MONASH University

Faculty of Information Technology

Master of Business Information Systems

# Literature Review

## AR-Facilitated Clinical Handover Process in Intensive Care Unit (ICU) Department

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# 1. Introduction

The handover process in Intensive Care Units (ICUs) is critical for patient safety and continuity of care, which involves the transfer of complex medical data between shifts. Traditional methods like verbal reports and written notes are prone to errors and inefficiencies, especially in high-pressure ICU settings (Cheah et al., 2005; Kowitlawakul et al., 2015). Despite advances with electronic systems, issues like fragmented data and poor integration with Electronic Health Records (EHRs) persist (Ebright et al., 2004; Spooner et al., 2018).

The electronic systems have enhanced data organisation and accuracy; however, usability and integration have remained challenging (Strople & Ottani, 2006; Spooner et al., 2018). Recent research underlines that traditional tools and reduced screen size are most often associated with cognitive overload and communication errors (Thomas et al., 2017). AR technology can project digital information onto the real world and, therefore, helps address such issues by offering intuitive, detailed visualisations. These enhance data interpretation and team communication, as explained in Hilary (2021). Integrating AR would likely make ICU handovers more efficient and effective with a view to improving patient care and staff coordination.

This literature review critically examines the current state of ICU nurse handover software and assesses how advanced data visualisation technologies, particularly AR, might address existing problems. The review will primarily focus on the interaction of ICU nurses with data during handovers, the adoption of electronic systems, and AR's potential to enhance communication, lower cognitive load, and reduce errors.

The first section investigates the nurse handover process in ICU settings, identifying key issues with traditional handovers and the interaction between nurses and data. This section will explore how nurses engage with vast amounts of information, often under time constraints, and the limitations posed by current documentation tools. A critical review of how traditional handovers impact workflow efficiency and patient safety will provide a foundation for assessing the need for improved data visualisation solutions.

The second section examines existing data visualisation applications within ICU handover processes, focusing on the implementation of electronic systems. This section will analyse current technologies used for nurse handovers, particularly the usability and efficiency of electronic interfaces, and assess their integration with EHRs. Subsections will review specific electronic tools, highlighting their advantages and limitations and how these systems manage to support or hinder ICU workflows.

The third section focuses on AR technologies and their potential application in medical data visualisation. This part of the review will outline the current state of AR technology in healthcare, exploring how AR enhances real-time access to critical patient data. Special attention will be given to the benefits of AR in providing hands-free, immersive visualisations that reduce cognitive load during high-stakes handovers. The review will also address advanced visualisation techniques, such as embedded or situated visualisation, and the role of collaborative immersive analytics in supporting teamwork in ICU settings.

Following this literature review, the research project plan will outline a structured approach to testing and implementing AR technologies for the ICU nurse handover process. The first phase of the plan involves defining objectives that align with the key challenges identified in the literature. These include improving the accuracy and efficiency of handovers, minimising cognitive overload, and enhancing user interaction with patient data. The methodology will involve developing a prototype AR system tailored to the ICU context. The prototype will aim to provide intuitive visualisations of patient data, improve situational awareness, and streamline the transfer of information during nurse handovers.

The ethical considerations of implementing AR in healthcare will focus on ensuring responsible research practices, particularly when using de-identified patient data. While this mitigates privacy concerns, it remains essential to maintain strict protocols around data handling and usage. The research plan will also address the ethical implications of introducing new technologies in a clinical environment, ensuring that the study adheres to ethical guidelines on informed consent, minimising harm, and ensuring that the technology benefits both staff and patients.

By examining the current literature and outlining a comprehensive research plan, this review aims to provide a detailed assessment of how AR could revolutionise the ICU handover process. It addresses both the theoretical and practical aspects of implementing AR technologies, offering insights into how data visualisation advancements can improve patient care and support healthcare professionals in critical care environments. Ultimately, the findings of this review will contribute to the development of more integrated and intuitive solutions for ICU nurse handovers, guiding future research and technology implementation.

# 2. Substantive Literature Review

## 2.1 ICU Nurse Handover Process and Data Interaction

### 2.1.1 Nurse Handover Process in ICU Unit

Intensive Care Units (ICUs) provide specialised care for critically ill or injured patients, characterised by a high staff-to-patient ratio and advanced medical resources. A critical challenge in ICUs is the "ICU patient handoff" or "care transition," involving the transfer of patient care responsibilities from one team to another (Manias & Street, 2000). This process is essential for maintaining continuity and quality of care (Thurgood, 1995) and promoting positive team dynamics, morale, and cohesion among healthcare staff (Parker et al., 1992).

The handover process varies in execution, with communication quality differing widely. Common methods include verbal handovers, written notes, tape recordings, and pre-prepared patient details (Pothier et al., 2005). In ICUs, the process often involves integrating data from multiple sources such as vital signs, health records, and notes before presenting it to the incoming team (Ebright et al., 2004). This complexity makes transitions time-consuming and prone to communication errors, potentially extending patient stays and impacting care quality (Cheah et al., 2005). Existing methods like spreadsheets, paper notes, and electronic copies often fall short in coordinating care transitions effectively (Hoskote et al., 2017). Additionally, the use of smaller displays like tablets and smartphones can contribute to cognitive overload and hinder collaboration due to limited screen size (Thomas et al., 2017).

A study by Kowitlawakul et al. (2015) further highlights factors affecting the handover process, including distractions and interruptions, particularly during longer transitions. Electronic health records (EHRs) and checklists are often underutilised, leading to reliance on memory and paper records. Important information such as patient concerns and DNR status can be overlooked, indicating a need for improved communication practices (Kowitlawakul et al., 2015).

Lastly, inadequate communication between outgoing and incoming shift nurses has been linked to decreased safety, lower service quality, and increased patient dissatisfaction (Raeisi et al., 2019). Standardising the handover process could enhance nurse communication and care quality, as suggested by Carroll et al. (2012) and Raeisi et al. (2019).

### 2.1.2 Interaction of ICU nurses with data during the handover process

**Cognitive load and challenges**

In ICU settings, nurses allocate approximately 22% of their shift to interacting with Electronic Health Records (EHRs), involving the documentation and interpretation of both continuous data (e.g., vital signs) and static data (e.g., delirium detection) (Pinevich et al., 2021). This significant engagement presents a considerable cognitive burden, as nurses must absorb and synthesise large volumes of information during handovers. This complexity can lead to inefficient workflows, communication issues, and potential patient safety risks. Effective handovers require both outgoing and incoming nurses to rapidly process and integrate extensive information, intensifying cognitive challenges.

Galatzan & Carrington (2022) highlight that increased cognitive load during handovers, influenced by environmental factors and communication content, contributes to cognitive overload. This overload impairs nurses' ability to accurately recall and integrate critical patient information. Transforming individual data elements, such as blood pressure and respiratory rate, into actionable knowledge further adds to cognitive strain, impacting the accuracy and efficiency of the handover.

