Enhancing Rapid Response Systems in Australian Hospitals through Human-Robot Collaboration (HRC RRS)

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Content list

Synopsis

Rapid Response Systems (RRS), also called Medical Emergency Response Teams (MERT or MET), are a crucial component of Australian hospitals to detecting and preventing patient deterioration. They function by monitoring the vital physiological signs of patients and by deploying specialized responder teams with sophisticated equipment if certain trigger factors are met. However, many factors that impact contemporary health care delivery, such as resource scarcity, increasing patient complexity and special situations like pandemics necessitate innovative approaches to sustain and improve the efficacy of RRS. Our research project proposes to overcome these challenges by introducing a novel Human Robot Collaboration (HRC) into RRS, leveraging the power of Artificial Intelligence (AI) and Robotics to augment healthcare professionals' capabilities in detecting and responding to patient deterioration.

This document outlines the first phase of our research, which will focus on identifying and analysing the requirements and challenges for designing and implementing a successful HRC RRS within Australian hospitals. We will assess the technical capabilities of existing Robots and AI systems of utility in this sphere, and use quantitative methodologies to engage with healthcare professionals, patients, and other stakeholders to understand their expectations and concerns for HRC RRS. We also propose to evaluate the 'robot friendliness' of hospital designs to be able to safely operate HRC RRS and to analyse its psychosocial, economic and cultural impacts in addition to conducting a comprehensive review of relevant literature.

The outcomes of this research will aid in the development of a framework for designing and implementing a HRC RRS that combines the strengths of humans, AI-enabled systems and robots. The framework will include the formulation of performance metrics specific to HRC RRS, auditing methodologies and a regulatory framework for HRC RRS, aligning with the responsible use of AI and Robotics. The ultimate goals of the project are to integrate AI and robotics within a safe and effective framework to prevent patient deterioration, enhance patient experience and outcomes, to empower human responders in RRS, reduce human error and to explore a futuristic health delivery architecture which is scalable, positively impactful, and socially acceptable for patients, health providers, health planners, administrators, regulators and to the society at large. User experience design of AI and Robotic systems, including expression of clinically pertinent social traits such as empathy by autonomous agents participating in HRC RRS, could also be enhanced through our project.

Abbreviations and Acronyms

HRC – Human-Robot Collaboration

RRS – Rapid Response System

ICU – Intensive Care Unit

MET – Medical Emergency Team

MERT – Medical Emergency Response Team

MEWS – Medical Early Warning Score

NSQHS – National Safety and Quality in Healthcare Standards

AI – Artificial Intelligence

ML – Machine Learning

1 Introduction

The Australian Committee for Safety and Quality in Healthcare has made it mandatory for hospitals to implement systems for recognising and responding to deterioration as a National Safety and Quality Health Service Standard (Australian Commission on Safety and Quality in Health Care, 2017). The primary objective of RRS is to provide Intensive Care expertise to patients in general hospital wards who are experiencing clinical deterioration, with the aim of preventing unfavourable outcomes such as cardiorespiratory arrests or death (White *et al.*, 2015; Lyons, Edelson and Churpek, 2018).

Conventional RRS systems, as described by the College of Intensive Care Medicine of Australia and New Zealand (Boots *et al.*, 2016), consist of two primary components:

- **Afferent Limb**: A computerised or paper-based patient deterioration detection system that analyses recorded vital signs such as Heart rate, Respiratory rate, Blood pressure, Body temperature, Blood sugar levels, and clinical concerns.
- **Efferent (Responding) Limb:** A trigger mechanism for the RRS, also known as the MET (or MERT) call consisting of a hospital wide alert system for RRS responders, when such analysis points to a patient at risk of deterioration. The response involves:
    - Doctors, nurses and other RRS team members; and
    - Specialised equipment carried in a trolley, cart, backpack or bag comprising vital sign monitoring devices, resuscitative equipment, point-of-care invasive and non-invasive diagnostic technologies, emergency medications, audio-visual telecommunication tools, event recorders and electronic documentation systems.

While RRS interventions have proven to be effective in improving patient outcomes, their implementation can potentially impact the workload of healthcare professionals – particularly hospitalists, who are already carrying their own patient load during their shift (Benin *et al.*, 2012). Such additional workload impacts of RRS interventions are particularly concerning in light of the projected shortage of healthcare professionals globally in the near future reported by World Health Organization (WHO, 2022) and more specifically in Australia, which is facing a shortfall of over 200,000 full-time care workers by 2050 (National Skills Commission, 2020). The demand for care workers is expected to double within a generation, with a predicted gap in the workforce emerging earlier than expected due to the Covid-19 pandemic (National Skills Commission, 2020). As a result, the shortage of healthcare workers in Australia is expected to worsen, further exacerbating the high workload for existing healthcare workers. These statistics suggest an urgent need to find innovative solutions to sustain RRS in a safe and efficient manner, while minimizing the workload of healthcare professionals now and into the future.

With the recent progress in Artificial Intelligence (AI), biosensors, wearable technologies, and robotics, there exists an opportunity for these technologies to alleviate the impact of aforementioned challenges by taking on some of the responsibilities and duties of human healthcare providers in RRS. In contemporary human only RRS, the Afferent Limb components capture vital signs data and subsequent human (or digital) analysis is performed to trigger the

Efferent RRS limb's activation through communication systems. Emerging AI technologies could supplement or even supplant those current processes. For instance, wearable sensors can continuously monitor patients' vital signs and alert healthcare providers to any concerning changes, while Rule-based RRS activation systems (such as the Guardian ™ solution developed by Philips™) can autonomously trigger the Efferent limb activation.

