Collaborative Robots for Empowering People: Key Insights from an OzCHI Workshop

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There is an increased interest towards robotic platforms for close and direct collaboration with people, given the benefits of utilising the complimentary capabilities of people and robots. This calls for research that considers how people are involved in design and development of these platforms. The term "empowerment" transverses Human-Robot Collaboration (HRC) research domains and disciplines, including the OzCHI community. Approaches to empower people vary between these disciplines and domains, creating a need for clarifying and consolidating the different roles people play in HRC research. This paper summarises the why, when, how, and who of empowerment in HRC, drawing from insights gathered in an academic workshop at the OzCHI conference in 2023. We present five key characteristics relating to the ways that empowerment in HRC can be facilitated, along with barriers and pathways towards those characteristics.

CCS Concepts: • **Computer systems organization → Robotics**; • **Human-centered computing → Collaborative interaction**; *Interaction design.*

Additional Key Words and Phrases: Human-Robot Collaboration, Robots, Empowerment

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1 INTRODUCTION

The shift towards Industry 5.0 comes with the promise of technological solutions that emphasise societal benefits, developed through human-centred approaches [8]. One promising aspect of Industry 5.0 is human–robot collaboration (HRC), but the concept of HRC has its roots in the early developments of automation and robotics. Initially, robots were primarily used to perform simple, repetitive tasks in environments like manufacturing plants [1]. The focus was on dull, dirty, or dangerous tasks—areas where human involvement can be unsafe or inefficient [16]. As technology has advanced, particularly with the advent of more sophisticated computer vision and machine learning, the potential for robots to assist rather than replace human labour began to be realised [7]. In the 1980s and 1990s, research expanded significantly in the field of robotics with the introduction of collaborative robots, paving the way for more advanced collaborations. These collaborative robots, also known as "cobots", are designed to work alongside and with humans. For example, in automotive assembly lines, cobots and humans can share tasks synchronously. Industry 5.0 comes with a shift from being technology-driven to being value-driven and, by extension, using robots as tools to empower humans in various activities [2].

In any collaborative work context, power is a fundamental aspect [18]. Given the ability of robots to act autonomously in various ways, power dynamics are naturally embedded in HRC. Yet, there are still open questions relating to how power is manifested through people interacting and collaborating with robots. At the 2024 ACM/IEEE Conference for Human-Robot Interaction, Hou et al. called for new conceptualisations of power in Human-Robot Interaction (HRI) that rely on multidisciplinary perspectives [17]. While "power" is a broad concept with various interpretations, this paper focuses on power as *power to* someone, through the term "empowerment". The research reported here was conducted as an academic conference workshop to explore when HRC empowers people and when it does not, how the empowerment of people in HRC can be facilitated, the benefits of empowering people in HRC, and who is empowered in HRC and who is not. This was framed as four central questions guided the workshop: (1) Why are we creating platforms for human-robot collaboration, and what are the benefits for people? (2) When does design and development of HRC empower people, and when does it not? (3) How can the empowerment of people in HRC be facilitated through design and development? (4) Who is empowered by HRC, and who is not? The main goal of the workshop was to facilitate a multidisciplinary discussion on these questions as a first step towards developing a working framework for empowerment in HRC. We analysed the discussions that took place throughout the workshop and present a resulting framework for empowerment in HRC, consisting of key characteristics, barriers for empowerment, and future pathways, as the main contribution of this paper.

2 EMPOWERMENT IN HUMAN-ROBOT COLLABORATION

Within Human-Computer Interaction (HCI), researchers have investigated concrete ways that robots can explicitly empower people. Taylor et al. engaged with nurses across five hospitals in a collaborative design process to elicit ideas for the use of a Robot-Centric Team Support System (RoboTSS) in interprofessional team settings [25]. Rather than focusing on empowerment in relation to organisational hierarchies, Taylor et al. engaged nurses to define teamwork challenges. Yang et al. investigated the use of a telepresence robot for a person to remotely join a shopping activity with a loved one [26]. At the OZCHI conference, researchers have focused more on empowerment within caregiving or for people with disabilities, *e.g.*, [4]. Carrasco et al. described empowerment as the possibility for family caregivers to use technology to respond to changing needs and challenges throughout daily life [9]. A key take-away from this existing body of research is that empowerment of people in HRC is a key goal, but the way that empowerment is achieved varies, relies on various theoretical conceptualisations of empowerment, and is heavily focused on the application domain.