**Interaction with ICT Systems**

The interaction between humans and ICT systems significantly affects the quality of information transferred during handovers. Festila and Müller (2021) note that while human-human handovers offer essential contextual understanding, they often suffer from issues related to accuracy and completeness. Verbal exchanges, though immediate, can result in incomplete information due to limited clarification opportunities. Conversely, human-ICT handovers provide improved accessibility and consistency through standardised input mechanisms. However, the rigidity of ICT systems may lead to data that does not fully reflect clinical realities, causing potential inaccuracies. ICT-human handovers enhance accuracy through critical review but can be time-consuming and affected by information overload and access difficulties.

Understanding these interactions is crucial for improving continuity and quality of patient care in ICUs. Each handoff type has unique strengths and weaknesses that must be addressed to optimise information transfer and decision-making processes.

**Data Elements and EHR Interfaces**

Lindroth et al. (2022) identified key data elements vital for ICU nurses during patient handoffs, including hemodynamics, mechanical circulatory support status, laboratory results, continuous IV medications, code status, and ventilation status. These elements are crucial for understanding a patient's current condition and planning ongoing care (see Figure 1).

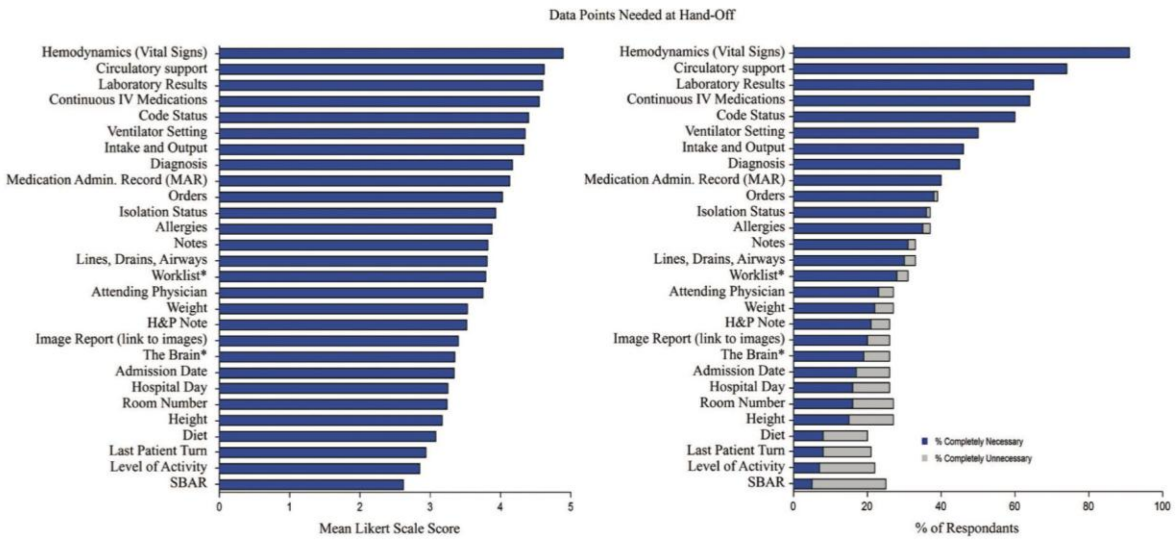



*Figure 1: Ranking of data elements needed for patient handoff for ICU according to the Likert's scale (left) and the necessity of each data element (right) for the handover process (blue as "Completely Necessary" and grey as "Completely Unnecessary") (Lindroth et al., 2022)*

Current EHR systems often present fragmented data, creating information silos that hinder comprehensive situational awareness and increase the risk of errors. Existing tools, typically relying on checklists or free-text entries, do not support effective integration and Visualisation of critical data. The study advocates for future EHR interfaces to incorporate integrated and visualised key data elements to enhance usability and reduce cognitive load. Adopting user experience frameworks and nurse-centered design approaches is recommended to develop interfaces that better support ICU workflows and decision-making.

## 2.2 Data visualisation applications for the ICU nurse handover process

### 2.2.1 Implementation of Electronic Systems for Nurse Handovers

The adoption of electronic systems for nurse handovers has become a significant trend as healthcare facilities aim to enhance the efficiency and accuracy of shift transitions. Research by Strople and Ottani (2006) and Randell, Wilson, and Woodward (2011) indicates that technologies such as electronic documentation, bedside documentation devices, and point-of-care tools can streamline and organise patient information, improving handover quality. Additionally, systems that enable junior doctors to input patient notes and task details while automatically generating patient lists with recent vital signs and laboratory values have been shown to be beneficial in enhancing the handover process (Van Eaton et al., 2005).

A notable research at Grady Memorial Hospital introduced a web-based handover application called WardManager that structured patient information, including demographic data, problem lists, medication lists, allergies, code status, historical illness data, team to-do lists, and handover tasks (see Figure 2). This approach led to a 50% reduction in perceived near-miss events, consistent inclusion of vital patient information, and increased resident confidence (Payne et al., 2012).

