants were unsatisfied with the interface, citing that it gave information that could not be used.

Inflexible Design Can Reduce User Satisfaction

Inflexible design gives the user less control and reduces their sense of system ownership, meaning that clinicians, for example, cannot go as far as they desire in terms of exploring information, whether at depth or at a shallow level. Joyce et al. (2016) mention that a sleep monitoring web app had limited flexibility and efficiency at expert levels, citing that the sleep app could not provide advanced search capability, reducing the tendency for re-engaging with the system at a capacity they desired. To counter inflexibility, systems should allow users to adjust the system's settings depending on the user efficiency or access level e.g., beginner or expert, or by user role within an organization, such as a nurse (clinician) or a healthcare provider. In works by Lazarou et al. (2016), the authors emphasized the importance of flexibility in design interfaces, showing the importance of tailoring sleep monitoring reports according to the user's (clinician and caregiver) needs, thus improving their engagement level. Lazarou et al. (2016) also commented on the use of configurable solutions that provide clinicians with the ability to define the display resolution, date range, to filter results according to activity type or sensor used, and to carry out a comparison of the traits that are being tracked or issues that the system has identified, hence allowing for improved interpretation and visualization of sleep patterns and trends.

The Importance of Visualization Design on Sleep Monitoring System Interfaces

Like general design, visualization helps assess patient histories, track therapy progress, and find health patterns. Whereas general design supports the dynamic interaction of the screen, Information Visualization gives us what we "see" from the data collected. Visualization allows healthcare workers to comprehend patient data in a straightforward manner. A more visually appealing interface supports quick decision-making and transforms complex data into comprehensible knowledge for application. Visualization assists users in visually perceiving

differences in size, shapes, colours and spatial position of objects on the interface (Turchioe et al., 2019). Visualization can range from simple infographics to complex scientific data representations, wherein complexity of visualizations should be tailored according to the user's technical and domain knowledge, goals, and the time and effort they are willing to invest (Munzner, 2014). Visualization plays a significant role in the dashboard display of sleep items and supports sleep monitoring in the following areas.

Visualization can support clinical decision making. Poor visualization can obscure critical information, leading to misinterpretations and incorrect diagnoses. Clinicians need to explore data, ask specific questions, and test hypotheses efficiently; therefore, when visualizations fail to support these activities, the risk of making incorrect clinical decisions increases, adversely affecting patient outcomes (Upadhyay & Hu, 2022). For instance, a poorly visualised interface might fail to highlight significant trends in a patient's sleep patterns, causing clinicians to overlook potential sleep disorders such as sleep apnea or insomnia. In the case of Lazarou et al. (2016), the clinician interface offered four separate sections to analyze sleep data comprehensively. The summary of the one-day section displayed specific sleep stages and durations for a single night, while the summary per day section allowed the display of multiple days to observe sleep patterns alongside other Activities of Daily Living (ADLs), such as bathroom visits during the night. The dashboard section enabled clinicians to set and monitor specific thresholds to identify potential sleep problems. Finally, the comparison per day or week section provided a broad view of sleep patterns over time, allowing clinicians to correlate sleep data with physical activity and other daily activities. The above example demonstrates how the information's perceptibility and intuitiveness of the interface allow clinicians to enhance their ability to make informed assessments and interventions (Lazarou et al., 2016).

Additionally, data slicing techniques (an interactive visualization method) are applicable when complex data segments are shown simultaneously. In this case, data can be segmented into pieces by specifying various properties in the visualization, for instance, you can segment data across categories using different colors or shapes. The available segmentation options depend on the type of visualization being used. Effective data slicing, such as by time or category, allows clinicians to focus on specific subsets of data, enhancing clarity and interpretability. Similar techniques, such as performing an overview first, zooming and filtering, and details-on-demand have shown the capability of managing complex data and supporting detailed interfaces. For instance, filtering data by specific sleep phases can help clinicians identify patterns and anomalies crucial for diagnosis (Backonja et al., 2018). This feature is also demonstrated by Lazarou et al. (2016) who incorporated data slicing techniques, which enabled the visualization of complex datasets and allowed clinicians to identify significant issues and introduce targeted interventions. In the same study, the interface allowed clinicians to detect abnormal REM sleep activity, a common characteristic in neurodegenerative diseases, which helped in the early detection of Primary Supranuclear Palsy (PSP) (Lazarou et al., 2016). Additionally, the data suggested a mechanism underlying excessive daytime sleepiness in individuals suffering from PSP, further illustrating the practical benefits of effective data slicing as a visualization technique on the sleep interface (Lazarou et al., 2016).

Overall, evaluating Sleep Senses' general design and visualization tools can provide suggestions for designing user-friendly visualization tools that balance complexity with clarity, reduce cognitive load, and integrate seamlessly into clinical workflows. Heuristics methods provide a better framework for evaluating the Sleep Sense interface.

Heuristic Methods

Heuristic evaluation is a general usability inspection method, which refers to a class of techniques in which evaluators examine an interface for usability issues. Inspection methods are considered as informal usability evaluation methods due to their reliance on heuristics and the experience and knowledge of the evaluators. The method has been broadly researched for assessing eHealth and technology products (Baumel & Muench, 2016). Jakob Nielsen pioneered the heuristic evaluation method, which has been widely used to help evaluate user interfaces and information systems (Nielsen & Landauer, 1993; Walsh et al., 2017). Heuristic evaluation involves one or more usability analysts systematically stepping through a user interface and noting the violations of well-known usability heuristics. The approach is based on applying the ten heuristics principles (Miller et al., 2018), as described below:

1. **Visibility of system:** The system should always keep users aware of what is happening by providing suitable feedback in a fair amount of time.
2. **Match between system and the natural world:** The system should communicate in the user's language, using words, phrases, and concepts that the user is familiar with rather than technology-oriented terminology. The system should adopt real-world norms to present information in an easy and logical sequence.
3. **User control and freedom:** Users frequently select system functions by accident, necessitating a clearly defined "critical exit" to quit the unwanted status without going through a lengthy discussion. The system should enable cancellation and redo.
4. **Consistency and standards:** Users should not have to question if different phrases, contexts, or actions indicate the same thing. The system should match the platform's needs and standards.

5. **Error prevention:** In its meticulous design, the system should communicate effectively and avoid error messages by default. If not, the system should either remove error-prone conditions or check for them and provide users with a confirmation option before committing to an action.
6. **Recognition rather than recall:** The system should reduce the user's memory load by highlighting items, actions, and alternatives. The user should not have to recall information from one interaction section to another. When applicable, system usage instructions should be displayed or easily accessible.
7. **Flexible and efficient use:** The system should accommodate novice and expert users by improving the interaction level for both calibres of users. It should also allow users to customize their frequent actions.
8. **Aesthetics and minimalist design:** The display should not include irrelevant or rarely required material. Every additional unit of information in a discourse competes with relevant information units, lowering their relative exposure.
9. **Help users recognize, diagnose, and recover from errors:** The error messages should be written in simple terms (no codes), clearly describe the problem, and constructively offer a solution.
10. **Help and documentation:** Although the system may be operated without documentation, it may be necessary to provide assistance and documentation. Documentation material should be easy to find, relevant to the user's task, have concrete steps to be taken, and be manageable.

Zuk and Carpendale's Heuristics

Zuk and Carpendale's heuristics was used primarily for visual evaluations, supplementing the Nielsen heuristics for general usability during the evaluation of the Sleep Sense interface (Nielsen & Landauer, 1993; Zuk et al., 2006). Zuk and Carpendale's heuristics are also called cognitive and perception heuristics, as they align interface design with how users think, learn, and perceive visual information, aiming to reduce cognitive load, ensure visual clarity, and maintain consistency, to ultimately improve user experience. There are thirteen key principles (Zuk et al., 2006):

1. Ensure visual variables (i.e., distinctions that are used to create and differentiate symbols on the interface includes the size, shape, orientation, texture, color objects on the interface) are sufficient length and purpose: The length of visual variables should be adequate to convey differences clearly and to prevent misinterpretation.
2. Do not expect reading order from colour: Colors do not inherently imply order; thus, relying on colour alone for sequencing information can lead to confusion.
3. Colour perception varies with item size: The perception of colour changes depending on the size of the items, requiring careful consideration in design.
4. Local contrast affects colour and gray perception: The perception of colours and grays is influenced by surrounding contrasts, necessitating context-aware design.
5. Consider people with colour blindness: Designs must account for colour blindness to ensure accessibility and accurate interpretation by all users.
6. Pre-attentive benefits increase with field of view: Visual elements that capture attention quickly are more effective when the field of view is larger.

7. Quantitative assessment requires position or size variation: Accurate quantitative comparisons depend on variations in position or size rather than colour alone.
8. Preserve data to graphic dimensionality: The data dimensions should be maintained in the graphical representation to prevent information loss.
9. Put the most data in the least space: Efficient use of space is essential to present the maximum amount of data without overwhelming the viewer.
10. Remove the extraneous (ink): Eliminating unnecessary elements helps to focus the viewer's attention on the most essential information.
11. Consider gestalt laws: Utilizing principles such as proximity, similarity, and continuity enhances the organization and readability of visual data.
12. Provide multiple levels of detail: Offering varying levels allows users to access high-level overviews and drill down into specifics as needed.
13. Integrate text wherever relevant: Combining text with visuals ensures that explanations and data are immediately accessible and comprehensible.

Determining the Heuristics Principles and Usability Factors

As noted earlier, this study combines the Nielsen heuristics methods and the Zuk and Carpendale heuristic principles (Nielsen & Landauer, 1993; Zuk et al., 2006). Both usability factors i.e., Zuk and Carpendale's and Nielsen's heuristics, had test questions per principle, which were be part of the usability checklist for examining the Sleep Sense remote monitoring solution.