Hou et al. present a systematic investigation into the concept of "power" in the HRI literature [17]. They point out that, since robots are often integrated to influence the behaviour of people, robotic systems inherently affect power structures. Since that power structure can be manifested in a plethora of ways, there is a need to make it visible and explicit. In this short paper, we focus on collaborative robots where the premise is, typically, that the robot should "support" the work of people. As such, we respond to the call by Hou et al. by outlining assumptions, barriers, and opportunities for empowering people in HRC.

3 METHOD

To investigate the why, when, how, and who of empowerment in human-robot collaboration, a full-day academic workshop at the 2023 OzCHI conference for the Computer-Human Interaction Special Interest Group (CHISIG) was organised by the Australian Cobotics Centre (ACC) and the Collaborative Intelligence (CINTEL) Future Science Platform, a multidisciplinary research programme of CSIRO, Australia's national science agency. The aim of the workshop was to collaboratively create a roadmap for research on the topic of HRC through discussions anchored in the four workshop questions as outlined in Section 1. Fifteen academic researchers, comprised of the authors of position papers accepted for the workshop, invited panellists and workshop facilitators, participated in the workshop. These workshop attendees were from diverse fields, such as HCI, robotics, psychology, and design, and they had experience in designing and developing cobots as well as HRC in multiple domains, including manufacturing, search and rescue, agriculture, and education. Participants submitted position papers that outlined current research in these topics.

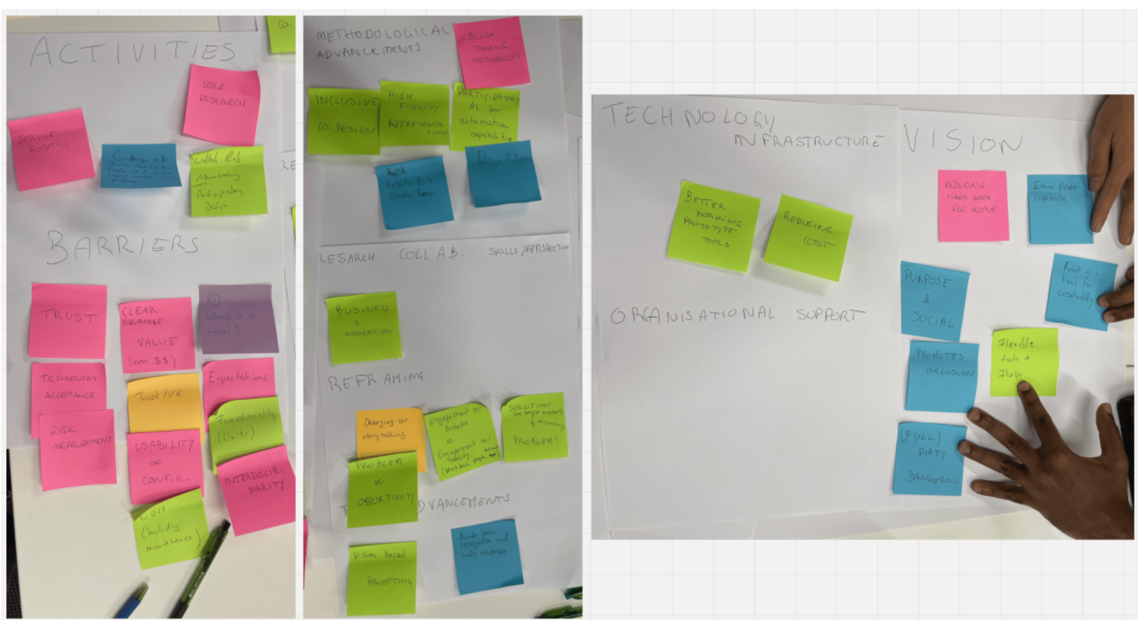

Fig. 1. In-person participants' notes.