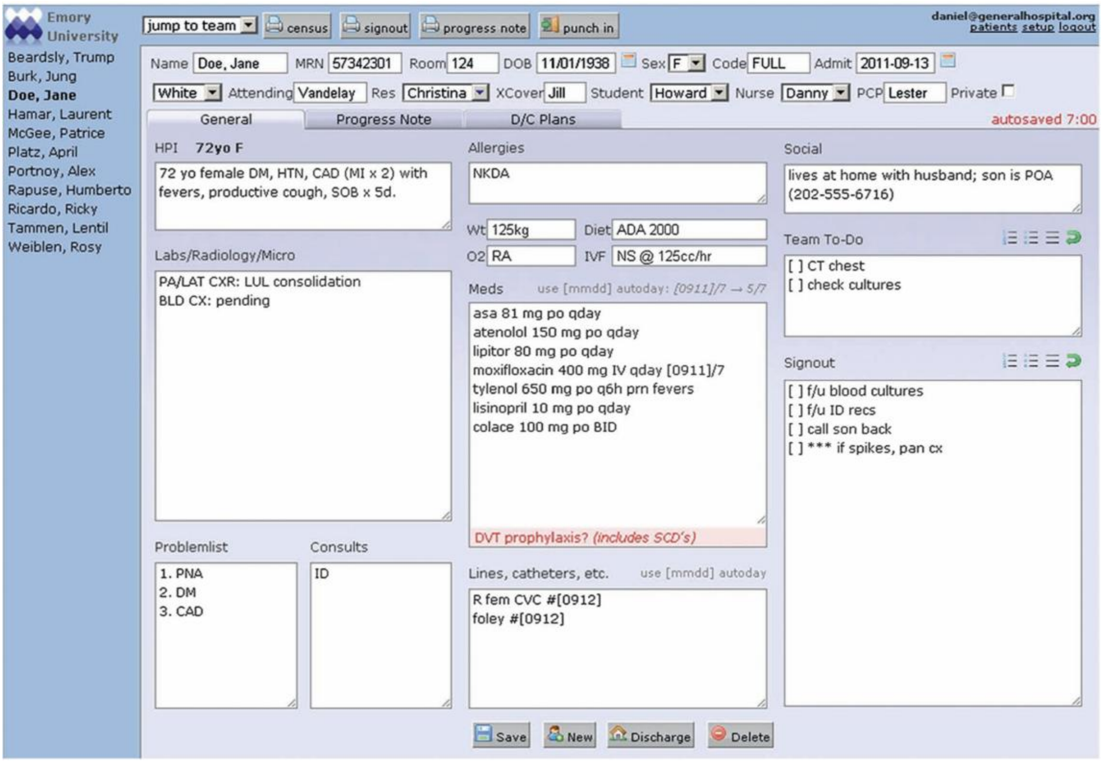



*Figure 2: Patient information entry dashboard on WardManager electronic handover system (Payne et al., 2012)*

Another study by Spooner, Aitken, and Chaboyer (2018) evaluated an electronic Medical Documentation System (eMDS) for ICU handovers using the Knowledge-to-Action (KTA) framework. Despite structured strategies like education, reminders, and feedback, the study found issues. After three months, eMDS was used by most team leaders, but key content was often missing, leading to additional documentation. Nurses receiving handovers had more positive views than those delivering them. Feedback indicated problems with the electronic interface, suggesting a need for usability improvements. The KTA framework was criticised for its lack of specific troubleshooting guidance. The study recommended integrating behavioral theories to address attitudes and improve knowledge translation. It also highlighted eMDS limitations, including integration issues and technical delays. Recommendations included making electronic tools flexible, user-friendly, and capable of integrating data from various sources, with adequate technical support for effective implementation.

### 2.2.2 Data visualisation interfaces used in the handover process

Research by Thomas, Kannampallil, Abraham, and Marai (2017) explored a web-based application designed for the ICU handoff process, addressing two main challenges: integrating multivariate data from various sources into a structured format and sharing aggregated information for meaningful discussion. The application used large display implementations with the assistance of personal displays to support collaboration through shared content, facilitating data-oriented conversations (see Figure 3).

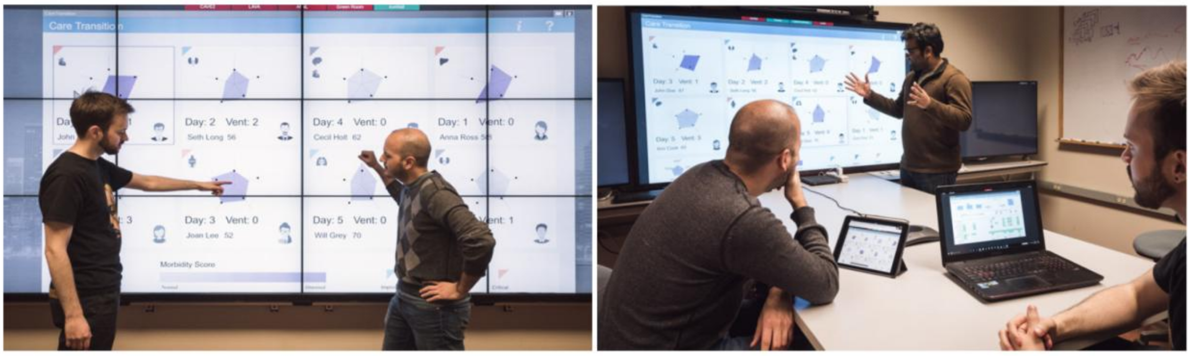


*Figure 3: (Left) Two testers collaborating on a common information space using Echo. (Right) A group of testers run Echo synchronously on a large display screen with additional personal displays (laptop and tablet for remote collaboration) (Thomas et al., 2017)*


*Figure 4: Card layout showing a summary overview of 8 patients in the ICU using Kiviat plot (Thomas et al., 2017)*

The first interface, Echo, provided data visualisations summarising key statistics, such as vital signs, morbidity scores, and medical conditions (see Figure 4). ICU nurses could quickly identify critical conditions through colour-coded indicators, and status glyphs highlighted whether patient health was improving or deteriorating (Thomas et al., 2017).

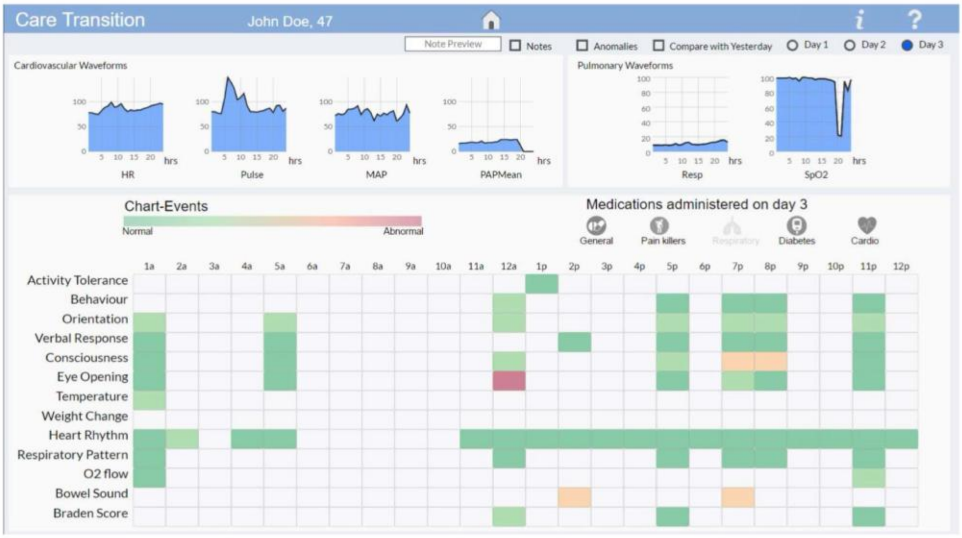
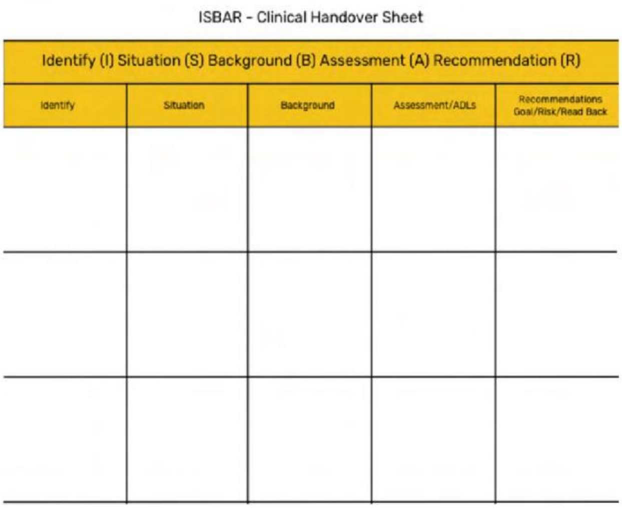



*Figure 5: Detailed view of individual patient (Thomas et al., 2017)*

The second interface offered a detailed patient view with waveform data for cardiovascular and pulmonary systems, a heatmap of frequently monitored events, and a summary of administered medications. It also included options to view notes, anomalies, comparisons, and historical data (see Figure 5) (Thomas et al., 2017).