The introduction of autonomous technologies into existing RSS systems and the broader healthcare environment may offer efficiencies and opportunities for improvement – but such potential benefits come with risks, including the possibility of significant unintended impacts on patients, the healthcare providers, existing workflow models and hospital design. They could also fundamentally alter patient-provider interactions, current diagnostic strategies, therapeutic options, and prognostication models. Hence, it is essential to develop and implement a comprehensive strategy for the integration of these technologies considering the human, organizational, and social dimensions of healthcare settings (Gleichauf, Schmid and Wagner-Hartl, 2022).

As an alternative to deploying fully autonomous technologies, designing these systems to work in collaboration with healthcare professionals is expected to be a more effective strategy for integrating these technologies into healthcare settings (Henry *et al.*, 2022). There has been an increasing focus on research exploring the potential benefits and challenges associated with related frameworks such as human-robot collaboration (HRC) (Ahmad, Stoyanov and Lovat, 2019; Alvarez, 2020; Chiriatti, Palmieri and Palpacelli, 2021). Therefore, this research proposes utilizing a human-robot collaboration framework as a means to successfully integrate innovative technologies into existing Rapid Response Systems within hospital environments.

The central hypothesis of this research project posits that HRC-enhanced RRS will alleviate the additional workload burden on human healthcare professionals, improve patient outcomes, reduce human errors and augment social acceptance of AI and robotics in acute health care.

This proposal represents the first stage of a larger research project aimed at user research, developing, testing, implementing and evaluating HRC RRS with a view of formulating a comprehensive HRC RRS framework. The current proposed study will explore the feasibility and acceptability of deploying HRC RRS in its early iteration using quantitative research methods for a safe and non-intrusive way to identify potential benefits and challenges by virtue of user feedback and stakeholder consultations. The insights gained will form the basis for subsequent stages of this research.

1.1 Literature review

The use of robotics in healthcare is an area of growing interest and development. Robots are being developed to assist with a variety of tasks in hospitals and clinics, from transportation to patient care (Kyrarini *et al.*, 2021). One example of a commercially available robot that is currently used in hospitals is Moxi, developed by Diligent Robotics (*Moxi*, no date). Moxi, shown in Figure 1, retrieves and brings supplies to hospital rooms and nursing stations, delivers samples to laboratories, and removes soiled linen bags.

Figure 1. Moxi developed by Diligent Robotics (Moxi, no date)

Another example is the dual-arm mobile laboratory robot called YuMi, demonstrated by robotics company ABB (ABB, 2019). YuMi (Figure 2) is designed to work alongside medical staff and lab workers. In Japan, the RIKEN and Sumitomo Riko Company Limited have developed an experimental nursing robot, called ROBEAR (Figure 3), which is capable of lifting a patient from a bed into a wheelchair or helping a patient to stand up (RIKEN, 2015).

Figure 2. Yumi developed by ABB (ABB, 2019)

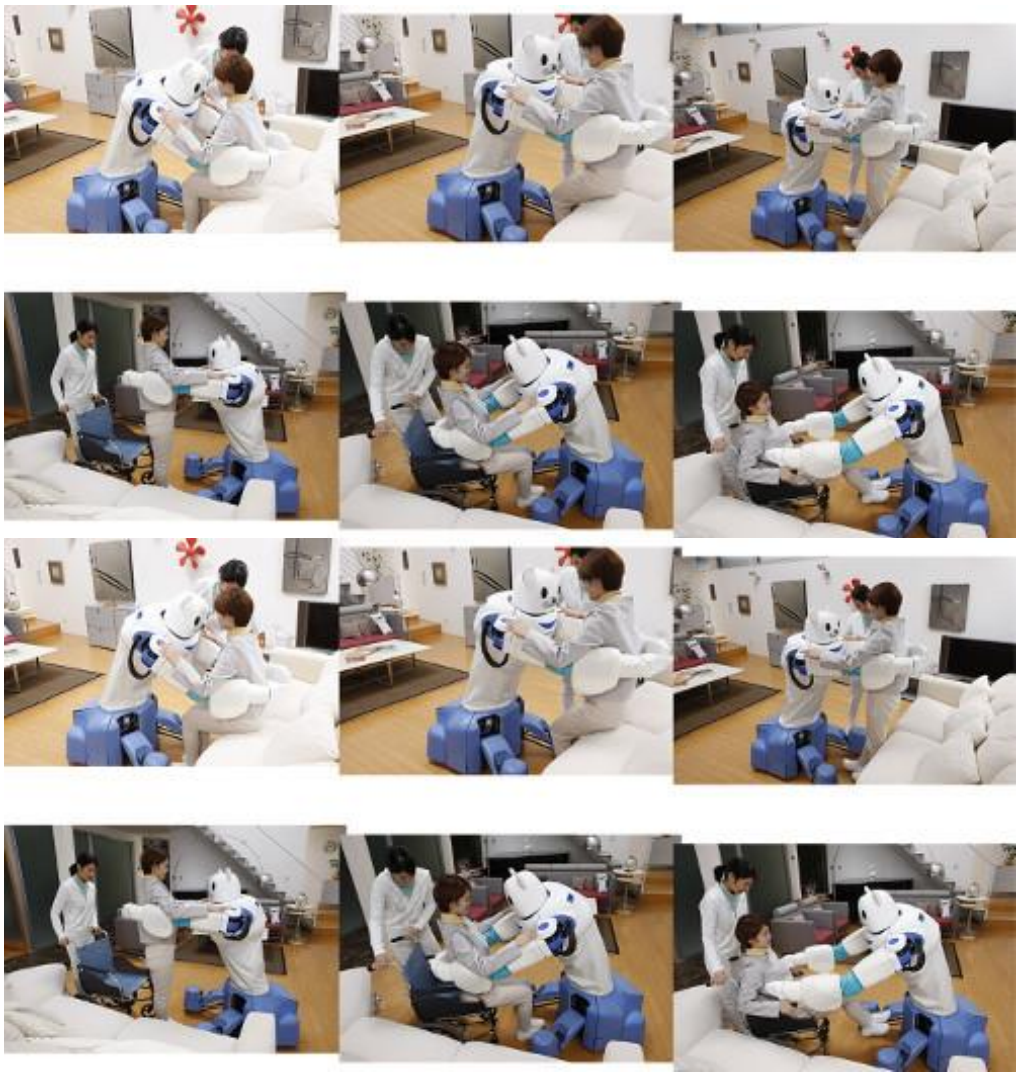

Figure 3. ROBEAR developed by RIKEN (RIKEN, 2015)

These commercial developments and the research backing suggest that it is feasible to integrate and AI-enabled robots in RRS to be of significant benefit.