Study Objectives

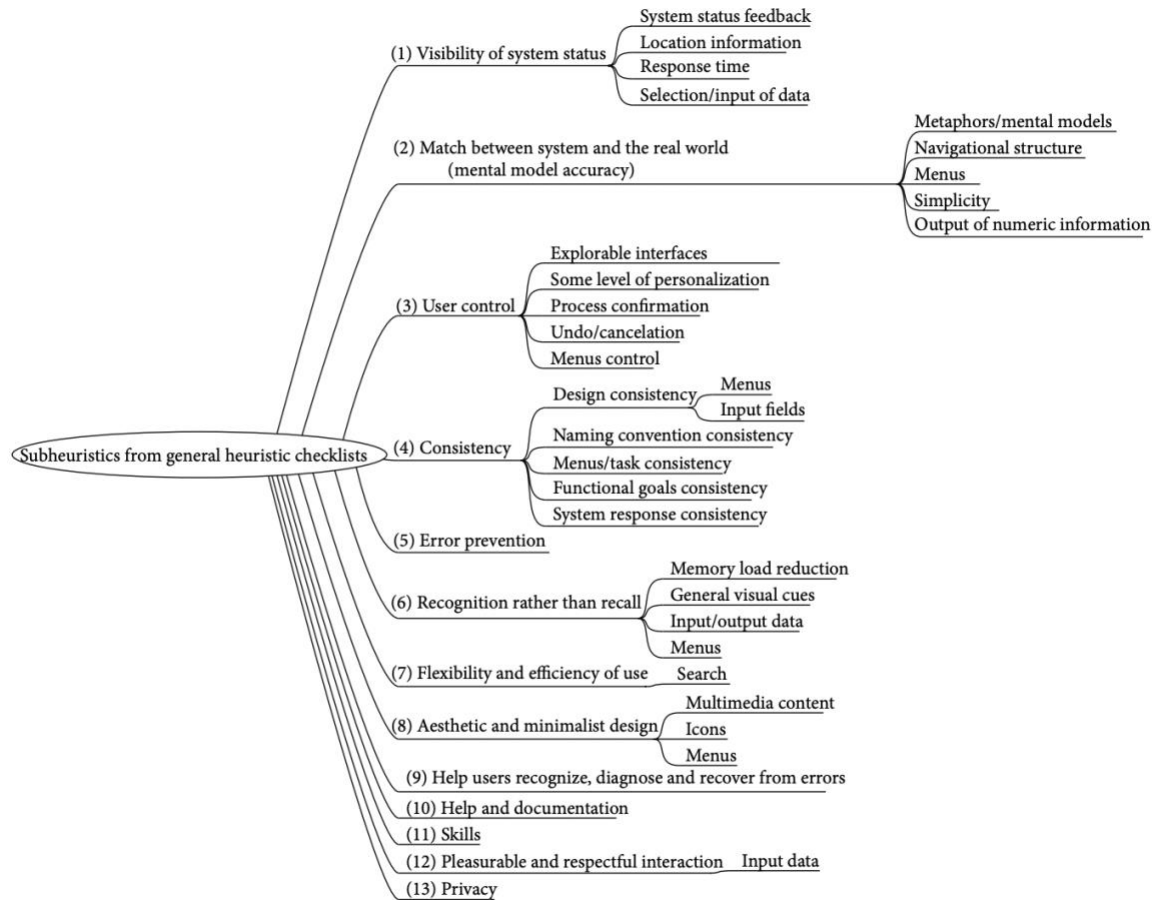
This was a descriptive qualitative usability study accounting for the evaluator's perception of the Sleep Sense interface and provides a description of the interface's violations

through the heuristic rules in the setting of LTCs. The research study used the two heuristic methods as they offer an organized and cost-effective means of evaluating interface design and visualization techniques. The heuristics helped in detecting usability issues that are frequently overlooked during system use but can be costly to the clinician and impact the LTC residents if not addressed; the study aims were:

1. Evaluating sleep monitoring dashboard and report interface for general and visualization design using the Nielsen's and Zuk and Carpendale's heuristics (Nielsen & Landauer, 1993; Zuk et al., 2006)
2. Analyzing the frequency and severity of the heuristic's violations of the evaluation.

Selecting the Usability Questions for Both Heuristics

The researcher developed a relevant checklist, guided by works by (Dowding & Merrill, (2018); and Yáñez Gómez et al., (2014), to aid the development of the checklist for general usability. Yáñez Gómez et al. (2014) developed 13 heuristics, each with sub-heuristics that guide the questions evaluating the interface (Yáñez Gómez et al., 2014). This study focused on nine Nielsen heuristics (Nielsen & Landauer, 1993). The principles “error prevention” and “help users recognize, diagnose, and recover from errors” were combined into one principle due to similarity of the question and outcome expectation. Figure 1 shows a map of the various heuristics and sub-principles used by Yáñez Gómez et al. (2014) to guide the question generation process of the evaluation.

Figure 1*Map of Heuristics and Sub-Principles*

Note. The image presents sub heuristics from general heuristic checklists, including principles such as visibility of system status, match between system and the real world, user control, consistency, error prevention, recognition rather than recall, flexibility of use, aesthetic and minimalist design, help, and privacy. Each principle is further broken down into specific focus areas like metaphors, design consistency, memory load reduction, and multimedia context, which guide the design and evaluation of system usability. Image source Yanez et al., 2014.

Heuristics principle and subtitles

The following questions were added for each general Nielsen heuristic principles:

1. Visibility of System Status

1. Hierarchy of content: Are high-informative contents placed in high-hierarchy areas?
2. Logo visibility: Is the logo meaningful, identifiable, and sufficiently visible?
3. Is there visual feedback in menus or dialogue boxes about which choices are selectable?
4. Does every screen have a title or header that describes its contents?
5. Is there a consistent icon design scheme and stylistic treatment across the system?

2. Match Between the System and the Real World

1. Metaphors: Are metaphors relevant to clinical sleep management?
2. Icon familiarity: Are icons concrete and familiar to clinicians?
3. Shape cues: Do shapes match clinical cultural conventions?
4. Colour codes: Do colours correspond to clinical expectations?
5. Hierarchy balance: Is the hierarchical structure balanced for clinicians?
6. Logical order: Are menu choices logically ordered for clinicians?
7. Menu categories: Do menu choices fit into clearly understood categories?
8. Grammatical parallelism: Are menu titles grammatically parallel?
9. Memory load: Are menu items limited to avoid memory overload?
10. Related fields: Are related fields grouped on the same screen?
11. Language consistency: Is the language consistent with clinicians' terminology?
12. Explicit language: Is the language clear and free of jargon?
13. Paragraph rule: Does each paragraph convey one idea?

3. User Control

1. Exit marking: Are exits marked?
2. System defaults: Can users set their own system, session, file, and screen defaults?
3. Task completion: Does the system wait for a signal from the user before processing when a task is complete?
4. Command confirmation: Are users prompted to confirm commands with drastic, destructive consequences?
5. Action reversal: Can users quickly reverse their actions, including a single action, a data entry, and a complete group of actions?
6. Operation cancellation: Can users cancel operations that are in progress?
7. Multiple menu levels: If the system has multiple menu levels, is there a mechanism for users to return to previous levels?

4. Consistency

Colour Scheme.

1. Are up to four colours used, with additional colours used only occasionally?
2. Are there no more than four to seven colours, and are they different?

Sound Notifications.

3. Are soft sounds used for regular updates and harsh sounds for rare important alerts?

Page Consistency.

4. If there are multiple pages for entering data, do they all have the same title format?

Menu Design.

5. Are there clear standards for designing menus, and are they used consistently across the system?

Icon Usage.

6. Are there at most twelve to twenty different icons?
7. Are icons designed in a consistent style across the system?
8. Are menu choices listed vertically?

5. Recognition Rather Than Recall

1. Are prompts, cues, and messages placed where the eye is likely looking on the screen?
2. Is white space used to create symmetry and lead the eye in the appropriate direction?
3. Have items been grouped into logical zones, and have headings been used to distinguish between zones?
4. Is colour highlighting used to get the user's attention?
5. Is colour coding consistent throughout the system?

6. Flexibility and Efficiency of Use

1. Is navigation between screens simple and visible?
2. If menu lists are short (seven items or fewer), can users select an item by moving the cursor?
3. Can users click on fields, or use a keyboard shortcut, if the system uses a pointing device?
4. On menus, do users have the option of either clicking directly on a menu item or using a keyboard shortcut?
5. Is the search box easily accessible?
6. Is there an advanced option available?
7. Are the results shown comprehensively to the user?

7. Aesthetic and Minimalist Design

1. Is only (and all) information essential to decision-making displayed on the screen?
2. Have large objects, bold fonts, and simple areas been used to distinguish sections?
3. Are field labels brief, familiar, and descriptive?
4. Are there any unnecessary data elements on each screen?
5. Is each lower-level menu choice associated with only one higher-level menu?
6. Are menu titles brief, yet long enough, to communicate?

8. Error Prevention

1. Are menu choices logical, distinctive, and mutually exclusive?
2. Are data inputs case-blind whenever possible?
3. Does the system warn users if they are about to make a potentially serious error?
4. Do data entry screens and dialogue boxes indicate the number of character spaces available in a field?
5. Do fields in data entry screens and dialogue boxes contain default values when appropriate?

9. Help and Documentation

1. Are online instructions visually distinct?
2. Does the system correctly anticipate and prompt for the user's probable next activity?

Creating a Visualization Questions Checklist Based on Zuk and Carpendale's Principles

The specific principles were selected based on the study's needs to include visual evaluation techniques, i.e., representative visuals and interactive visuals (Dal et al., 2002). Representative visuals include data density, logical order, information mapping and visual orientation. The principles below (numbers one to eight) are all representative visuals. Interactive

visuals include filtering, clustering or plumbing the visual interface to get multiple levels of details (number nine). The visual interactions also include navigation and querying, e.g., the user can expand clustered or hidden data elements or manipulate geometric representation. The following questions were added based on Zuk and Carpendale's heuristic principles:

1. Ensure the Visual Variable Has Sufficient Length

Visual elements should be long enough to represent data differences.

1. Are the visual variables (e.g., bars, lines) long enough to accurately convey data variations?

2. Color Perception Varies with the Size of the Coloured Item

Colour perception changes with the size of the coloured areas.

1. Are the coloured items large enough to be perceived?

3. Local Contrast Affects Colour and Gray Perception

Surrounding colours influence the perception of colours and grays.

1. Is there sufficient contrast between adjacent elements to ensure clarity?

4. Pre-attentive Benefits Increase with Field of View

Features that catch attention quickly are more effective when they cover a larger area.

1. Are prominent features adequately sized to stand out quickly in the field of view?

5. Preserve Data-to-Graphic Dimensionality

Maintain consistency between the data dimensions and the graphic dimensions.

1. Does the graphic accurately represent the number of data dimensions?

6. Put the Most Data in the Least Space

1. Is the information density optimized to convey the most data in the least space without overwhelming the user?

7. Remove the Extraneous (Ink)

1. Is the data visualized clearly and straightforwardly, minimizing complexity?
2. Is there white space between colour representations?