The tool was tested with both naive users and experts, demonstrating its effectiveness in identifying trends, detecting anomalies, and improving communication during handovers. Experts praised its large display, patient card layout, and comparison features, noting its potential for both clinical use and training junior clinicians (Thomas et al., 2017).

Another study by Hilary (2021) found that using digital data visualisation dashboards (Figure 7,8,9) improved nurse shift handovers in terms of communication of essential information, efficiency, and overall satisfaction compared to traditional paper-based systems using the ISBAR communication tool (Figure 6). This indicates that electronic systems and data visualisation interfaces can significantly enhance the handover process, leading to better patient care and improved workflow efficiency in healthcare settings.


ISBAR - Clinical Handover Sheet

| Identify (I) Situation (S) Background (B) Assessment (A) Recommendation (R) | | | | |
|---|---|---|---|---|
| Identify | Situation | Background | Assessment/ADLs | Recommendations Goal/Risk/Read Back |
| | | | | |
| | | | | |
| | | | | |

*Figure 6: ISBAR paper prototype (Hilary, 2021)*

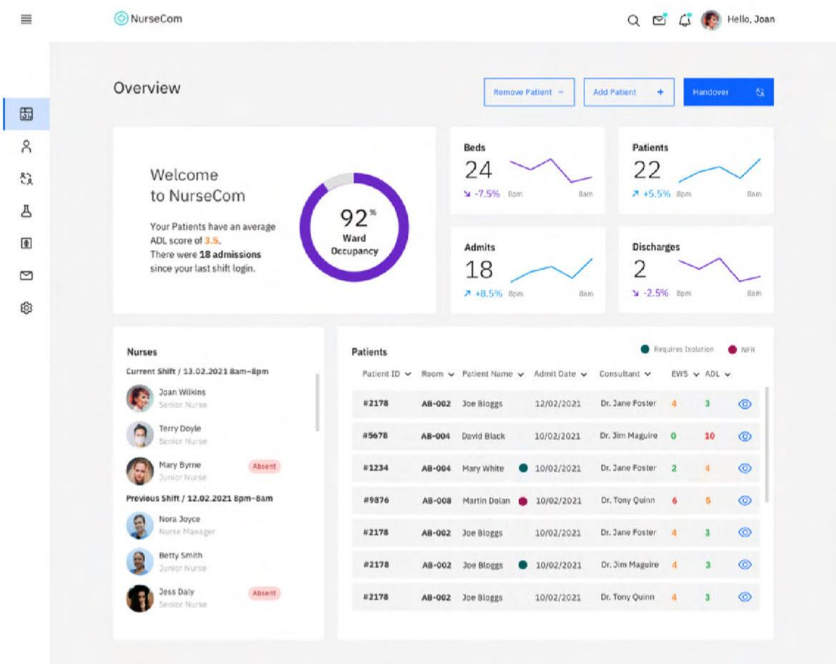



*Figure 7: Ward overview screen showing ward statistics, important tasks, nurses on duty, and patient profiles (Hilary, 2021)*

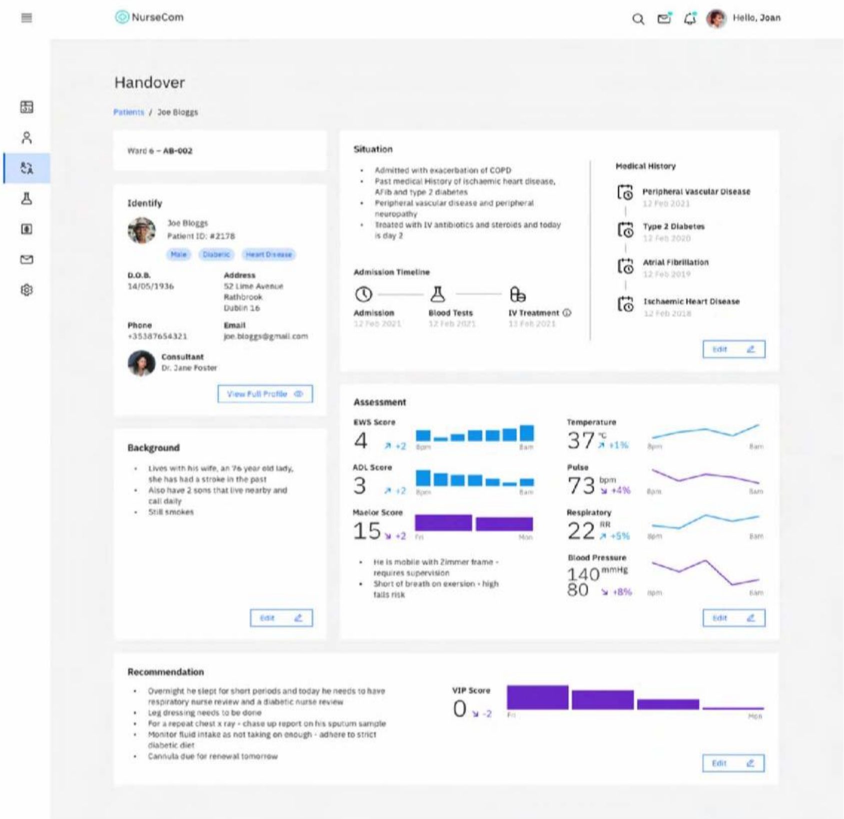



*Figure 8: Handover patient profile interface featuring the patient's medical history, admission timeline, personal information, records, and key statistics (Hilary, 2021)*