1.2 Fully autonomous systems vs Human Robot Collaborations for Rapid Response Systems

While it may be tempting to use fully autonomous robots or AI-enabled systems to reduce the workload of humans involved in RRS, past research has shown that such fully autonomous systems can have several issues. These include brittleness, automation bias, decreased situational awareness, poor function allocation design, lack of transparency, skill degradation, and mis-calibrated trust (Bainbridge, 1983; Baxter *et al.*, 2012; Tokadlı and Dorneich, 2022). In particular, in a safety critical context such as healthcare, it is essential to keep the human in the loop to maintain a supervisory role in the care of patients. Despite the many advantages of autonomous systems, it is crucial to ensure that human judgment and decision-making remain

central to patient care (Budd, Robinson and Kainz, 2021). Human responders bring clinical knowledge and experience, critical thinking skills, and an ability to adapt to complex and unpredictable situations, all of which are necessary for effective patient care.

Building on the understanding that both human expertise and technological efficiency are vital in healthcare, the role of collaboration in Rapid Response Systems (RRS) becomes paramount. It is not just about the coexistence of humans and technology, but about how they interact effectively. Team members, whether human or augmented by technology, need to collaborate seamlessly to ensure that patient care is both well-coordinated and promptly delivered. This necessitates not only effective communication and teamwork but also a comprehensive understanding of each member's role and responsibilities, whether they are directly administering care or providing support. Such a collaborative environment ensures that the strengths of both human and robotic participants are utilized to their fullest, fostering a more resilient and responsive system in critical healthcare situations.

In this light, we advocate for a human-robot collaborative approach in RRS. This model combines the advanced capabilities of robots with the nuanced decision-making skills of human professionals (Semeraro, Griffiths, Cangelosi 2023). A key element in this approach is the use of collaborative robots, or "cobots," which are designed to work alongside human professionals, complementing their abilities and enhancing efficiency (Weiss, Wortmeier, and Kubicek 2021).

The implementation of HRC in healthcare, particularly within RRS, responds to urgent needs such as the rising demand for healthcare services due to an aging population and the increasing intricacy of medical tasks. By combining the precision, strength, and consistency of robotic systems with the critical thinking and empathetic aspects of human professionals, this collaboration aims to foster a more robust and efficient healthcare system. This symbiosis not only elevates patient care outcomes but also significantly enhances the professional satisfaction and well-being of healthcare workers, mitigating issues like professional burnout.

1.3 Literature gaps

Despite the potential benefits of human-robot collaborative teams in rapid response systems, there is still a significant literature gap regarding the effective integration of HRC into healthcare teams. There is a need for further research on how to design and develop robots that can collaborate seamlessly with healthcare professionals, ensuring that they are useful and reliable in real-world settings. In addition, there is a lack of understanding of the potential barriers to the integration of robots into healthcare systems, including issues related to acceptance, trust, and ethical considerations. As such, future studies need to investigate the attitudes of healthcare professionals towards the use of robots in healthcare, as well as the ethical implications of using robots in care provision.

Furthermore, there is a need for research on how to effectively train healthcare professionals to work with robots in healthcare settings. Training programs must be developed that equip healthcare workers with the necessary skills and knowledge to work collaboratively with robots, including communication and teamwork skills.

Another area of concern is the impact of human-robot collaborative teams on healthcare worker job satisfaction and workload. While robots may be able to perform certain tasks more efficiently than humans, it is important to understand how this affects the overall work environment and whether or not it leads to job dissatisfaction or burnout. Additionally, stakeholder perceptions of care provided by human-robot collaborative teams need to be better understood in order to ensure that patients and their families are comfortable with the use of robots in healthcare.

Implementation of novel health delivery models may, to a variable extent, future proof health systems from future pandemics and other unpredictable mass events which may paralyse conventional contemporary health care institutions. The impact of Human-Robot collaboration in this area has not been adequately studied.

Conventional health delivery still heavily relies on centralized large hospital models but with the ability to be integrated across the health care spectrum ranging from community-based services to in-hospital settings. Human-Robot collaborative models could potentially pave the way for a better distributed health care delivery models which could reduce health inequity particularly in regional, remote Australia and indigenous communities. Studies into this aspect are much needed.

Design of hospitals and other health care spaces could have a major impact when HRC models are deployed. These may include design of robot-friendly health spaces and development of design standards specific to this area.

The sociological aspects of Human-Robot collaboration--specifically the design of care provider robots taking into account clinically pertinent characteristics such as empathy and emotions—also need to be studied. Culturally sensitive user-experience design of such machines could aid in their effective integration and application in healthcare environments. This is a large area of research which must consider the needs of vulnerable communities and minorities in designing both the external appearance, functionalities and the artificial intelligent component of care provision Robots.

While it is feasible to hypothesize that Human-Robot collaboration could reduce harm in many ways, studies have to explore effective regulatory frameworks, legislation and insurance models that reduce risks for patients, health care providers and the hospital managerial personnel and to cover them for any harm that may ensue from Human-Robot collaborative models.