8. Insert Text Wherever Relevant

1. Is text integrated effectively with graphics to provide context and explanations where relevant?

9. Provide Multiple Levels of Details (Interaction Mechanism in the Visual Evaluation)

1. Can the user filter information to adjust rapidly to the focus of interest?
2. Can the user cluster information into a subset of data elements?
3. Can the user prune information, cutting off information irrelevant to their understanding of the visual representation?

Methods

Study Participant

This study involved one participant, which is the author. The author analyzed the research independently as a double subject matter expert, i.e., a nurse and a health informatics specialist. The evaluator was best suited for the task owing to his expertise in design principles and workflow in LTC facilities. The evaluator is familiar with heuristics rules and navigated the Sleep Sense web app, i.e., the dashboard and the report items in the design interface that support the clinician's usability. The Sleep Sense dashboard is accessible to the author (writer) for the purpose of this study, providing privileges to explore the system as an expert user.

Working as independent evaluator was supported by the works of Nielsen and Landauer (Nielsen & Landauer, 1993), who mention that, conceivably, individual evaluators can perform a heuristic evaluation of a user interface. The authors further clarify that the averaging of outputs

by multiple individual evaluators was recommended where resources are adequate to perform the evaluations. In the case of this study, the constraints of time and resources necessitated the use of a single person evaluation process.

Data Collection and Evaluation Process

The final checklist included nine heuristics principles from each of the works by Nielsen and by Zuk and Carpendale (Nielsen & Landauer, 1993; Zuk et al., 2006). A total of 65 heuristics questions were included in the final round of the Nielsen principles, while a total of 12 heuristic questions made it to the final round of visualization heuristics based on Zuk and Carpendale, arriving at a total of 77 usability questions available for evaluation purposes (Zuk et al., 2006).

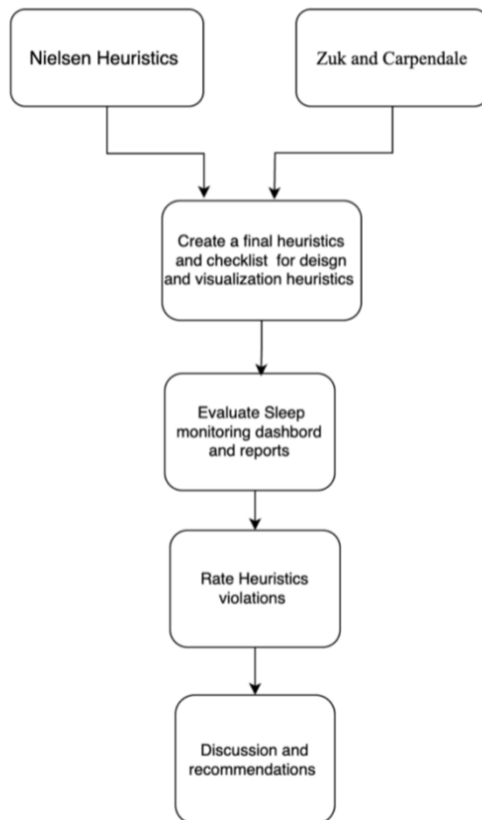
The usability evaluation process was challenging due to its subjective nature. Scientific methods classify various ways of evaluating usability, such as expert or user-based methods (Cho et al., 2022). Expert-based evaluations (e.g., heuristic evaluations, cognitive walkthroughs, field observations) aim to ensure optimal system functioning and that evidence-based interface standards and norms are fulfilled. One guiding question answered during the evaluation process include: 1. Is the user interface consistent with evidence-based design principles? The questions identified guided the layout of this study as its focus is on expert assessment using heuristics methods.

The system evaluation process included scoring the results using the Likert scoring system (Rangraz Jeddi et al., 2020). Each question was gauged on compliance or violation with the heuristics in its category. The results were presented in a table and graphs followed by describing the problem title, the heuristics violated, the location, a brief description, and a score margin of 0-4 based on the severity of the findings. The severity levels were defined as follows:

a "No problem" rating (0) indicated that the issue is not considered a usability problem, a "Cosmetic" rating (1) implied that the problem need not be addressed unless additional time is available, a "Minor" rating (2) suggested that the issue should be resolved, however, the issue is not urgent, a "Major" rating (3) denote a high-priority problem that is important to fix, and finally, a "Catastrophe" rating (4) indicated that the issue must be resolved due to a potential impact on clinician or resident safety. Additionally, screenshots of the dashboard with accompanying descriptions were added to illustrate the violations discovered during the evaluation process. Figure 2 illustrates the evaluation process. See Appendix B for a sample of the evaluation table.

Figure 2*Illustration of the Evaluation Process*

Heuristics Evaluation Process for Sleep Monitoring Dashboard and Reports



Note. The diagram outlines the evaluation process for a sleep monitoring dashboard, starting with Nielsen and Zuk and Carpendale heuristics to create a checklist for design and visualization. This checklist is used to evaluate the dashboard, rate heuristic violations, and offer recommendations.

Data Analysis

The statistical analysis focused on identifying usability violations encountered while navigating the system using general and visual heuristics guidelines. A Multi-Criteria Decision Analysis (MCDA) approach was used (Takhar et al., 2024), with guiding questions categorized into subcategories, each assigned multiple violation scores to convert qualitative reasoning into quantifiable data. The evaluation began by describing issues for each principle and assigning severity scores (Farzandipour et al., 2022). Descriptive statistics, including median scores and interquartile ranges, were used to analyze trends and outliers across heuristic principles (Cho et al., 2022; Microsoft Corporation, 2018). By assessing severity score variability, the study identified usability concerns requiring urgent attention (Kennedy et al., 2019). Frequency distributions of severity levels (minor, moderate, severe, or critical) was done to provide further insights into the most prevalent usability issues. To standardize the analysis, mean scores were calculated for each heuristic category and its subcategory. These scores were then compared across all 18 heuristic categories, ensuring a structured usability evaluation.

The severity of scores were further visualized through histograms, heat maps, and stacked bar charts, illustrating distribution patterns and highlighting critical issues. The findings informed actionable recommendations to address high-severity issues while aligning with best practices in interface design. By integrating quantitative analysis with heuristics, the study provided a structured, data-driven framework for future usability assessments and improvements.

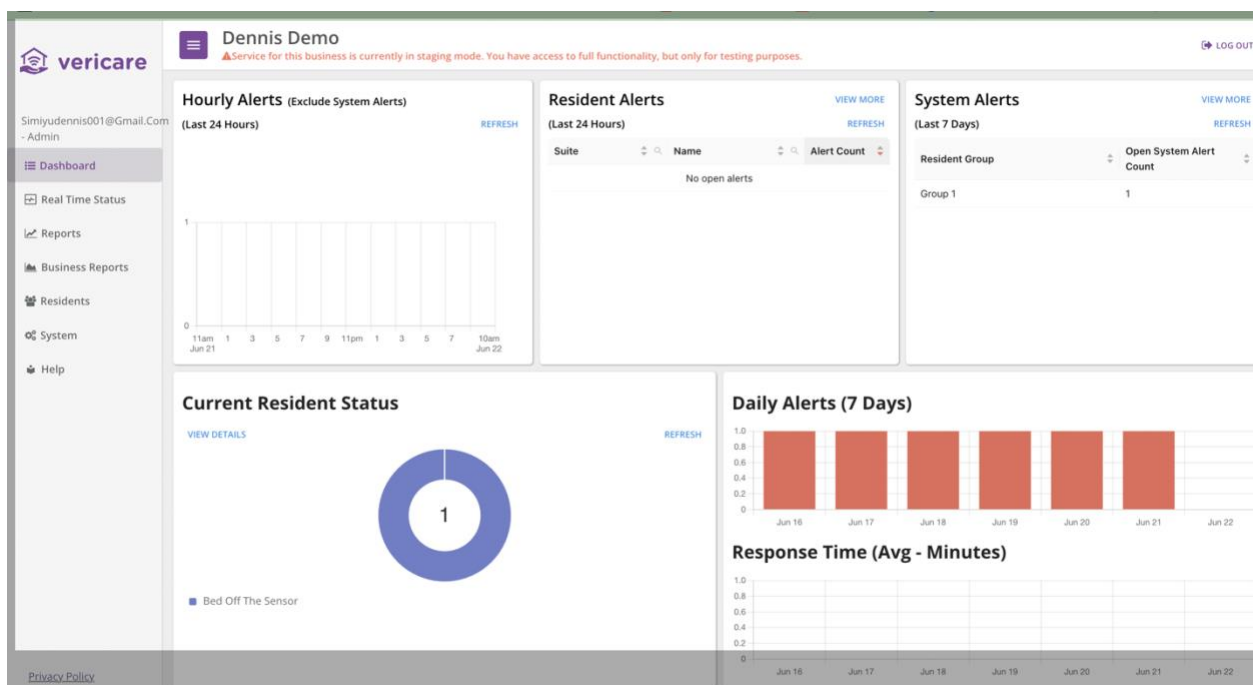
Ethics

Although no participants were being recruited for this study, an ethical review was required as the study involves human evaluation of the clinical software (the researcher). The study used the vendor's sandbox (dummy, non-patient) data and interface for testing. The

interface provided is for testing purposes, as stipulated by the software provider. Figure 3 illustrates sample of the interface of the dashboard used for evaluation. A formal process to obtain consent was signed with the vendor (Sleep Sense) for the purpose of this study. Ethics approval was received on January 8, 2025, ethics protocol number 24-047 from the University of Victoria Human Research Ethics Board (See Appendix).

Figure 3

Dashboard Interface



Note. This figure is a brief representation of the dashboard and menu of the sleep monitoring system, indicating various alerts. The details of the residents' reports are found within the indicated menu items e.g., real time status. The notification in red shows that this is in staging mode, for testing purpose. Image source: <https://vericarebp.tochtech.com/>.