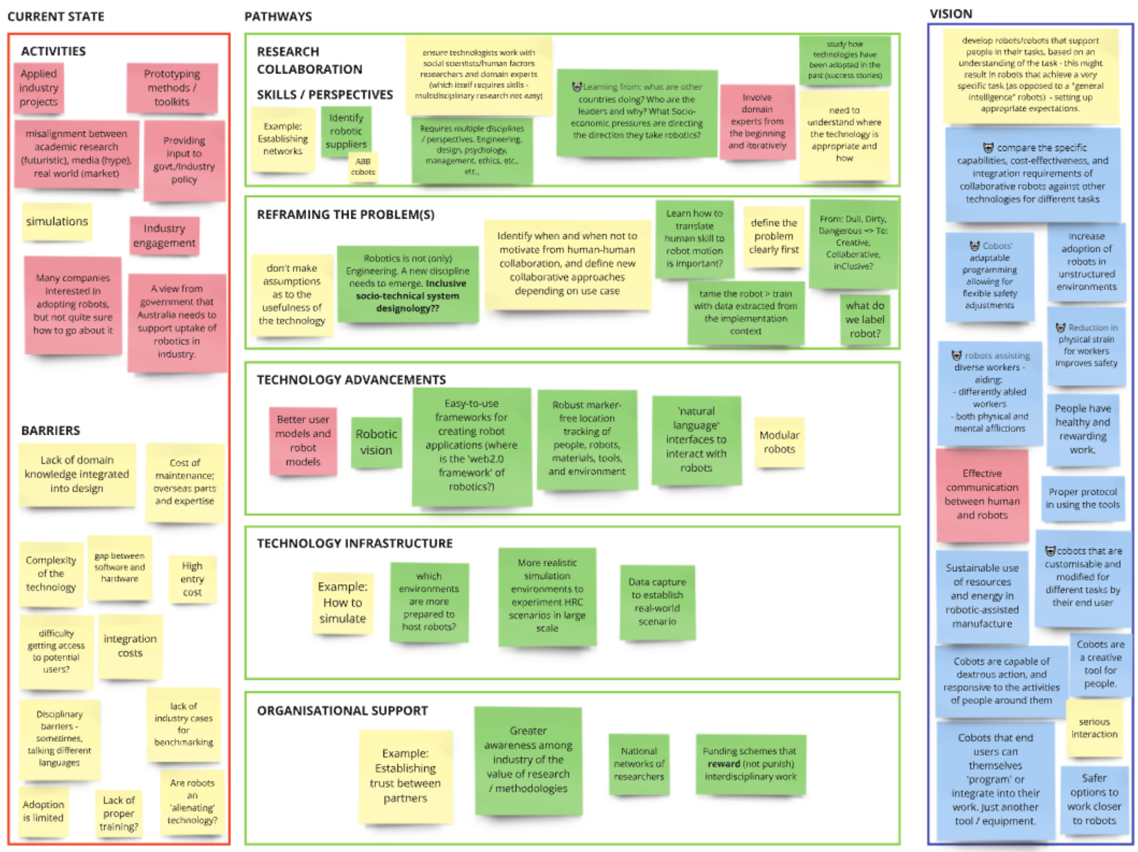

Fig. 2. Online participants' notes.