Finally, more research is needed to evaluate the cost-effectiveness of implementing human-robot collaborative teams in acute hospital settings. While there may be long-term cost savings associated with the use of robots, there may also be significant upfront costs associated with purchasing and maintaining the technology, and carrying out the training needed to integrate it successfully into hospital settings.

Addressing these research gaps will be critical in ensuring the safe and effective use of human-robot collaborative teams in healthcare settings.

1.4 Aims

The objective of this research is twofold: firstly, to explore the feasibility of creating a human-robot collaborative team for rapid response systems in hospitals, and secondly, to provide guidance for the design and development of a human-robot collaborative team for RRS. This includes determining the optimal team composition, architectural design, and AI-enabled technologies to be utilized, as well as identifying the essential communication protocols and interfaces required.

1.5 Impact

The results of this study have the potential to make a significant impact in healthcare settings. By exploring the use of human-robot collaboration to integrate emerging technologies, this study could provide a framework for the successful implementation of novel technologies in healthcare environments. Additionally, the development of human-robot collaborative teams for rapid response systems in hospitals could significantly reduce the workload of RRS team members. Ultimately, the successful implementation of a human-robot collaborative team in a real-world healthcare environment could revolutionize the way rapid response teams are structured and function, with the potential to improve patient care.

1.6 Outcome

The overarching goal of this research is to design, create, test, implement and evaluate a HRC-enhanced RRS. This system will incorporate collaborative robots and AI-based technologies, working alongside trained healthcare professionals and providers. To ensure the integrity and ethical adherence of this research, the project will unfold in sequential phases, each with specific objectives and outcomes:

- **Phase 1:** The first phase is dedicated to evaluating how well the introduction of a collaborative robot is received by involving multiple stakeholders and identifying potential obstacles to its integration. The details of this phase have been outlined in the next section of this document.
- **Phase 2:** Building on the insights from the first phase, this stage will focus on the design of the collaborative robot, incorporating multiple iterations and actively seeking input from stakeholders which will involve observations, interviews and focus groups.
- **Phase 3:** The third phase is dedicated to prototyping and experiments. Here, the design plans from Phase 2 are transformed into tangible prototypes. These prototypes will be used for testing and validation, providing a real-world assessment of the robot's functionality, usability, and effectiveness in a healthcare setting. This stage will also involve iterative testing, with each prototype undergoing rigorous evaluation to ensure it meets the required standards and stakeholder needs before moving to the next stage of development.
- **Future Phases:** The subsequent phases of the project will be determined based on the outcomes and insights gained from the initial three phases. These future

stages will be designed to further develop, refine, and implement the collaborative robot within healthcare settings, taking into account evolving needs, technological advancements, and feedback from continuous stakeholder engagement.

1.7 Outputs

Firstly, the research will contribute to a PhD thesis on human-robot collaboration in healthcare being conducted at the Australian National University (ANU), with the PhD student and two of his supervisors being members of the research team. Secondly, the findings of the study will be disseminated through academic publications and presentations, as well as through workshops and conferences. Moreover, future research projects and students may also be involved in building upon the findings of this study.

The research team will also provide a summary report of the study's key findings to the hospital's management and research team, highlighting the potential benefits and challenges of integrating human-robot teams in rapid response systems.

1.8 Objectives

To provide a clear direction and purpose for the project, the following objectives have been established:

- **Overall Objectives:**
    - **Design a Collaborative robotic system for RRS**: To conceptualize and design collaborative robot for RRS, including:
        - Investigate the feasibility of developing a human-robot collaborative (HRC) team to enhance rapid response systems (RRS)
        - Defining team composition and architecture.
        - Outlining AI-enabled technologies for use.
        - Determining function allocation, task allocation, and performance metrics.
        - Establishing communication protocols and interfaces between team members and technologies.
        - Developing a Human-Robot collaboration platform for operation oversight, performance quantification, and quality control.
        - Creating and implementing training programs for team members, with performance evaluations.
        - Conducting simulations and real-world experiments to assess effectiveness and refining the design based on feedback.
- **Phase Objectives:**

- **Phase 1 - Initial Evaluation**:
    - Evaluate the reception of the collaborative robot among stakeholders, e.g. hospital staff, RRS members, patients, and visitors.
    - Identify potential challenges and barriers of integration.
    - Develop strategies to overcome barriers
- **Phase 2 - Design and Feedback**:
    - Build upon Phase 1 findings to design the collaborative robot.
    - Incorporate multiple design iterations and actively seek stakeholder input through observations, interviews, and focus groups.
- **Phase 3 - Prototyping and Testing**:
    - Transform design plans into tangible prototypes.
    - Conduct extensive testing and validation in healthcare settings to assess functionality, usability, and effectiveness.
    - Perform rigorous evaluations of each prototype to ensure they meet high standards and stakeholder requirements.
- **Future Phases - Development and Integration**:
    - Based on insights from initial phases, further develop, refine, and integrate the collaborative robot in healthcare environments.
    - Adapt to evolving needs, technological advancements, and continuous stakeholder feedback.

2 Phase 1 - Project Design

2.1 Research project setting

The study will be conducted at the University of Canberra Hospital (UCH), a major healthcare facility in the Australian Capital Territory (ACT). As the largest purpose-built rehabilitation centre in the region, UCH is equipped with a rapid response system and is supportive of our research. This makes it an ideal setting for investigating Rapid Response Systems. The hospital's involvement in research initiatives presents a unique opportunity for in-depth study of Rapid Response Systems in a safe and realistic environment. This preliminary work at UCH is essential before expanding the research to other hospitals.