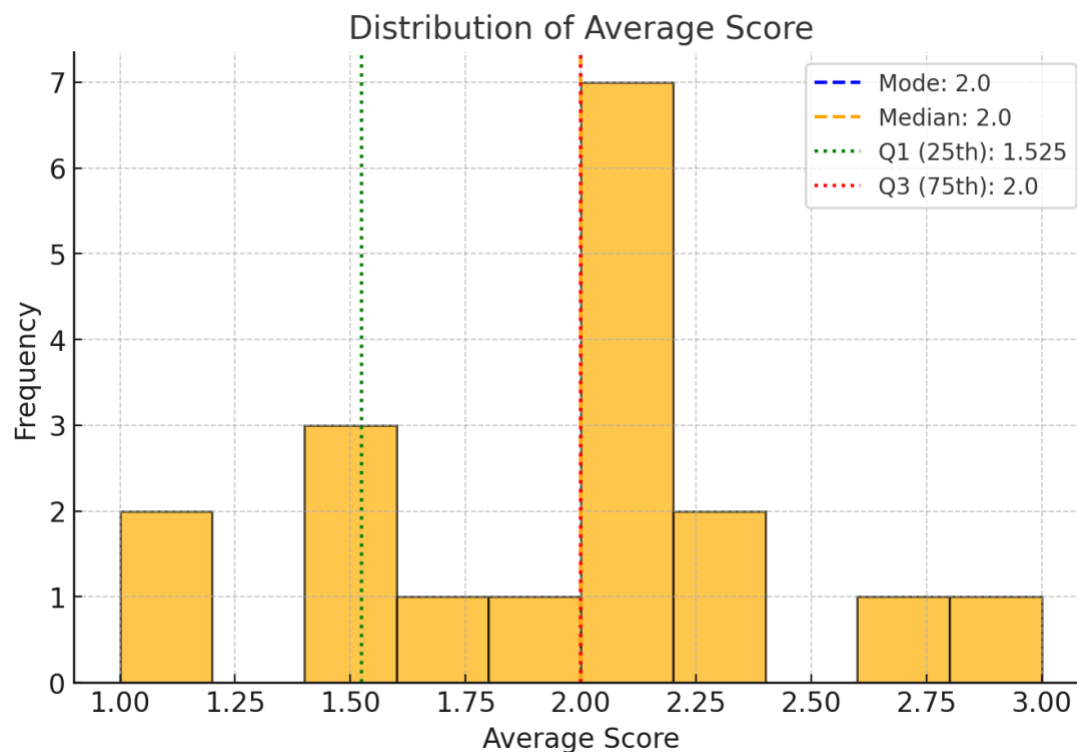
Results

A total of 77 questions were evaluated, while fifty-eight violations were identified under the general heuristics category, nine questions from the general heuristics exhibited zero violations. Additionally, there were nine categories with twelve questions pertaining to visual heuristics, scoring mostly 2 for violation in each category. The results demonstrated that the majority of heuristic violations (79.49%) stemmed from general heuristics, while visual heuristics accounted for 20.51% of the total violations.

In general, the across all the 18 categories, the mode = 2, median = 2, first quartile (Q1) = 1.52 third quartile (Q3) = 2, and interquartile range (IQR) = 1. Figure 4 demonstrates an illustration of heuristic data distribution.

Figure 4

Heuristic Data Distribution (No Critical Scores)



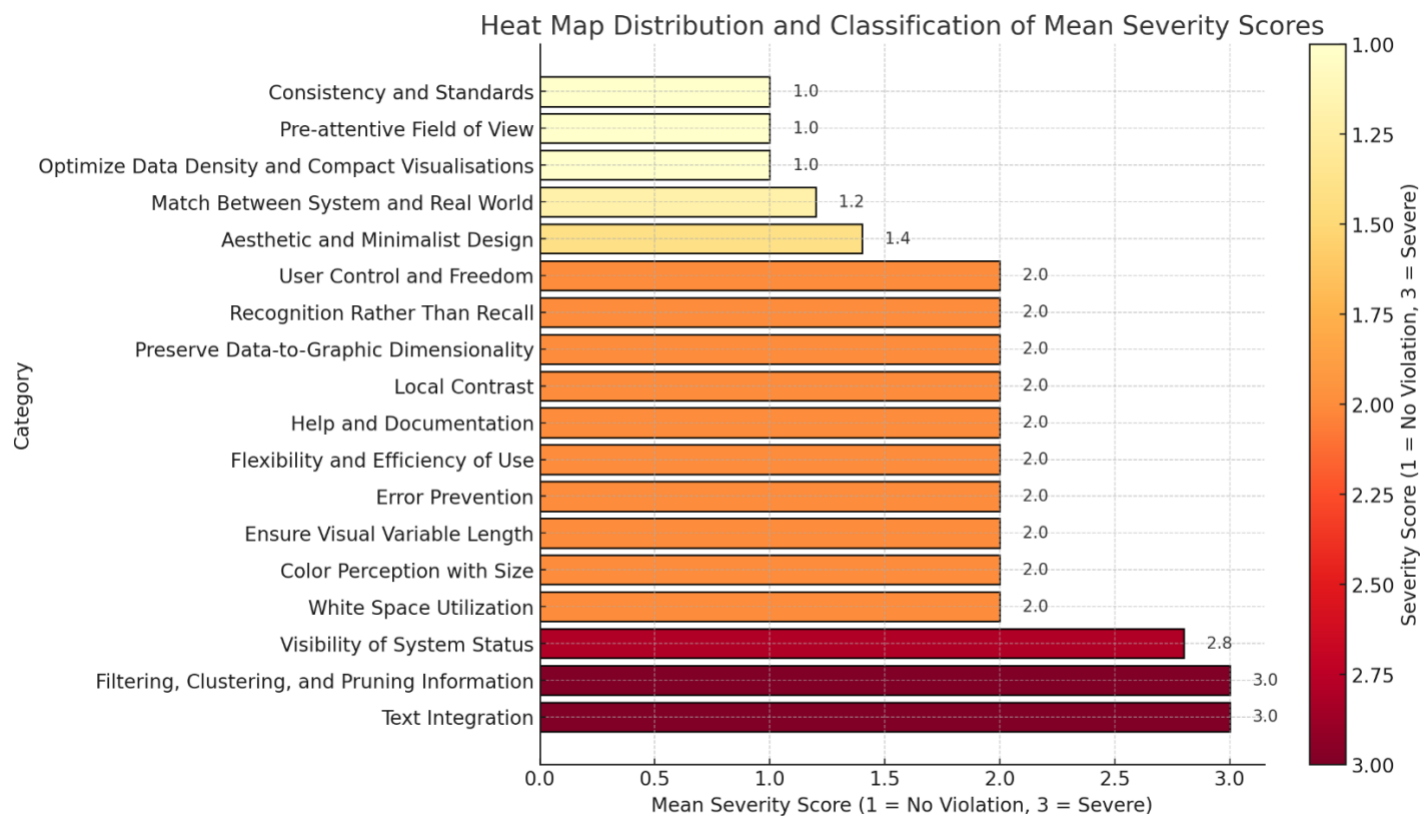
Note. This figure illustrates the frequency density of heuristic violations across severity scores. Most violations cluster at a medium severity score, while fewer violations occurred at low and high levels. No scores were reported at catastrophic level, demonstrating that the majority of issues are of moderate severity.

Score Results on a Heat Map

The categories and respective mean scores were further classified on a heat map as shown below in Figure 5. Notably two categories were at the extreme side i.e., severe (3), majority scoring a modest score of two and lowest at 1 per category.

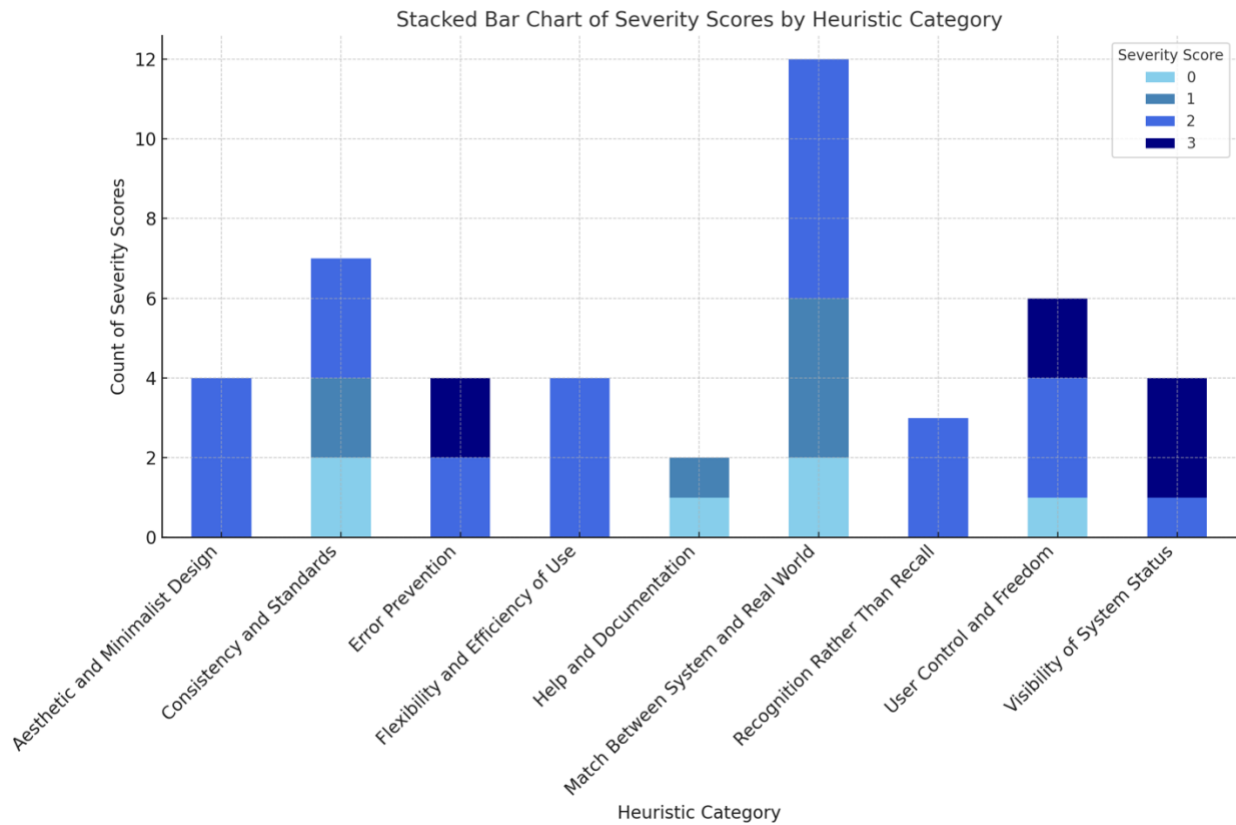
Figure 5

Heat Map Distribution and Classification of Mean Severity Scores



Note. The heatmap provides a clear visualization of the average heuristic severity scores (ranging from 1 [cosmetic violation] up to 3 [severe]) across categories, with darker shades of red showing the critical areas requiring immediate attention, while lighter shades indicate minor issues. High severity categories included Filtering, Clustering, and Pruning Information and Text Integration. Categories like Consistency and Standards, Data Density and Pre-attentive Field of View demonstrated lower severity scores, reflecting strengths such as cohesive design and intuitive menu systems with need for minor refinements.