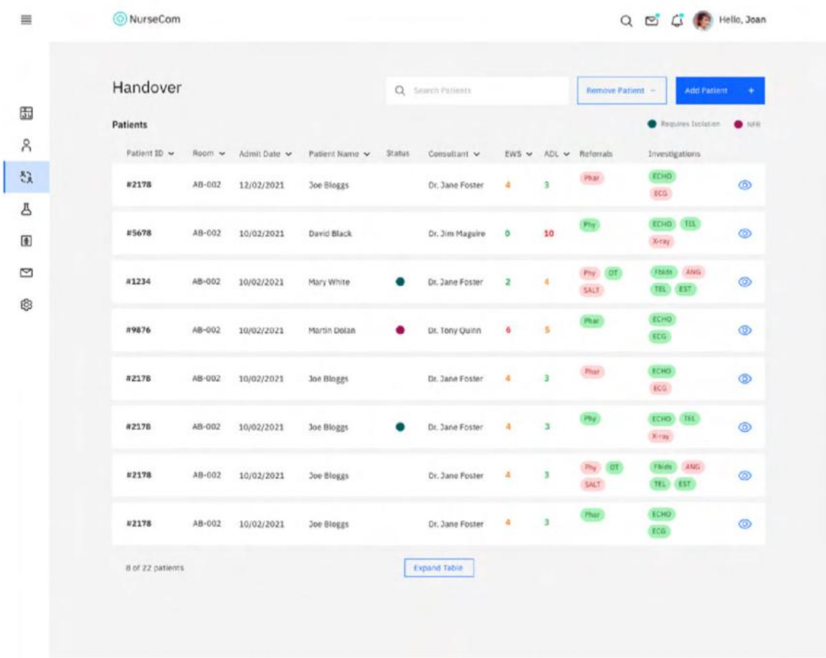



*Figure 9: Handover interface showcasing colour-coded scores, labels, patient status, and a search feature for quick access (Hilary, 2021)*

## 2.3 Augmented Reality applications for medical data

### 2.3.1 Current technologies in medical Augmented Reality

AR glasses offer transformative potential for nursing processes (Wüller et al., 2017). These devices enhance spatial usage and support hands-free tasks, timely execution, and sustained attention (Klinker et al., 2020). While AR's adoption in healthcare has focused on surgery and education, there is a growing body of research exploring its potential in other areas, such as nursing handovers.

Research into AR's role in data analysis highlights its benefits. Wang et al. (2020) demonstrated that AR, using Microsoft’s HoloLens, can significantly improve data exploration and understanding in particle physics. This suggests similar enhancements could apply to nurse handovers by providing immersive, interactive patient data visualisations. Such integration could complement traditional documentation, boosting handover efficiency and accuracy.

However, challenges such as AR input methods and device usability are crucial. Wang et al. (2020) identified the need for intuitive interaction techniques and specialised devices, which are essential for creating a practical AR system for nursing. Solutions like touch controls or voice commands could address these concerns and enhance usability.


*Figure 10: Screenshots from the prototype (Gansohr et al., 2024). Image (a) displays the most recent recorded status. The top button allows users to access the specific steps in wound care and documentation as outlined by the nursing staff involved. In (b), the nurse adjusts the window to the preferred position for their task. Image (c) demonstrates how a new pain score is recorded, while (d) shows the activation of an additional window for documenting the wound stage.*

Recent studies on AR in wound management also provide relevant insights for handovers. Albrecht-Gansohr et al. (2024) explored AR glasses for wound care using a HoloLens 2 prototype (see Figure 10). Developed with nurse input, this system offers hands-free access to real-time data, improving work conditions and care quality. The AR glasses' hands-free nature enables nurses to focus on patient care while accessing critical information, thus streamlining the handover process and reducing the cognitive load (Albrecht-Gansohr et al., 2024).

The integration of AR glasses in nursing holds significant potential for improving handover efficiency and accuracy. By providing interactive Visualisations and real-time data access, AR can enhance workflow and reduce cognitive load. Insights from data analysis and wound care research highlight the importance of user-friendly AR systems tailored to nursing needs. As AR technology advances, its potential to revolutionise healthcare practices and improve patient care continues to grow, making it a promising area for future research and development.

### 2.3.2 Benefits of Augmented Reality Data Visualisation

**Minimising Cognitive and Information Overload**

Research highlights AR as a powerful tool for reducing cognitive and information overload, particularly through improved data visualisation. For example, Millais, Jones, and Kelly (2018) found that virtual reality (VR) outperformed 2D visualisations by reducing perceived performance workload and increasing user satisfaction. Users of VR, despite its requirement for more physical movement, reported fewer inaccuracies in their insights, likely due to enhanced engagement and detailed analysis (see Figure 11). This suggests that AR, akin to

VR, could similarly improve user experience and accuracy through immersive, interactive visualisations.

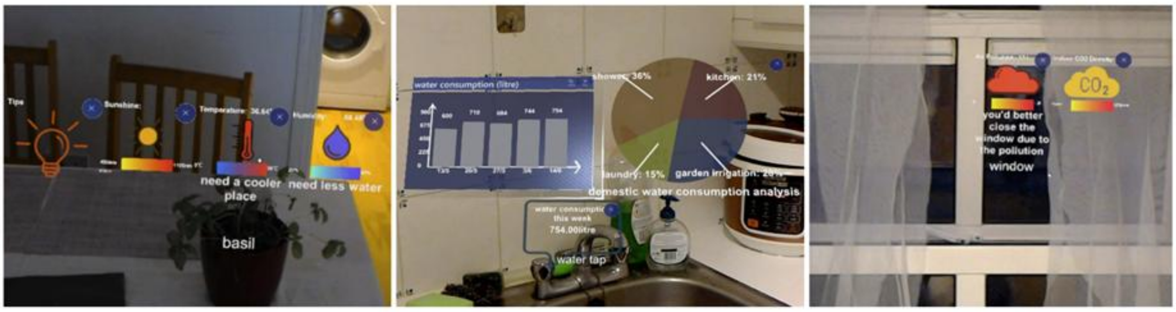



*Figure 11: Enhance physical objects by overlaying relevant data along with brief, actionable suggestions to provide instant, explainable decision support (Zheng et al., 2022)*

The STARE framework, which integrates AR technology into smart home decision support systems, underscores AR's potential to manage information overload effectively (Zheng et al., 2022). By focusing on pertinent data and minimising distractions, AR systems like STARE enhance decision-making efficiency. In the context of ICU nurse handovers, AR could facilitate access to real-time, contextual information, crucial for efficient transitions between shifts.

**Practical Considerations and User Satisfaction**

The STARE study found that user satisfaction with AR did not significantly increase, underscoring the need to integrate AR into existing workflows without adding cognitive or physical burdens (Zheng et al., 2022). In ICU settings, AR systems must be user-friendly and seamlessly integrate with current practices to be effective and accepted by staff.

A review by Buchner, Buntins, and Kerres (2022) of 58 studies found that AR generally imposes less cognitive load compared to other technologies and can enhance performance. AR reduces the cognitive load during handovers by presenting information visually and contextually, allowing nurses to focus on critical details rather than recalling or manually accessing information.