2.2 Methodological approach

In the first phase of our research, we will employ a quantitative approach. The Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) (Venkatesh et al. 2012) will be used as the primary methodology for this phase. UTAUT2 is an expansion of the original UTAUT model, specifically tailored to understand user acceptance and the use of technology in consumer contexts. Given the novelty of integrating Human-Robot Collaboration (HRC) into Rapid Response Systems (RRS), it is imperative to understand the behavioural intentions and actual usage of such technology among healthcare professionals and other potential users. The UTAUT2 model examines several key determinants, including performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit. These constructs will provide comprehensive insights into the factors that influence healthcare professionals' intentions to use and subsequently adopt the HRC in their RRS practices. By utilising UTAUT2, our research project will benefit from a well-established and validated framework that has proven its efficacy in predicting and explaining technology adoption behaviours in diverse settings.

2.3 Participants

For a comprehensive understanding of the implications of introducing Human-Robot Collaboration (HRC) into Rapid Response Systems (RRS) within the healthcare domain, it is paramount to collect feedback and insights from an array of perspectives. This is particularly crucial because the integration will not only affect healthcare professionals but will also have an impact on the broader community interacting with the system. This ensures that the planned integration is not only clinically efficient but also socially and operationally acceptable. Here's a breakdown of our chosen participants and the value of their perspectives:

- **UCH staff**: This group comprises individuals either directly affiliated with UCH's RRS team or those working closely with them, including:
    - **Doctors and Nurses:** As primary healthcare providers, they play critical roles in patient care. Their opinions on the feasibility and practicality of HRC in RRS are crucial, given their direct interactions with patients and healthcare systems.

    - **Ward Support Staff:** Ensuring the smooth functioning of wards, their insights can highlight ground-level logistical and operational challenges that might arise from integrating robots.
    - **Management**: As decision-makers, their perspective is vital for understanding institutional challenges, opportunities, and the overarching vision for HRC integration.
    - **Other Healthcare Professionals:** This encompasses specialists, therapists, and individuals who work in close proximity to the RRS. Their understanding can provide a comprehensive view of the system's potential improvements.
    - **Other Staff:** Including security, administrative personnel, IT teams, and more, their diverse roles can offer varied insights into the potential impact and advantages of introducing robotics into RRS.
- **Patients and Visitors:** Patient and visitor input will also be gathered to ensure that their needs and concerns are addressed. We will ensure to only include patients and visitors who are not undergoing critical medical care. By taking a patient-centred approach, we can ensure that the human-robot team will be optimized to meet the needs of those who matter most - the patients.

2.3.1 Inclusion Criteria

- Must be 18 years of age or older.
- Proficient in English to ensure understanding and completion of the survey.
- Specific to Hospital Staff and healthcare professionals:
    - Personnel employed at the University of Canberra Hospital (UCH).
    - Individuals professionally associated with the University of Canberra Hospital.
- Specific to Patients and Visitors:
    - Patients, patient advocates, and visitors of UCH.
    - Must have visited the University of Canberra Hospital at least once in person.
    - In a stable condition and mentally and cognitively capable of providing informed consent and participating in the survey.

2.3.2 Exclusion Criteria

- Individuals under the age of 18.
- Lack of English proficiency which would preclude understanding of the survey or study materials.
- Specific to Patients and Visitors:
    - Patients currently receiving critical medical care or undergoing procedures.
    - Patients and visitors with cognitive impairments or conditions that might impede their ability to participate.
    - Have not visited the University of Canberra Hospital in person.

2.4 Sample size

To ensure a representative sample that captures a broad spectrum of experiences and insights, we aim to involve between **80 to 130** participants in our study.

Based on preliminary discussions with UCH, we have ascertained that:

- There are about 20 individuals directly affiliated with the RRS. We aim to include 8-12 members from this group. Given their immediate connection with the system, their insights will be invaluable.
- The broader workforce at UCH encompasses roughly 500 individuals. From the wider pool of UCH staff members, we intend to engage with 40-60 individuals. This will ensure that we capture a diverse range of perspectives from different departments and roles within the hospital.
- The remaining participants will be selected from the patients and visitors, projected to be from 30 to 60 participants. Their viewpoints will offer a unique understanding of how the integration of HRC into RRS might affect those directly receiving care or those who visit the hospital.

2.5 Participant recruitment strategies

To ensure a diverse and representative sample of participants, multiple recruitment strategies will be employed:

1. **Booth in High-Traffic Waiting Areas:** With the approval of UCH management, a booth will be established in the hospital's high-traffic waiting areas. This will act as a focal point for engaging both hospital staff and patients/visitors in our study. The booth is designed to be an accessible and prominent hub for sharing information and facilitating participation.
2. **Use of Informational Posters:** Alongside the booth, informational posters will be strategically placed to draw attention and invite individuals to participate in the study. These posters will be visible in various parts of the hospital, guiding potential participants to the booth.
3. **Engagement of Hospital Staff:** To specifically reach hospital staff, internal communication channels such as emails and departmental meetings will be utilised. These communications will detail the study's objectives and encourage staff to visit the booth and participate.
4. **Outreach to Patients and Visitors:** For patients and visitors, the assistance of hospital staff will be sought. These staff members will proactively approach individuals, providing them with information about the study and inviting them to complete the survey, either at the booth or through other available means.

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2.6 Timeframes

- **Initial Contact and Briefing**
  For surveys, once the ethics application has received the necessary approval for ACT Health, we will collaborate with UCH management and staff to disseminate posters or flyers, and to identify and approach suitable individuals to participate in the survey.
- **Confirmation of Participation**
  For surveys, individuals will be provided with a survey link or QR code to read the Participant Information Sheet and participate in the survey on Qualtrics, if they choose to do so.
- **Data Collection**
  All data collection session is anticipated to be conducted over a period of 2 months.
- **Follow-up and Debriefing**
  At the survey's conclusion, they will be provided with research team's contact information can also if they want to change their response or withdraw their response. All participants will have the email addresses of the researchers and are encouraged to share any concerns, queries, or other matters with the research team as required.
- **Sharing of Publication**
  Participants who are interested in the outcomes of the research and the subsequent publications can refer to a designated webpage. This webpage will be regularly updated with the study's progress, key findings, and publications.