While the heat map was useful in demonstrating further details on the categories of the mean scores, it does not provide detailed information on scores per category of general heuristics. To further break down the results of general heuristics, the stacked bar chart below was used to illustrate the distribution of severity scores across various general heuristic categories (Figure 6). Among the categories, Visibility of System Status had the highest cumulative count of severity scores, indicating it as the most problematic area. Similarly, Match Between System and Real World showed a high total count of violations, predominantly in the medium severity range. Conversely, categories like Error Prevention and Help and Documentation exhibited fewer violations across all severity levels.

Figure 6*Stacked Bar Distribution of Mean Severity Scores*

Note. This visualization highlights the variation in the frequency and severity of violations across different heuristic principles. Each bar is divided into sections corresponding to the severity scores, with darker shades representing higher severity levels. The x-axis lists the heuristic categories, such as Aesthetic and Minimalist Design, Consistency and Standards, and Recognition Rather Than Recall. The y-axis represents the count of severity scores within each category.

Discussion of Findings

In evaluating the usability of the system, a dual-heuristic approach was employed, combining general and visual heuristics to provide a comprehensive perspective on the interface. The study was carried out over one month, with the aim of analyzing the system using a broader

lens by integrating both general and visual heuristics. This combined approach successfully identified usability challenges while also highlighting the system's strengths.

As noted earlier, multi-criteria decision analysis (MCDA) approach was utilised in, assigning severity scores to each heuristic category. MCDA approach provided systematic transparency and consistent decision making, ensuring a balanced approach to study in areas with multiple violations (Takhar et al., 2024). The mean scores were assigned to translate qualitative observations into quantifiable data, enabling an objective statistical analysis. These tools illustrated the distribution of violations and highlighted critical areas requiring attention.

In general, there were no catastrophic violations noted during evaluation level 4. For the most part, the system was able to convey visual interaction and display that it is comprehensible to the users. However, there were instances of a few violations that required further attention to improve the level of system interaction and visualization. The findings revealed significant strengths alongside areas requiring targeted improvements across various heuristic categories as follows:

Visibility of System Status

The Visibility of System Status category emerged as a high-priority area for enhancement, with a severity score of 3. The current system design does not offer priority alerts for residents requiring immediate action, potentially delaying critical responses. To address this, a redesigned dashboard should prominently feature a "Residents Needing Immediate Action" section, incorporating bold colors and concise text for emphasis.

Additionally, the logo's lack of a sleep monitoring context, as seen in Figure 7a, creates potential user confusion, which could be mitigated by incorporating a healthcare-related icon representing the functionality of the system. The absence of clear and consistent page headers

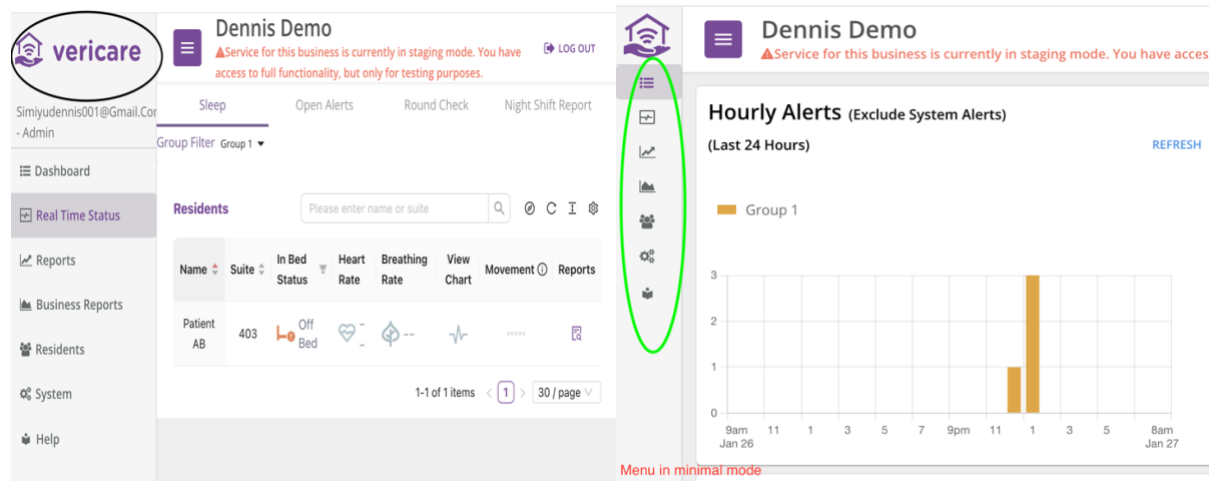
further complicates navigation, necessitating the addition of prominently displayed titles on each screen to improve user orientation. This also applies to the menu in minimalistic view (seen in Figure 7b), whereby the menu is shown in icons that lack corresponding descriptive text, which cannot be found even when hovering the cursor over the icons. It is recommended to provide an appropriate response when the menu is in minimalistic view mode, indicating the title on the icon when hovering cursor over.

Figure 7

Overview of Dashboard Logo and Menu Options in Minimalistic View

a)

b)



Note. Screenshots obtained from the dashboard view illustrate the main logo and menu display in minimalistic view.

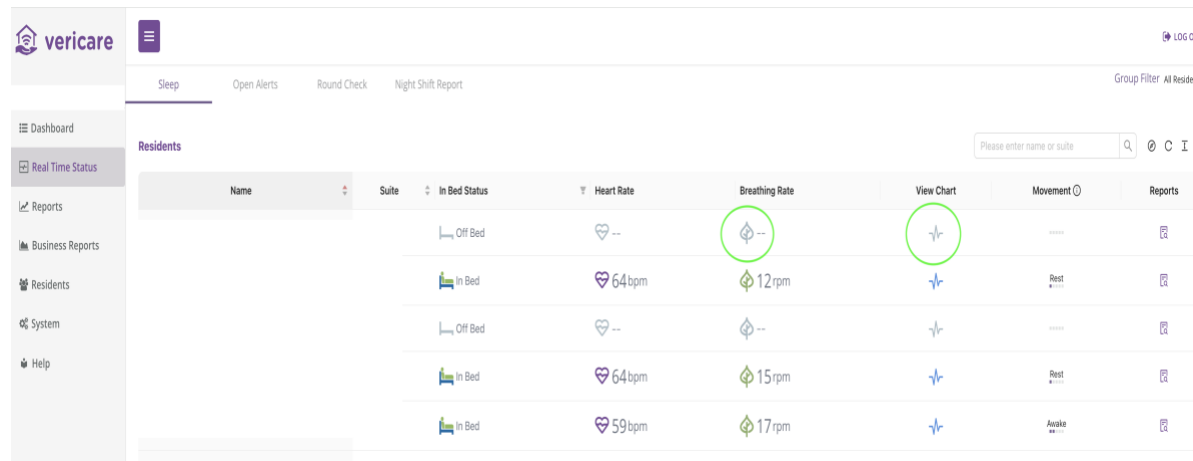
Match Between System and Real World

Several elements were misaligned with clinical conventions, earning a severity score of 2. For instance, as seen in Figure 8, icons such as a "leaf" for breathing and a "pulse" for charts lack clinical relevance. Replacing these with symbols like lungs or respiratory waveforms would

improve intuitiveness. Menu organization also presented challenges, as critical items like "Residents" were buried lower in the hierarchy. Moving frequently accessed items to higher positions and introducing customizable menu options are recommended to enhance usability.

Figure 8

Icons Lacking Relevance to Pertained Information



Name	Suite	In Bed Status	Heart Rate	Breathing Rate	View Chart	Movement	Reports
		Off Bed	--	--	+	---	
		In Bed	64bpm	12rpm	+	Rest	
		Off Bed	--	--	+	---	
		In Bed	64bpm	15rpm	+	Rest	
		In Bed	59bpm	17rpm	+	Awake	

User Control and Freedom

This category exhibited critical gaps, particularly the absence of undo/redo options and of confirmation dialogs for high-impact actions, contributing to an overall severity score of 2. There was a lack of visible "Cancel" buttons for operations in progress like fetching data (severity score of 3), which restricted user control (Figure 9). In the example below, the system is processing a synchronization to update resident information from point click care. When fetching data, there is no visible button or mechanism to cancel the operation if the user no longer wants to proceed or if the process is taking too long. It is recommended to include a visible "Cancel" button on the modal that allows users to stop the operation immediately. For example: "Cancel Fetch" can stop the fetching process and return the user to the previous state. Alternatively, adding a timeout mechanism in cases of prolonged inactivity may be considered (e.g., due to

network issues). The system can benefit from displaying a timeout message with options to retry or cancel, as seen below:

Figure 9

Absence of “Cancel” Button for In-Progress Operations



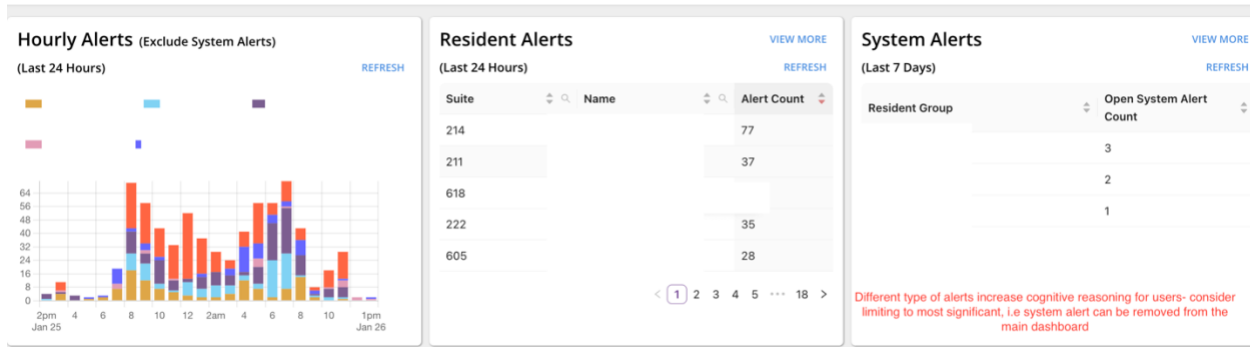
Note. Figure 9 demonstrates the lack of user control during fetch operations.