Integrating AR into ICU nurse handovers offers significant potential to improve data presentation, reduce cognitive load, and minimise information overload. Future research should explore practical applications in clinical settings, focusing on hardware ergonomics, system integration, and the overall impact on nurse efficiency and patient care.

## 2.3.3 Embedded/Situated Visualisation

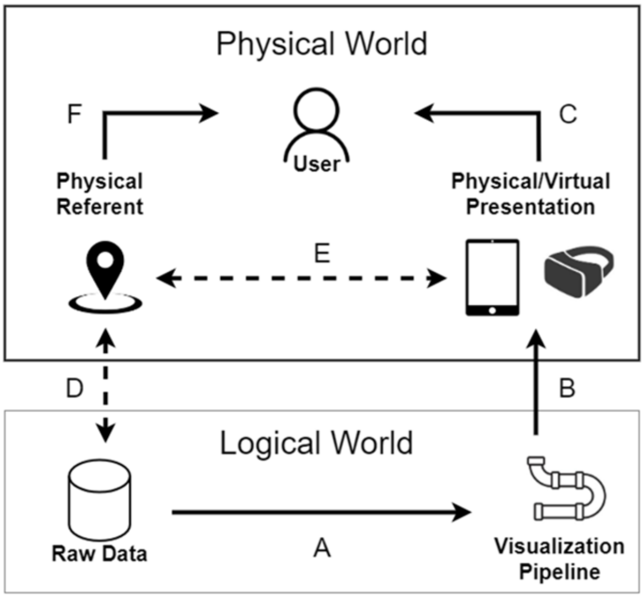



*Figure 12: The classical spatial SV model demonstrates the pathways through which information is processed and transmitted before being delivered to the user (Martins et al., 2023).*

Embedded or situated visualisation has gained recognition for its ability to enhance data representation in real-world settings, particularly within healthcare. Unlike traditional visualisation methods, which present data separately from physical contexts, embedded visualisation overlays data close to their physical referents, improving alignment and perception (Willett et al., 2016; Figure 12). This approach is particularly advantageous in clinical settings where real-time decision-making is crucial (Martins et al., 2023).


*Figure 14: Case studies (C1) Corsican Twin; (C2) Situated Glyphs; (C3) Cairn, (C4) Chemicals in the Creek; (C5) Activity Clock; (C6) Public Polling Displays (Bressa et al., 2021)*

A detailed study by Bressa et al. (2021) sheds light on the effectiveness of embedded and situated visualisations. Key insights include:

1. **Spatial Perspective**: The Corsican Twin (C1) project illustrates the importance of maintaining spatial integrity when transitioning from virtual to physical environments.

In healthcare, positioning data near relevant locations—such as patient bedsides and medical equipment—can significantly enhance decision-making speed and accuracy.

2. **Temporal Perspective**: The Activity Clock (C5) highlights the benefits of real-time data presentation. Minimising delays in data visualisation allows users to process and act on information promptly, which is critical in high-stakes environments. This immediacy helps in timely interventions and reduces errors from outdated information.

3. **Place Perspective**: The Public Polling Displays (C6) study demonstrates that tailoring vsualisations to specific locations increases their relevance and user engagement. Contextually appropriate and accessible information enhances usability in various healthcare settings.

4. **Activity Perspective**: The Situated Glyphs (C2) study shows that integrating context-aware displays into daily activities can reduce cognitive load and streamline workflows. Embedding visualisations into routine tasks supports more efficient and informed decision-making.

5. **Community Perspective**: The study emphasises the importance of customising technology to team needs. Involving healthcare professionals in the design process, as seen in projects like C4 and C6, can reduce cognitive load and improve efficiency. Similarly, integrating AR into ICU workflows can enhance handovers by tailoring tools to support healthcare professionals' activities.

These insights suggest that leveraging spatial, temporal, place, activity, and community perspectives can lead to more effective visualisations in healthcare, improving situational awareness and the accuracy of information transfer during critical processes like ICU handovers.

### 2.3.4 Collaborative immersive analytics

Recent research underscores the potential of augmented reality (AR) and virtual reality (VR) technologies to enhance ICU nurse handover processes, improving collaboration and efficiency. Studies by Cordeil et al. (2016) and Lee et al. (2020) demonstrate that shared VR environments can effectively foster communication and organise visual data on virtual walls, aiding both presentation and analysis.

Chen et al. (2021) further support the advantages of collaborative immersive environments. Their research shows that VR-based tools improve task performance and learning outcomes, particularly when used in pairs. This indicates that similar AR technologies could enhance decision-making in ICU settings by facilitating teamwork and increasing efficiency.

Engagement patterns in immersive settings highlight that shared interactive views improve communication and coordination. Participants in shared view environments exhibited higher engagement, effective task division, and proactive collaboration compared to those in non-shared setups. These findings suggest that AR visualisation could significantly boost nurse communication and coordination during handovers.

The arrangement of participants within immersive environments is also crucial. Research shows that side-by-side positioning (Figure 15a) is more effective for communication and task performance than back-to-back arrangements. Applying this principle to AR design for ICU handovers could enhance collaboration and satisfaction among nurses by ensuring clear visibility and intuitive interaction.

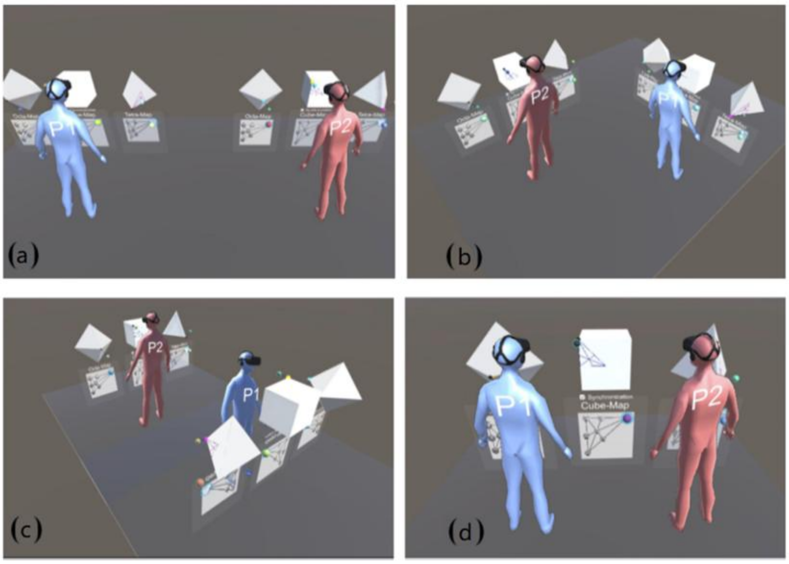



*Figure 15: The spatial configurations for immersive collaborative analytics include: (a) side-by-side, (b) corner-to-corner, (c) back-to-back, and (d) public workspace. Arrangements (a-c) can be utilised by both shared and non-shared users, whereas (d) is exclusively for shared groups (Chen et al., 2021)*

Recent insights from Tong et al. (2023) on asymmetric collaborative Visualisation reveal that combining VR with spatial sensemaking and PC with typing functions can balance the strengths of each device. Asymmetric setups, like PC-VR, maintain task performance and reduce mental load for PC users, as VR users manage comprehensive spatial views. This division of roles and integration of awareness cues can improve communication and efficiency, making asymmetric collaboration a promising approach for AR applications in healthcare.