2.7 Approaches to provision of information to participants and consent

2.7.1 Information Provision

To ensure that participants are fully aware of the nature and requirements of the study, each will be provided with a Participant Information Sheet at the beginning of the survey. This document will comprehensively cover the aspects such as purpose of the study, procedures involved, potential risks and benefits, rights to confidentiality and data protection, rights to withdraw from the study at any point up until the commencement of data analysis.

2.7.2 Consent process

The consent process is a critical component of ethical research, designed to respect participants' autonomy and protect their rights. This section outlines the procedures and responsible parties involved in confirming or re-negotiating consent throughout the study.

- **Procedures for Initial Consent**
  - **Implied Consent:** At the beginning of the survey, participants will encounter a checkbox indicating their consent to participate. By checking this box, they are providing their implied consent to be a part of the study.
  - **Confirmation and Re-negotiation of Consent:** Participants have the right to change their decision after having given their consent. If, at any point, a participant wishes to withdraw their consent or make any modifications to the extent of their participation, they may reach out to the researchers. It is essential

for them to understand that requests for data removal should be made prior to the publication or submission of findings. This ensures their data can be withdrawn in time.

- **Modifications to Study Protocol:** In the event of significant changes to the study protocol, participants will be informed through updates on the designated webpage. This ensures that participants remain informed about any pivotal changes to the research they are a part of, and they can always refer to this webpage for the most up-to-date information regarding the study.

2.8 Participant commitment

This subsection outlines what is expected from participants in terms of time commitment, participation in different research activities, and ongoing engagement with the study.

- **Time Commitment:** Based on the structure of our survey, participants can expect to spend approximately 15 to 25 minutes to complete it.
- **Activity Involvement:** Participants will primarily engage in answering a set of structured questions, consisting of Likert scale items and a few optional open-ended questions.
- **Ongoing Engagement:** This research requires a one-time commitment for the survey completion. Upon conclusion of the survey, participants will be inquired about their interest in engaging in subsequent phases of the research. Those willing to continue will provide their email addresses through a distinct survey, ensuring their anonymity and reducing identification risks. Once the research design and ethical approvals for the forthcoming phases are finalised, these participants will be contacted for further involvement.

2.9 Further Subject Follow-up

Participants will not be followed up after their involvement in the study and confirmation of their data. However, if any participants express distress or concerns during the study, they will be provided with appropriate support and resources in the Participant Information Sheet. They can also contact the researchers to seek clarification, discuss their feelings, or be directed to additional resources and support avenues if needed.

2.10 Project duration and timeline

The data collection and analysis for this phase of the project is anticipated to be 6 months long, with the outlined timeline below. However, the timeline for each stage may be subject to change due to factors such as study complexity, resource availability, and unforeseen events. Nevertheless, this framework serves as a broad reference for the expected timeline of the study.

Duration	Stage	Activities
Month 1 -3	Recruitment and Data Collection	Development and dissemination of recruitment materials Administering the survey to the participants
Month 4-5	Data Analysis and Synthesis	Initial data cleaning and sorting Comprehensive data analysis
		Synthesis of findings, identification of key themes, and preliminary conclusions
Month 5-6	Write-up	Drafting initial findings and results Review and refinement of draft

2.11 Impact of and response to participant withdrawal

Participant withdrawal is a possibility in any research study. This section outlines the potential impact of such withdrawals on the study and the measures that will be taken to address them.

2.11.1 Impact on the Study

- **Statistical Significance:** If a substantial number of participants withdraw, it might affect the statistical power of the study, potentially leading to inconclusive or non-representative results.
- **Potential Bias**: If withdrawals are not random (e.g., a specific demographic or group predominantly opts out), this could introduce bias into the results, making them less generalisable to the broader population.
- **Timeline Delays:** Replacing participants can lengthen the recruitment phase, leading to potential delays in the overall study timeline.

2.11.2 Response to Withdrawal

- **Immediate Action**: Should a participant choose to withdraw, all of their data will be immediately segregated and marked for exclusion from the study.
- **Ethical Consideration**: Participants have the right to withdraw from the study at any point up until the data has been submitted for publications, without any negative repercussions.
- **Data Replacement:** If feasible, a new participant fitting the original participant's profile may be recruited to replace the withdrawn participant, especially if the withdrawal significantly impacts the study.

- **Communication:** Participants who choose to withdraw will be asked (but not required) to provide a reason for their withdrawal to help the research team understand any potential issues within the study design or execution.
- **Study Adjustment:** The research team will periodically assess the impact of any withdrawals to determine if adjustments to the study design or methodology are necessary.

2.12 Data Management

This section outlines the comprehensive Data Management Plan developed in accordance with National Statement 3.1.45 and 3.1.56.

2.12.1 Data Management Plan

- **Data collection:** The collection of data for this study will be conducted using Qualtrics which has been approved by Australian National University's Privacy Officer. Qualtrics has also been whitelisted by the Australian National University's Chief Information Security Officer (CISO), ensuring compliance with the highest standards of data security and privacy.
- **Form of Data Storage:** Data will be stored in digital format only. Digital data will be encrypted and stored in a secure server provided by Australian National University (ANU).
- **Purposes for Data Use/Disclosure:** Data will be used solely for this research. Aggregated data may be published, but individual responses will remain confidential.
- **Conditions for Data Access**: Access to the data will only be granted to authorized members of the research team.
- **Information to be Communicated to Participants:** Participants will be informed of the data management plan, specifically how their data will be used and stored in the Participant Information Sheet.
- **Disposal and Destruction:** Upon completion of the study and analysis, any identifying information will be irreversibly destroyed. Non-identifying data will be retained for a period of five years following the latest date of any publication associated with this data, after which it will be securely disposed of in accordance with ethical guidelines and institutional policies.