Recognition Rather Than Recall

The Recognition Rather than Recall category received a severity score of 3 due to ineffective use of white space and redundant alerts. As seen in Figure 10, poor spacing within sections, such as "Hourly Alerts" hampers readability and cognition as the data is overly clustered. Recommendations include redistributing white space to improve visual flow and consolidating redundant alerts like "Hourly Alerts" and "Alerts per Day" to streamline the interface and reduce cognitive load. Additionally, it may be useful to ensure that related components (e.g., resident alerts and system alerts) are visually closer, reducing the cognitive load of recalling connections between them.

Figure 10

Poor Spacing and Clustering of Data



Note. This figure shows clustered hourly alerts, which increases cognitive load and the number of alerts that can be consolidated which would reduce cognitive overload.

Aesthetic and Minimalist Design

Strengths in this category include the use of a clean color palette and concise field labels. However, missing tooltips for terms like "wellness alert" and redundant data presentations (severity score: 2) hinder usability. Adding tooltips or brief explanations for unfamiliar terms would aid new users, while consolidating overlapping charts would reduce visual clutter. Although the menu is at a minimal set with seven items, there is unnecessary splits of the reports to "reports and business reports". The two items could be consolidated with filter functionality.

Visual Heuristics

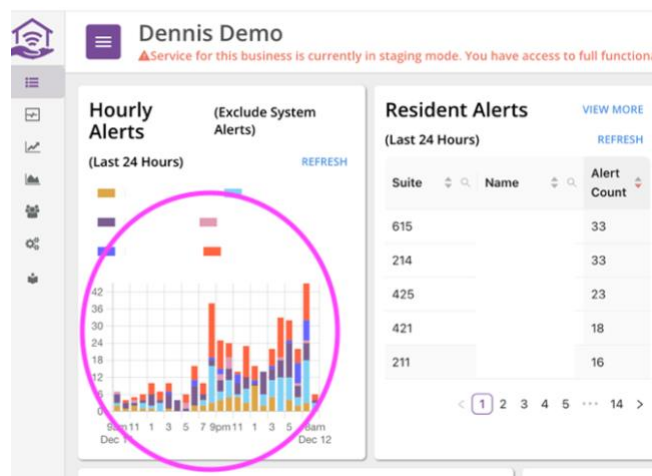
An evaluation based on Zuk and Carpendale's heuristics highlighted areas for visual improvement (Zuk et al., 2006). Bar charts effectively represented data but struggled with smaller variations due to limited bar lengths (severity score: 2). Dynamically scaling charts and allowing users to zoom into specific data ranges are recommended. Contrast issues were observed in smaller elements, such as gray text and short bars (severity score: 2), which could be

resolved by improving size, contrast, and adopting accessibility-compliant color schemes.

Additionally, graphics often lacked supplementary text or actionable insights, earning a severity score of 3. Figure 11 shows how integrating explanatory text and actionable recommendations near charts would enhance usability.

Figure 11

Cluttered dashboard with no explanatory text limiting visual interpretation.



Note. Figure 11 above shows bar graphs cluttered in main dashboard, smaller variation reduces data visibility at a glance, especially with no explanatory text.

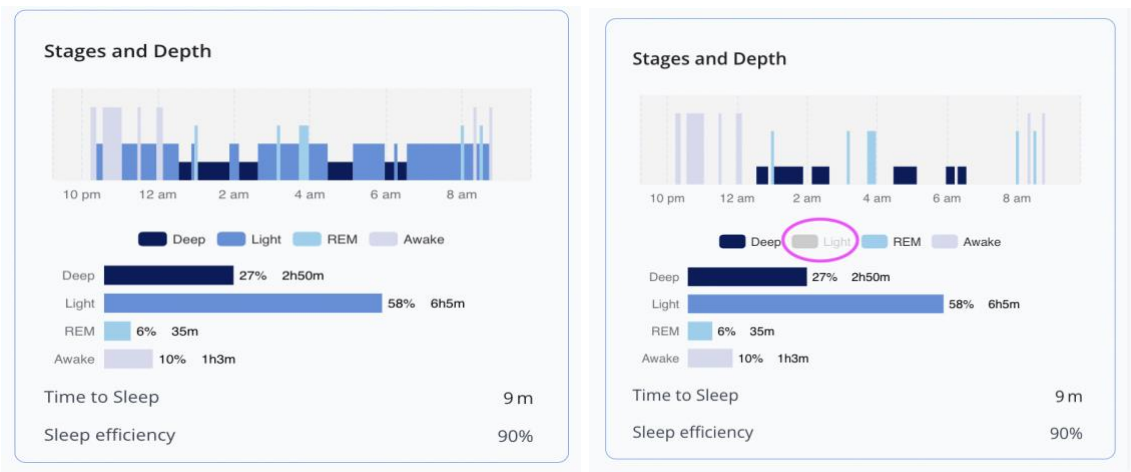
Filtering, Clustering, and Pruning

The system demonstrated visual interaction mechanisms in that were well implemented in certain areas, however other key areas suffered from minimal filtering and the clustering of tools. This deficiency resulted in a severity score of 3. Introducing dynamic filters, clustering by attributes, and pruning options to hide irrelevant data would significantly enhance the interface's visualization capabilities (Figure 12). Furthermore, these enhancements would ensure the interface aligns more closely with clinical workflows. This may serve to improve efficiency, user

satisfaction, and overall performance. The examples below show a well implemented visual filtering capability and where it also failed to be implemented.

Figure 12

Dynamic Filtering, Clustering and Pruning Options

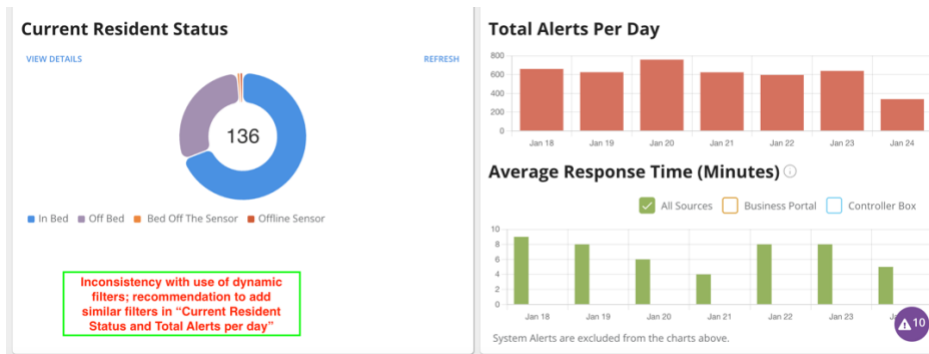


Note. This figure showcases a well-implemented filtering functionality. Sleep summary report with dynamic filtering options. Notably users can filter through the Deep, light, REM and Awake options well implemented.

As seen in Figure 13, there is a lack of consistency in the filtering functionality in other area such as total alerts where users can filter by type of alerts for the day. We recommend introducing dynamic filtering: “Add filtering tools” across all tables and charts to allow users to prune irrelevant data based on time ranges (e.g., last 24 hours, specific hours), categories or groups (e.g., specific resident groups or statuses).

Figure 13

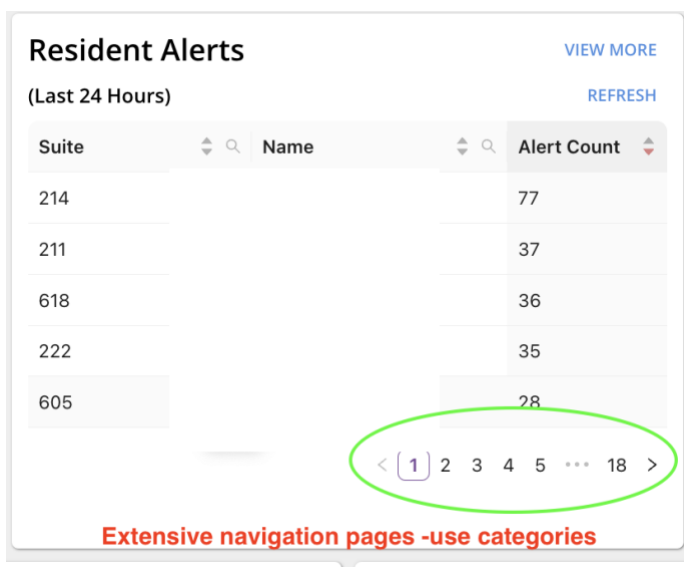
Observed Lack of Consistency in Filtering



The dashboard also fails to provide cluster functionality whereby the user can group residents in categories corresponding to their alerts. This makes it inconvenient to visualize data as the users must go through several pages of resident records to view resident data, as seen in Figure 14.

Figure 14

Lack of Cluster Functionality



The evaluation of the heuristic categories and visual heuristics highlight areas of strength and opportunities for improvement. Several categories had questions scoring at 0, indicating no violations or issues. These include aspects like avoiding menu overload, using clear and jargon-free language, ensuring consistent system behavior, maintaining effective use of core colors, providing clear menu titles, and ensuring cursor selection functionality. These areas meet expectations and require no immediate action.

For categories with a score of 1, there are minor issues that warrant improvement. For example, local contrast between elements could be enhanced by using darker shades of gray or increasing contrasts, which would improve visibility, especially for users with visual impairments.

Prominent features, such as alerts, could be made more noticeable with larger areas, borders, or shadows. In terms of menu organization, grouping items into broader and more intuitive categories and revising ambiguous menu titles, such as changing "System" to "System Settings," could significantly enhance usability. Similarly, using dynamic colors to highlight abnormalities and ensuring that tooltips or labels clarify complex terms would help make the system more intuitive and user-friendly.

In conclusion, most aspects of the design and functionality were found to be robust, focusing on these smaller adjustments—particularly in areas related to visual clarity, accessibility, and terminology. Table 2 presents a summary of mean severity scores in select heuristics categories, their strengths, weaknesses, and recommendations for improvement.