In summary, integrating AR Visualisation into ICU nurse handovers can leverage features that support collaboration, enhance engagement, and optimise interaction arrangements. The positive impacts observed in immersive environments suggest that AR technologies could significantly improve the efficiency and effectiveness of critical healthcare processes.

# 3. Summary of the State of the Art

The integration of augmented reality (AR) technology in ICU nurse handovers represents a promising advancement for addressing the persistent challenges in this critical process. Traditional handover methods and electronic systems have shown limitations in usability and data integration, which contribute to inefficiencies and heightened cognitive burden for nurses (Pinevich et al., 2020; Cheah et al., 2005). This summary evaluates the current state of AR applications in healthcare, identifies gaps in traditional handover tools, and explores the potential of AR to enhance data integration, alleviate cognitive load, and improve the efficiency of ICU nurse handovers.

**Key Findings:**

Handovers by ICU nurses are complex, requiring the integration of extensive data such as patient history, vital signs, and treatment plans (Pinevich et al., 2020; Ebright et al., 2004). Traditional methods, including verbal reports and written notes, are prone to communication errors and inefficiencies, impacting patient safety and care quality (Cheah et al., 2005). Relying on outdated tools like spreadsheets and paper records contributes to cognitive overload, especially with fragmented data in Electronic Health Record (EHR) systems (Thomas et al., 2017; Hoskote et al., 2017).

Existing electronic systems for nurse handovers face usability and integration challenges. Studies by Kowitlawakul et al. (2015) and Pinevich et al. (2020) reveal that these systems often struggle with seamless EHR integration and lack user-friendly interfaces. Traditional electronic documentation can be cumbersome, leading to incomplete information and inefficient handovers. Spooner, Aitken, and Chaboyer (2018) found that the eMDS system, despite its structured format, suffers from missing content and interface difficulties, reducing its effectiveness. These issues underscore the need for more intuitive and integrated solutions to improve the handover process.

Recent research suggests that AR technology could significantly enhance healthcare, particularly in nursing. AR glasses enable hands-free operation, timely task execution, and improved focus (Wüller et al., 2017; Klinker et al., 2018). Although AR has shown effectiveness in surgical and educational contexts, its application in ICU handovers is still underexplored. Studies indicate that AR could enhance handovers by providing immersive visualisations of patient data, potentially improving accuracy, reducing cognitive load, and minimising information errors (Wang et al., 2020; Albrecht-Gansohr et al., 2024).

**Proposed Research Contributions:**

This research aims to bridge these gaps by developing and evaluating an AR application specifically designed for the ICU nurse handover process. Building on existing AR technologies and healthcare research, the project will:

1. **Design and Develop an AR Solution Prototype:** Create an AR system prototype to enhance the ICU handover process, incorporating real-time data visualisation, patient history access, and interactive features to support nurse communication and decision-making.

2. **Evaluate Effects on Cognitive Load, Usability and Integration:** Assess the AR system's usability and impacts on user's cognitive load within the ICU setting, focusing on data integration, workflow compatibility, and user feedback from ICU nurses.

By addressing these areas, the research seeks to establish a new standard for AR use in critical care environments, aiming to improve the quality of ICU handovers and patient care. The introduction of AR in this context promises to enhance information transfer, reduce errors, and streamline communication among healthcare professionals.

# 4. Research Project Plan

This research initiative aims to enhance ICU nurse handovers through the development of an AR application. Building on advancements in AR technology, particularly AR glasses, the project will create a prototype to improve data visualisation and hands-free access to information during handovers. By integrating insights from recent studies on AR's benefits for data analysis and healthcare applications, this project seeks to optimise the efficiency and accuracy of nurse handovers. The focus will be on addressing usability challenges and leveraging immersive visualisations to streamline communication and reduce cognitive load, ultimately enhancing patient care and workflow efficiency.

## 4.1 Objectives

The primary objectives of this research are:

**Design and Develop a Prototype of AR Application for ICU Handover**: Develop an AR system that integrates with existing electronic health records (EHR) to enhance and streamline the ICU handover process. The system will be tailored to support ICU nurses by presenting real-time, relevant patient information in an accessible and intuitive format.

**Evaluate Effectiveness, Usability and Integration**: Assess the usability of the AR system within the context of ICU settings and its potential integration with current workflows and EHR systems. This will involve testing the system's effectiveness in reducing cognitive load, improving handover efficiency, and aligning with established clinical practices.

**Identify Challenges and Recommendations**: Explore the challenges encountered during the implementation of the AR system and provide actionable recommendations for future improvements. This includes addressing issues related to usability, data integration, and the practical application of AR technology in clinical settings.

## 4.2 Methodology

The research will use a co-design methodology, as advised by Bressa et al. (2021), involving stakeholders and end-users to ensure the AR system aligns with ICU nurses' needs. This collaborative approach is essential for healthcare innovations (Istanboulian et al., 2023) as it integrates user feedback into the system's development. By engaging ICU nurses and stakeholders throughout, the system is more likely to fit seamlessly into workflows, enhancing usability and effectiveness (Slattery et al., 2020). Clear communication and detailed documentation ensure shared understanding, while addressing behavioral engagement challenges will further improve user interactions with the AR system (Slattery et al., 2020).

### 4.2.1 Development of AR System

The AR system will be designed to assist ICU nurses during the handover process by providing real-time, contextually relevant information. The development process will include the following steps:

**Requirement Analysis:** Detailed analysis of the ICU handover process will be conducted to identify key information needs and pain points. This will involve reviewing existing literature and interviewing ICU nurses to gain insights into their workflows and challenges.

**System Design:** Based on the requirements gathered, the AR application will be designed. This will involve creating wireframes and prototypes to visualise the interface and interactions. The design will focus on integrating critical data such as patient history, hemodynamics, mechanical circulatory support status, laboratory results, continuous IV medications, code status, and ventilation status (Lindroth et al., 2022) into an AR interface.

**Implementation:** The AR system will be developed using appropriate technologies and frameworks. Unity3D will be used for the development of the AR application, leveraging AR development tools such as AR Foundation. Key features will include real-time data overlay, interactive elements, and data integration.