2.13 Future Research and Data Sharing

- **Permission from Review Body:** If needed, permission will be sought from the ethics review body to waive the requirement for consent for future, yet unspecified, research.

2.14 Data Analysis

This section outlines the methodologies that will be employed for measuring, manipulating, and analysing the data gathered through surveys based on UTAUT2.

- **Data Preparation:**

Prior to analysis, the data will be cleaned to remove any inconsistencies, errors, or missing values. The raw survey responses will be coded to facilitate quantitative analysis. For instance, Likert scale responses might be converted into numerical values for ease of computation.

- **Descriptive Analysis:**

Basic statistical measures like mean, median, mode, and standard deviation will be used to describe the dataset and gain an initial understanding.

Frequency distributions will be evaluated to understand the distribution of responses across different questions and categories.

- **Reliability and Validity:**

Cronbach's alpha will be calculated to measure the internal consistency and reliability of the survey questions.

Factor analysis might be conducted to assess the validity of the survey constructs and to understand the underlying structure of the data.

- **Inferential Analysis:**

Based on the UTAUT2 model, regression analysis will be employed to determine the relationships between independent variables (e.g., performance expectancy, effort expectancy) and the dependent variable (e.g., user acceptance).

Additional tests like ANOVA or t-tests might be employed to discern differences in user acceptance across different demographic groups or other relevant categories.

- **Qualitative Analysis (for open-ended questions):**

Thematic analysis will be conducted on the open-ended responses to identify recurring themes, patterns, and insights.

Manual coding and the aid of qualitative analysis software may be used to categorise and understand the depth of the responses.

- **Interpretation and Discussion:**

Findings from both quantitative and qualitative analyses will be integrated and discussed in the context of the UTAUT2 framework and any deviations or unique patterns identified.

The results will be critically evaluated, considering potential biases, limitations, and implications for the broader research field and practical applications.

2.15 Matching and sampling strategies

To ensure the representativeness of the sample and to achieve robust findings, the following matching and sampling strategies will be implemented**:**

- **Stratified Random Sampling:** Considering the varied roles and affiliations of potential participants within the UCH, the population will be divided into distinct strata (e.g., RRS team, other hospital staff, and patients and visitors.). A random sample will then be drawn from each group. This approach ensures representation from all key groups and can lead to more accurate and insightful conclusions.
- **Matching**: Given our use of the UTAUT2 model, matching becomes essential. UTAUT2 identifies several key determinants of technology acceptance, such as performance expectancy, and effort expectancy, among others. By matching participants based on certain criteria like age, gender, years of experience, or specific roles, we ensure that these determinants are evenly distributed across comparison groups. This approach ensures that any differences observed in the acceptance and use of technology can be accurately attributed to the primary variables of interest posited by the UTAUT2 framework, rather than other extraneous factors.

2.15.1 Accounting for potential bias, confounding factors and missing information

Potential Bias: In any research, there exists the potential for bias, which can affect the validity of results. Several types of bias that can arise in our research are:

- **Selection Bias:** By not representing all groups equally or overlooking some, the sample might not truly represent the UCH population. We'll continually assess the sample's composition to ensure broad representativeness.
- **Response Bias:** The way questions are posed or the environment in which the survey is taken can influence responses. To mitigate this, we'll employ neutral phrasing in our questions and ensure participants can respond in a comfortable setting.

Confounding Factors: These are variables that might distort the true relationship between the study variables. For instance, prior technology experience might influence one's readiness to accept a new system. To account for such factors:

- **Multivariate Analysis:** We'll use statistical techniques that allow for the inclusion of multiple variables simultaneously. This approach can help in isolating the effect of each variable while controlling for others.
- **Matching:** As previously discussed, matching participants based on certain criteria can help control confounding.

Missing Information: Not all participants might complete the survey in its entirety or might skip certain questions:

- **Multiple Imputation:** This statistical technique can be used to replace missing values based on the information from other respondents. It is a way to ensure the data set remains robust even with missing values.
- **Sensitivity Analysis:** By comparing the results obtained from the original data and the data after imputation, we can assess how sensitive our results are to the missing information.

2.15.2 Statistical power calculation

To ensure that the study is sufficiently powered to detect a true effect, if one exists, between the independent and dependent variables as per the UTAUT2 model, we will conduct a statistical power calculation. This calculation will assist in determining the minimum sample size needed to achieve a result that is statistically significant.

Key Steps in the Power Calculation

- **Determine Effect Size:** We will start by estimating the expected effect size based on prior studies that have used the UTAUT2 model in similar settings or from preliminary data.
- **Set Significance Level (α):** Typically, a significance level of 0.05 is used for social science research. This threshold represents a 5% risk of concluding that a difference exists when there is no actual difference.
- **Set Power (1-β):** The power of the study—the probability of correctly rejecting the null hypothesis when it is false—will be set. A common benchmark is 0.80, indicating an 80% chance of detecting an effect if one truly exists.
- **Determine Sample Size:** Using these parameters, we will calculate the minimum number of participants required. This will be done using a power analysis formula or software designed for such calculations.
- **Adjust for Estimated Dropout Rate:** Recognising that participant withdrawal can reduce the effective sample size, we will inflate the initial calculation by an estimated dropout rate to ensure robustness against participant attrition.
- **Consider Design Effects**: If the study design has elements such as clustering, which might impact the analysis (e.g., participants within the same department might be more similar to each other than to those from other departments), we will include a design effect in our calculation to compensate for this potential non-independence of observations.