Table 2
Mean Severity Scores from a Sample of General and Visual Heuristics Categories

Heuristic Category	Strengths	Areas for Improvement	Recommendations	Avg. Severity Score
Visibility of System Status	Visual feedback for menus	Mis prioritized alerts; unclear logo and page titles	Redesign dashboard to highlight urgent residents; add healthcare icon to logo; use clear page headers	2.75
Match Between System & Real World	Limited menu items reduce cognitive load	Misaligned icons; poor menu hierarchy	Replace icons with clinically relevant symbols; prioritize key menu items; allow menu customization	1.2
User Control and Freedom	Effective prompts for specific actions	Lack of undo, cancel options, and confirmation for critical actions	Add undo/redo functionality; introduce confirmation dialogs; implement 'Cancel' buttons for processes	2.0
Error Prevention	Case-blind data entry	Missing safeguards for irreversible actions; insufficient error message guidance	Add confirmation dialogs for deletions; provide actionable buttons in error alerts	2.0
Recognition Rather Than Recall	Effective color-coding	Poor white space usage; redundant alerts	Redistribute white space; consolidate similar alerts (e.g., hourly/daily alerts)	2.0
Aesthetic and Minimalist Design	Clean color palette and concise field labels	Missing tooltips; redundant data presentations	Add tooltips for unclear terms; consolidate overlapping charts into a unified display	1.4
Consistency and Standards	Cohesive design, intuitive icons	Minor inconsistencies in secondary navigation menus	Align dropdowns and tabs with primary menu standards	1.0
Data-to-Graphic Dimensionality	Consistent representation of most data	Alerts lacked dimensional depth; limited graphical enhancements	Use icon size/variations to indicate alert urgency; add depth to graphical elements	2.0
Integration of Text & Graphics	Text clarity	Lack of supplementary text in graphics	Add labels or explanatory text near charts and visualizations	3.0
Filtering, Clustering, Pruning	Some static sorting capabilities	Minimal dynamic tools for user interaction	Introduce dynamic filters, clustering tools, and pruning options to customize displayed data	3.0

Summary of Recommendations and Clinical Relevance

By addressing both types of heuristics, the study achieved the evaluation of key aspects, providing a deeper understanding of the system's usability. Combining different types of heuristics is consistent with other studies that indicate the advantages of gathering more insight using a combination of heuristics compared to using general heuristics alone (Thyvalikakath et al., 2009).

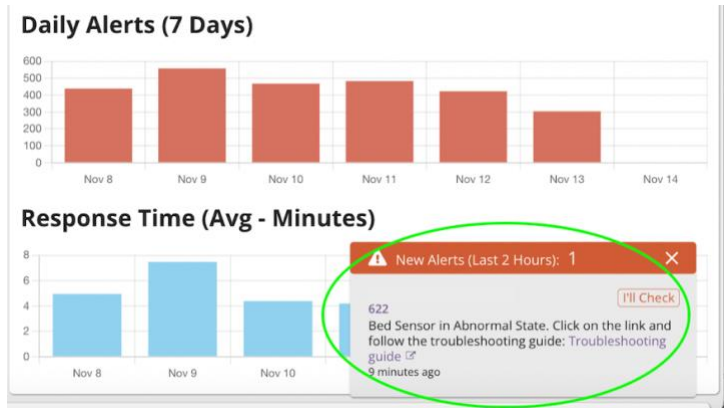
Key areas of concern included categories such as "Visibility of System Status" and "Match Between System and the Real World." In the former, mis prioritized alerts emerged as a high severity issue. Hourly alerts were given undue prominence over urgent resident needs, potentially delaying critical interventions. Additionally, unclear navigation cues, such as the absence of page headers and ineffective logo designs, added to user confusion. The study recommended to addressing these issues through redesigning the dashboard to emphasize urgent actions, integrating healthcare-relevant icons, and enhancing menu visibility through clear text or tooltips for minimalist icon designs.

In the category of "Recognition Rather Than Recall," clustered content and redundant alerts were identified as significant usability challenges, increasing cognitive load and hindering the user's ability to process information efficiently. This study proposed redistributing white space to improve visual flow, consolidating redundant alerts, and visually aligning related components to streamline the interface. Although these areas posed challenges, the system demonstrated notable strengths in other categories, such as "Consistency and Standards," where cohesive design, consistency with using four colours, and intuitive menus provided a robust foundation for usability.

Visual heuristics added an important dimension to the analysis by focusing on graphical representation and accessibility. While bar charts effectively displayed data, their limited bar lengths hindered the representation of smaller variations. Additionally, contrast issues in elements such as gray text and short bars were identified as barriers to accessibility. The study recommended dynamically scaling charts, improving contrast, and incorporating explanatory text near visualizations as potential measures to enhance user comprehension. The evaluation also identified critical gaps in areas such as "Filtering, Clustering, and Pruning," where the absence of dynamic tools restricted users' ability to filter or group data efficiently. Proposed solutions include implementing advanced filtering mechanisms, clustering tools, and pruning options to customize displayed data, thereby improving efficiency.

Clinical Relevance of the Findings

In healthcare environments, system usability directly impacts patient outcomes and operational efficiency. The mis prioritization of alerts in the system, as observed in this study, can delay critical interventions i.e., resident at risk vs hourly alerts, potentially endangering patient safety. Similarly, the phenomena of alert fatigue that may result with constant alerts when a resident is out of bed can inundate the users. In works by Horsky et al., the authors discussed how alert fatigue may contribute to users overriding alerts (Horsky et al., 2012). To address alert fatigue, the system may benefit from including a flexible customization setting to allow alerts in 15-minute or 1-hour intervals (as seen in Figure 15), or by filtering through only accepting alerts based on severity level i.e., synchronous interruptive alerts dedicated for high severity warnings (Horsky et al., 2012).

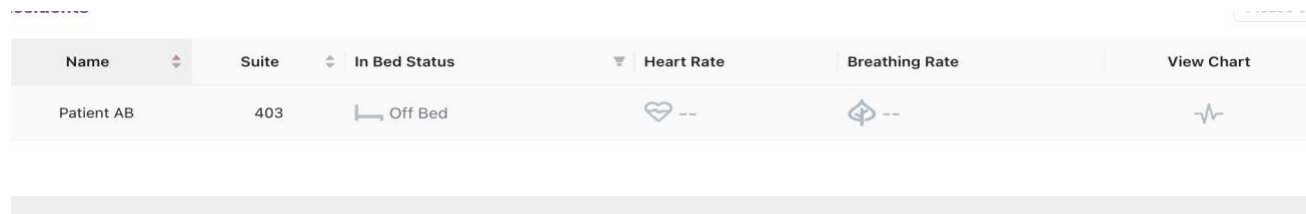
Figure 15*Alert Display at Designated Time Intervals*


Furthermore, a poor menu hierarchy, inflexibility and inefficient filtering mechanisms increase the cognitive load on healthcare providers, distracting from their ability to deliver timely responses. The system should allow users to create and customize their menu profiles according to their desired priority of use.

Improving visual tools, such as increase in whitespace distribution around key items, improvising dynamic clustering, and enhancing the background, can improve the system's visual outlook, which consequently improves information synthesis. Previous publications illustrate the importance of displaying information within the human eye readability light spectrum (380 to 700 nanometers), otherwise, humans would not be able to perceive the information being displayed if the visual display is below human detectability levels (Pruitt et al., 2023). In this work, we also highlight that the consequences of poor visual display are quite profound, and may lead to clinician burnout, diagnostic errors, and even patient harm. Looking at the example below in Figure 16, the user interface can lead to excessive straining due the limited contrast of the icons against the background color.

Figure 16

Poor Contrast Impacting Visual Display of Critical Information



Name	Suite	In Bed Status	Heart Rate	Breathing Rate	View Chart
Patient AB	403	Off Bed	--	--	

By addressing some of the challenges mentioned above, the system can better support clinical workflow, allowing providers to focus on patient care rather than navigating interface obstacles. Recommendations such as redesigning dashboards to emphasize urgent actions, allowing clinicians to customize the menu according to their preferred hierarchy, implementing dynamic filtering tools, and enhancing visual contrast, will align with these clinical priorities, highlighting the potential to enhance both user satisfaction and system effectiveness.

Limitations

Limitations of the Methodology and Findings

Despite its strengths, the study has encountered limitations that should be considered. Regarding methodology, one significant challenge was the interdependence of heuristics, where certain issues, such as limited filtering capabilities, were found to affect multiple categories. This has hindered the attribution of specific problems to individual heuristics. The sensitivity of the severity scale has also posed a limitation, as medium-severity issues (score = 2) often involved significant implications that were not fully captured. Moreover, the selection of evaluation questions based on different heuristics and the study trajectory introduced potential bias, as acknowledged in works by Carpendale, who highlighted the challenges in selecting an optimal heuristics checklist (Carpendale, 2008).

While a sample size of 77 questions across 18 heuristic categories provided valuable insights, it may not have fully captured the system's performance under diverse real-world conditions. Additionally, the study's one-time snapshot nature has limited continuous assessment and omitted feedback from clinicians as the product evolved. The scope was further constrained to the perspective of the author, and including other care teams in future studies could allow for more diverse insights. Lastly, the surface-level evaluation also failed to address potential workflow procedures that clinicians may find strenuous. Future studies exploring the dynamic facets of workflow processes will enhance overall understanding and provide a more comprehensive evaluation.

Future Recommendations

Future heuristic evaluations could adopt a multi-modal approach, such as cognitive walk-through methods and multiple evaluators approach, to gain a broader perspective on workflow usability. This multi-modal approach allows researchers to analyze real-world system interactions and identify usability challenges that traditional heuristic evaluations may overlook. Secondly, expanding heuristic criteria to reflect evolving user expectations is also essential. Modern interfaces require assessments of adaptive user interface elements, personalization, and accessibility features to ensure an intuitive and inclusive user experience.

Future heuristic evaluation metrics should also address AI-driven functionalities, such as explaining automated resident alerts. With AI playing an increasing role in healthcare systems, usability studies must assess whether AI-generated alerts provide clear, transparent explanations, such as detailing how risk levels are determined based on user sleep patterns. Ensuring clarity (through proper interface design) in AI decision-making enhances trust and system usability. We

believe that future heuristic studies can offer more comprehensive insights into improving interface design and user experience by integrating these considerations.

Conclusion

In summary, both general and visual heuristics were used to analyze the Sleep Sense system through a broader lens. By addressing both dynamic interaction and visual design principles, the analysis successfully identified areas for improvement while validating the system's core strengths. The use of visual tools such as heatmaps and histogram plots further emphasized the importance of presenting usability findings in an accessible manner, facilitating decision-making for stakeholders.