### 4.2.2 Data Collection and Analysis

**Interviews with ICU Nurses:** Semi-structured interviews will be conducted with ICU nurses to gather qualitative data on their experiences with the current handover process and their expectations for an AR solution. The interviews will focus on understanding their needs, challenges, and how an AR system might improve their workflow.

**Usability Testing:** The AR system will be tested in a simulated environment to evaluate its usability and effectiveness. Participants will perform typical handover tasks using the AR system, and their interactions will be observed and recorded. Feedback will be collected through questionnaires, follow-up interviews, and two key assessment tools: the System Usability Scale (SUS) and the NASA Task Load Index (NASA-TLX). The SUS will be used to gauge overall user satisfaction and perceived usability of the AR system, while the NASA-TLX will assess participants' perceived cognitive workload across six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration (Brooke, 1996; Hart, 2006). This data will provide insights into how the AR system impacts cognitive load and user satisfaction compared to traditional handover methods.

**Data Analysis:** Qualitative data from interviews will be analyzed using thematic analysis to identify common themes and insights. Usability testing data, including results from the NASA-TLX, will be examined to assess the system's impact on cognitive load, user satisfaction, ease of use, and handover efficiency. The NASA-TLX will provide quantitative insights into the cognitive demands of the AR system compared to traditional methods. The analysis will help determine the system’s effectiveness in improving the handover process and highlight areas for refinement.

### 4.2.3 Project Timeline

**Semester 1**

**Task 1: Literature Review (Weeks 1–8)**

Conduct a thorough review to identify gaps and challenges in the ICU nurse handover process. Focus on academic articles, case studies, and industry reports related to handovers and the role of AR. Assess existing AR applications in healthcare, identifying strengths and limitations to highlight areas where AR could improve ICU handovers.

**Task 2: Design interview questions and apply for ethics approval (Weeks 9-10)**

Create and finalise questionnaires and interview guides to gather insights from ICU nurses. Develop questions on communication, workflow, and challenges, ensuring clarity and relevance. Apply and obtain ethics approval from the Monash University Human Research Ethics Committee. Plan interview logistics, including participant selection, scheduling, and consent forms, to ensure consistent and ethical data collection.

**Task 3: Requirement Gathering and Analysis (Weeks 11-14)**

Conduct interviews with ICU nurses to identify requirements and challenges. Analyse the data to define precise AR system features that address identified issues and enhance the handover process. This analysis will guide the development of the AR prototype to align with real-world needs.

**Task 4: Learn Relevant Technical Skills (Weeks 9-14)**

Acquire technical skills for AR development, including Unity 3D and AR tools. Engage in tutorials, online courses, and practice exercises to build proficiency. Set learning goals and track progress to prepare for developing the AR system.

**Semester 2**

**Task 5: Design and Develop Prototypes (Weeks 1-6)**

Create wireframes and initial prototypes for the AR system. Develop these prototypes based on gathered requirements and seek feedback from supervisors and domain experts. Refine the designs to improve usability and ensure they meet the needs of ICU nurses.

**Task 6: Evaluation (Weeks 7-10)**

Test the AR prototype in a simulated ICU environment. Collect feedback from ICU nurses on usability and functionality through observations, questionnaires, SUS assessments, and NASA-TLX assessments to measure cognitive load. Analyze the data to evaluate user satisfaction, system performance, and the effectiveness of the AR system in supporting the handover process.

**Task 7: Data Analysis and Report (Weeks 11-14)**

Analyse interview and usability test data to draw conclusions. Prepare the thesis report, detailing the research process, findings, and recommendations for the AR system's implementation in ICU settings. Ensure the report is well-organised and clearly presents the research outcomes.

### 4.2.4 Ethics Considerations

In our research on developing an AR application for the ICU nurse handover process, ethical considerations are central to ensuring the integrity and impact of our work. Adherence to ethical standards is critical, particularly due to the sensitive nature of healthcare data and the involvement of participants in the study.

**ICU Medical Data Source:** Our research utilises the publicly available MIMIC-III dataset, which complies with HIPAA regulations. This dataset includes de-identified, multi-dimensional healthcare data from over 60,000 patients admitted to the critical care units of Beth Israel Deaconess Medical Center between 2001 and 2012 (Johnson et al., 2016). MIMIC-III provides rich temporal resolution with data such as lab results, electronic documentation, bedside monitor trends, and waveforms (Thomas et al., 2017). It also includes comprehensive information on demographics, vital sign measurements, and laboratory test results, procedures, medications, caregiver notes, imaging reports, and post-hospital discharge mortality. Importantly, all data in MIMIC-III is de-identified, ensuring that individual patient identities are confidential and protected.

**Informed Consent:** To ensure ethical conduct, all participants, including ICU nurses involved in interviews and usability testing, will be fully informed about the study's purpose, procedures, and potential risks. Consent will be obtained prior to participation, ensuring that participants are aware of their rights and can withdraw from the study at any time without penalty.

**Confidentiality:** The confidentiality of participants' personal information and responses is paramount. Data collected will be anonymised and stored securely to protect privacy. Only aggregated results will be reported to prevent any individual identification.

**Minimising Harm:** The study will be designed to minimise potential discomfort or disruption to participants' regular duties. Testing of the AR system will occur in a controlled environment to avoid interference with actual clinical workflows.

**Data Handling:** Data collected during interviews and testing will be managed in accordance with relevant data protection regulations. Secure storage and access protocols will be implemented to ensure the integrity and confidentiality of the data.

This methodology provides a comprehensive framework for developing and evaluating an AR system for ICU nurse handovers, ensuring that the system is effectively designed and tested while adhering to high ethical standards.

# 5. Conclusion

This research paper examined the application of Augmented Reality technology to enhance the ICU nurse handover process, identifying both its potential benefits and challenges. AR offers significant advantages, such as hands-free operation, real-time patient data visualisation, and the ability to streamline communication during handovers. Current AR implementations in fields like surgery and medical training demonstrate how the technology can improve workflow efficiency and accuracy, offering insights into how it could address key limitations in traditional nurse handover practices. Specifically, AR has the potential to reduce cognitive overload, enhance focus on patient care, and mitigate communication errors, which are critical during high-pressure ICU handovers.

The study emphasised the necessity of user-centered design principles to create an AR system that meets the specific needs of ICU nurses. Iterative testing in simulated environments and feedback from healthcare professionals play a crucial role in refining AR applications for this purpose. Challenges such as device usability, intuitive interaction techniques, and seamless data integration were also noted as areas requiring further attention to ensure the practical adoption of AR in ICU settings.

Future research should focus on continued refinement through usability testing, particularly in real-world ICU environments, and the integration of advanced interaction techniques, such as voice commands and intuitive gesture controls, to improve system usability. This project aims to contribute to the development of a more efficient, accurate, and reliable handover process using AR technology, ultimately enhancing patient safety and the overall quality of care in critical care settings.

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