2.16 Data Linkage

The first phase of our study sets the foundation for data linkage, where we will prepare to integrate quantitative data from surveys with data from observations, interviews, and focus groups on the next phase. This will create a multi-faceted dataset, essential for a comprehensive analysis of collaborative robots within Rapid Response Systems in healthcare settings.

2.17 Outcome measures

In the overall project, we plan to measure a variety of outcomes to capture the multifaceted impact of integrating Human-Robot Collaboration (HRC) into Rapid Response Systems (RRS). Some of the outcome measures we intend to include are metrics such as Efficiency of Response, Quality of Patient Care, Healthcare Professionals' Workload and Stakeholder Acceptance. Within this phase of the research, the primary outcome measure of interest is

Stakeholder Acceptance, which aligns closely with the UTAUT2 framework utilised in our methodological approach.

2.18 Plans for dissemination and publication of project outcomes

The research team is dedicated to ensuring that the dissemination of study results and publication policy follows ethical guidelines. This includes sharing the findings of the study not only within scientific media, but also with the broader community and study participants. Ensuring open access where possible, we'll also share results directly with participants and stakeholders, supporting transparency and the widespread application of our research insights.

2.19 Project closure processes

Upon completion of the study, our project closure processes will involve a thorough review and documentation of the outcomes, the consolidation of findings, and the archiving of data in accordance with ethical and institutional guidelines. We will ensure all contractual and reporting obligations are fulfilled, participant and stakeholder communications are concluded, and resources are reallocated or decommissioned as necessary. A final project report will be compiled, encapsulating the research insights, lessons learned, and recommendations for future studies, thus formally concluding the project lifecycle.

2.20 Plans for sharing, future use of data, and follow-up research

At present, there are no definitive plans for the sharing or future use of data collected in this phase of the research. Similarly, follow-up research initiatives will be considered independently and will seek separate ethics approval when the next phase is formulated. Our immediate focus remains on the successful completion of the current study and the thorough analysis of its findings.

2.21 Anticipated secondary use of data

There are no anticipated secondary uses of the data collected in this phase of the study. The data will be gathered, analysed, and reported solely for the purposes outlined in the research protocol.

2.22 Risk and Benefit

The risks associated with participating in the study are minimal, and steps will be taken to ensure the safety and privacy of all participants. Some potential risks include:

- **Data Privacy:** Potential risk of personal information breach.
    - *Mitigation:* Implementation of robust data protection protocols and not collecting identifiable information.
- **Participant Discomfort:** Individuals may encounter inconvenience or discomfort during data collection.

    - *Mitigation:* Ensuring supportive measures are in place and the process is as non-intrusive as possible.
- **Indirect Identification**: Participants might be identifiable due to the nature of the study.
    - *Mitigation*: Clear communication about confidentiality limits and the use of data anonymisation where possible.

Some of the potential long-term benefits of the overall project include:

- **Improved Patient Care:** Enhanced rapid response systems effective Human-Robot Collaboration (HRC) could lead to better patient outcomes.
- **Professional Support**: Alleviation of staff workload and reduction of stress through effective HRC.
- **Academic and Social Value:** The study's findings are expected to contribute to the body of knowledge in healthcare robotics and potentially influence future technological integration in healthcare settings.

It is important to note that in this initial phase of our research at University College Hospital (UCH), we are focusing on a preliminary survey to gather opinions and concerns regarding the integration of robotics and AI in healthcare. It is crucial for participants to understand that the beneficial impacts of this research, such as improved patient care and more efficient healthcare practices through the use of robotics and AI, are anticipated to be long-term developments. The current stage primarily aims to collect and analyse data on healthcare professionals' and patients' perspectives, which will inform future stages of our research. To ensure clarity, we will explicitly communicate this information in our Participant Information Sheet, maintaining transparency about the long-term nature of the research benefits and the immediate objectives of this initial phase.

2.23 Partnership requirements

In addition to the cooperation and participation of hospital staff and patients and visitors, the research team may require partnerships with other organizations or companies to achieve the objectives of the study. These partnerships will be determined based on the study's needs and objectives and will be established in collaboration with relevant stakeholders. The team will work closely with the UCH's management and research team to ensure that these partnerships are aligned with the hospital's goals and objectives and are beneficial for all parties involved.

2.24 Quality assurance, monitoring & safety

To ensure the quality and safety of the study, the research team will implement several measures for quality assurance, monitoring, and safety. These measures include adhering to ethical guidelines, ensuring data confidentiality and security, and mitigating risks and discomfort associated with participation in the study.

As this is a small-scale research project, there will not be any external committees overseeing the study. However, the research team will reassess this decision as the project proceeds and may seek external oversight if deemed necessary to ensure the quality and safety of the study.

2.25 Finance and resource use

This research project is currently in the exploration stage for external funding. We are targeting prominent grants like the Medical Research Future Fund (MRFF) to secure financial backing for the later phases of the project, which will involve design, implementation, and evaluation. At this initial stage, external funding is not yet essential for the project's progress.

In terms of internal funding, all researchers involved in this study receive compensation through salaries from their respective workplaces and organisations.

In particular, Amir Asadi who is currently a PhD candidate at the Australian National University (ANU), is supported by ANU's Higher Degree Research (HDR) Fee Merit Scholarship, University Research Scholarship, and the Florence McKenzie Supplementary Scholarship in a New Branch of Engineering.

As the research is in the data collection stage, no specific budget is required at this time. However, there may be potential costs associated with transcription services, which can be managed using the resources available at the Australian National University (ANU). The research team will explore cost-effective options to minimize expenses while ensuring the quality and integrity of the study.

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