The study highlights the importance of a balanced approach to usability evaluation—one that integrates both interactive design and visual information presentation. By implementing the suggested refinements, the system can better align with user needs, ensuring a seamless and efficient experience for all stakeholders, particularly in clinical and operational settings. To meet current and future demands, future studies on system flexibility and enhancing user trust through thoughtfully designed interfaces that are well-suited for AI applications are recommended.

In conclusion, despite faced limitations, the findings in this study provide a clear roadmap for targeted refinements. Future evaluations may consider increasing the sample size, incorporating dynamic interactions, and refining severity metrics to current user needs, which can lead to enhancing the comprehensiveness of the analysis.

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Appendix

Appendix A: Ethics certificate of approval for the study.



**University
of Victoria**

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Certificate of Approval

PRINCIPAL INVESTIGATOR: Karen Courtney (Supervisor)	ETHICS PROTOCOL NUMBER: 24-0475 Expedited review - delegated
PRINCIPAL APPLICANT: Dennis Natembeya Master's student	ORIGINAL APPROVAL DATE: 08-Jan-2025
UVIC DEPARTMENT: Health Information Science HEIS	APPROVED ON: 08-Jan-2025
	APPROVAL EXPIRY DATE: 07-Jan-2026
<p>PROJECT TITLE: Evaluating a Remote Monitoring Sleep Interface in Long Term Care Using a Combined Heuristics Approach</p> <p>RESEARCH TEAM MEMBERS: Francis Lau - committee member, UVic</p> <p>DECLARED PROJECT FUNDING: None</p> <p>DOCUMENTS INCLUDED IN THIS APPROVAL: tcps2_core_certificate Pdf.pdf - 01-Nov-2024 signed Confidentiality_and_NonDisclosure_Agreement_Tochtech 1.0 copy copy (2) - signed.pdf - 07-Nov-2024 Screen shot for data collection.png - 07-Nov-2024 Letter from TochTech.pdf - 21-Nov-2024 Heuristic evaluation sample.xlsx - 25-Nov-2024 Combined Heuristics Questions word.docx - 31-Dec-2024</p>	

Appendix B: TCPS 2 CORE training certificate



Appendix C: Combined Heuristics Evaluation Table With Scores and Recommendations

	Subcategory / Detailed Criteria	Severity Score	Recommendations
Visibility of System Status	1.1 Hierarchy of content	3	Reconfigure the dashboard to prioritize a “Residents Needing Immediate Action” section at the top with clear visual cues.
	1.2 Logo visibility	3	Add a healthcare-specific icon to enhance the logo’s meaning for new users.
	1.3 Visual feedback in menus	2	Provide consistent hover feedback and add titles to icons in minimal menu mode.
	1.4 Screen titles or headers	3	Add clear page-level titles and place them consistently at the top of each screen.
Match Between System and Real World	2.1 Relevant metaphors	2	Use sleep-specific icons to avoid confusion with other clinical metrics like heart rate or respiration.
	2.2 Icons familiar to clinicians	2	Replace abstract icons with standard clinical ones (e.g., lungs for breathing rate).
	2.3 Shapes match clinical conventions	2	Align shapes with cultural expectations, such as using chest movement icons for respiratory rate.
	2.4 Colors correspond to clinical expectations	1	Increase contrast for muted colors and adjust icon colors dynamically to highlight abnormalities.
	2.5 Hierarchical structure balanced	2	Highlight critical sections like “Real-Time Status” for better visibility.
	2.6 Menu choices logically ordered	2	Reorganize menus to reflect usage frequency, moving “Residents” higher.
	2.7 Menu choices fit clear categories	1	Group menu items under broader, intuitive categories like “Resident Management.”
	2.8 Grammatically parallel menu titles	1	Expand ambiguous titles like “System” to “System Settings” for clarity.

	Subcategory / Detailed Criteria	Severity Score	Recommendations
	2.9 Limited menu items to avoid overload	0	No violation.
	2.91 Related fields grouped on the same screen	1	Maintain proximity of related fields for better usability.
	2.92 Language consistent with clinical terminology	2	Replace terms like “Suite” with more intuitive clinical terms like “Room Number.”
	2.94 Language clear and free of jargon	0	No violation.
	2.95 Paragraph conveys one idea	1	Add tooltips or labels to clarify terms like “Off-Bed Alert Window.”
User Control and Freedom	3.1 Marked exits	3	Add an exit or return option for the Help page to simplify navigation.
	3.2 User system and screen defaults	2	Introduce user preferences for system settings and customizable menus.
	3.4 System waits for user signal	0	No violation.
	3.5 Confirmation for drastic commands	2	Add confirmation prompts for irreversible actions like deleting resident data.
	3.6 Quick reversal of actions	2	Implement undo options and temporary restore buttons for accidental deletions or edits.
	3.7 Cancel operations in progress	3	Add visible “Cancel” buttons for long or unintended processes.
	3.8 Return mechanism for multi-level menus	2	Include breadcrumb trails or “Back” buttons for hierarchical navigation.
Consistency and Standards	4.1 Use of four core colors	0	No violation.
	4.2 Limited to four-seven colors	2	Use distinct colors for warnings and avoid overusing red to prevent alert dilution.
	4.3 Soft sounds for updates, harsh for alerts	2	Add sound customization options for regular updates and critical alerts.

	Subcategory / Detailed Criteria	Severity Score	Recommendations
	4.4 Same title format for data entry pages	0	No violation.
	4.5 Clear menu design standards	2	Ensure consistent design across all menus, including dropdown filters.
	4.6 Twelve-twenty unique icons	1	Use tooltips to clarify icon meanings and reduce the learning curve.
	4.7 Consistent icon design style	1	Align all chart-specific icons with the primary design style.
	4.8 Vertical menu choices	0	No violation.
Error Prevention	5.1 Logical and distinctive menu choices	2	Merge ambiguous menus like “Reports” and “Business Reports” under one category with submenus.
	5.2 Case-blind data input	0	No violation.
	5.3 Warning for potential serious errors	3	Add actionable buttons for resolving issues within alerts.
	5.4 Indication of character spaces in data entry	3	Add character limits and counters for fields like Suite Number.
	5.5 Default values in fields where applicable	2	Use placeholders for fields like “Date” to guide users on the required format.
	5.6 Clear and concise action prompts	2	Add hover cues for sections like “Health Watch” to explain their purpose.
Recognition Rather Than Recall	6.1 Prompts and cues where the eye looks	2	Add more descriptive labels or visual cues to charts like “Daily Alerts.”
	6.2 White space for symmetry	2	Add vertical white space between bottom panels like “Daily Alerts” and “Response Time.”
	6.3 Logical zones with clear headings	2	Move critical metrics like “Daily Alerts” to a more prominent position.
	6.4 Color highlighting for attention	1	Use consistent color prioritization to ensure clarity.

	Subcategory / Detailed Criteria	Severity Score	Recommendations
Flexibility and Efficiency of Use	6.5 Consistent color coding	2	Differentiate warning colors (e.g., orange vs. red) more distinctly.
	6.6 Section identification for alerts	2	Add brief descriptions or tooltips for alert types like “Safety” or “Wellness.”
	7.1 Simple and visible navigation	2	Allow horizontal bar navigation for more flexibility.
	7.2 Cursor selection for short menu lists	0	No violation.
	7.4 Option for keyboard shortcuts	2	Add a “Keyboard Shortcuts” section under the Help menu to guide users.
	7.5 Search box accessibility	2	Keep the search box visible across workflows and add keyboard shortcuts for easy access.
	7.8 Advanced options available	1	Allow users to save customized views for advanced personalization.
	7.7 Comprehensive results display	2	Add timestamps and tooltips for better data clarity and interpretation.
Aesthetic and Minimalist Design	8.1 Essential information displayed	2	Categorize alerts by severity to improve decision-making efficiency.
	8.2 Bold fonts and large objects for distinction	2	Highlight action buttons and critical sections with bold fonts and prominent colors.
	8.3 Brief, familiar, and descriptive field labels	2	Add tooltips for field labels like “Breathing Rate” for new users.
	8.4 Redundant data elements	2	Consolidate redundant charts like “Hourly Alerts” and “Daily Alerts.”
	8.5 Menu choice association with higher levels	0	No violation.
	8.6 Brief and communicative menu titles	0	No violation.
	8.7 Use of white space for symmetry	2	Redistribute white space for better readability in clustered items.

	Subcategory / Detailed Criteria	Severity Score	Recommendations
Help and Documentation	9.1 Visually distinct online instructions	2	Use hover feedback for Help menu icons to improve discoverability.
	9.2 Prompts for probable next actions	1	Add actionable buttons like “Resolve Alert” or “Follow Up” for unclear alerts.
Visual Heuristics	Visual variable length sufficient?	2	Scale bars dynamically for smaller variations and provide zooming functionality.
Ensure the Visual variable has sufficient length	Colored items large enough for perception?	2	Enhance size and contrast of smaller elements for better color perception.
Color Perception Varies with the Size of the Coloured Item	Sufficient local contrast between elements?	1	Use darker shades of gray and improve contrast for clearer visibility.
Local Contrast Affects Colour and Gray Perception	Prominent features sized for quick attention?	1	Highlight alerts with larger areas and distinct borders or shadows.
Pre-attentive Benefits Increase with Field of View	Data dimensions match graphic representations?	2	Add graphical elements like size variations or icons for better dimension representation.
Preserve Data-to-Graphic Dimensionality	Data density optimized without overwhelming users.	2	Optimize panel layouts to reduce pagination reliance and add trend data.
Put the Most Data in the Least Space	Are data visualizations compact, yet clear and informative?	2	Interactive elements (e.g., tooltips for exact values) would enhance informativeness without increasing space usage
Remove the Extraneous (Ink)	White space used effectively?	2	Add space between bars and charts for clarity. Use dividers where needed.
Insert Text Wherever Relevant	Text integrated with graphics for context?	3	Include graphical elements for text-heavy sections and add actionable insights alongside visualizations.
Provide Multiple Levels of Details (Interaction Mechanism in the Visual Evaluation)	Can users filter?	3	Add Dynamic Filtering Options across the dashboard for consistency.
	Cluster subset of data	3	Enhance table grouping.

Subcategory / Detailed Criteria	Severity Score	Recommendations
Prune data effectively?	3	Add advanced filtering, pruning, and clustering options across dashboards and charts