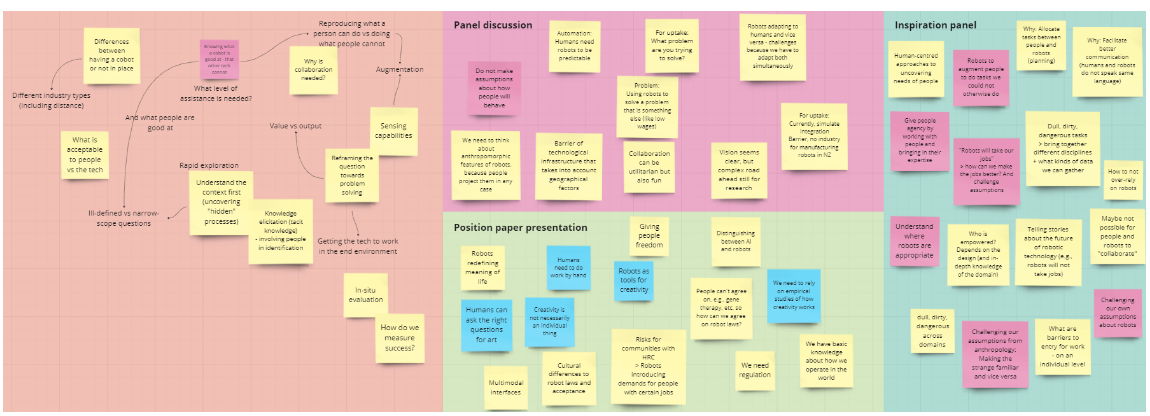

Fig. 3. A sample of notes taken by organisers.

3.1 Workshop Procedure

The workshop was facilitated in a hybrid format, dividing participants into two groups, online and in-person, for all collaborative activities. Four workshop organisers participated online, and two organisers participated in person. Each workshop activity was first introduced by one organiser and then facilitated by three organisers, 1 organiser in-person and 2 organisers online. After each workshop activity, a discussion was held, bringing together both in-person and online participants. Altogether, the workshop consisted of four main activities: (1) an inspirational panel discussion on four main topic areas (why, when, how and who), with panel members from the two organising research centres, (2) position paper presentations and a follow-up plenary discussion, (3) a panel discussion on barriers to HRC research, with external invited panel members, and (4) a road-mapping activity that envisaged the vision and pathways for HRC research and a follow-up plenary discussion.

The collected data throughout these activities were sticky notes (physical and digital) produced by participants throughout the activities, see Figure 1 and Figure 2, as well as note-taking by two organisers, see Figure 3, one facilitating the online group and one facilitating the in-person group. This approach to data collection is common in HCI research [12, 19], including prior published research at OZCHI [14], with the advantages of enabling quick brainstorming and allowing participants to speak freely without worry of being audio or video recorded.

3.2 Data Analysis

To analyse the collected data, we conducted an inductive thematic analysis [5]. This served the purpose of identifying connections between topics in the discussion outside of the given structure. As such, our goal was to capture core ideas across the discussions through a reflexive analysis rather than creating topic summaries, in accordance with Braun and Clarke's recent note on good practice in thematic analysis [6]. The researchers individually analysed the workshop data and identified a set of codes. These codes were labelled and restructured to capture recurring ideas, themes, or concepts in the data. The codes were discussed among four researchers; two organisers and two other workshop participants. The findings were grouped into three analytical themes and refined through a subsequent iteration between two researchers.

4 FINDINGS

We summarise our findings in Figure 4. The figure includes an overview of key characteristics of empowerment that were identified from our analysis, as well as the barriers and pathways towards those characteristics, encompassing a first step towards a framework for empowering people in HRC.

4.1 Characteristics of Empowerment

We identified that empowerment in HRC was discussed as five key characteristics associated with the design processes and robotic systems. These characteristics focus primarily on human aspects as opposed to technical opportunities. Below, we describe those characteristics relating to ways that empowerment is facilitated (1) through design methodologies, (2) by challenging traditional assumptions, (3) by addressing innate human needs, (4) by utilising multimodal communication, and (5) by investigating innately human aspects of existence. These findings emphasise that empowerment can be enabled in many ways beyond what previous research has demonstrated.

4.1.1 Empowerment Through Design Methods. Researchers agreed that empowerment in HRC can be supported through the methods employed. Design methodologies, in particular co-design, can help prioritise a human-centred perspective

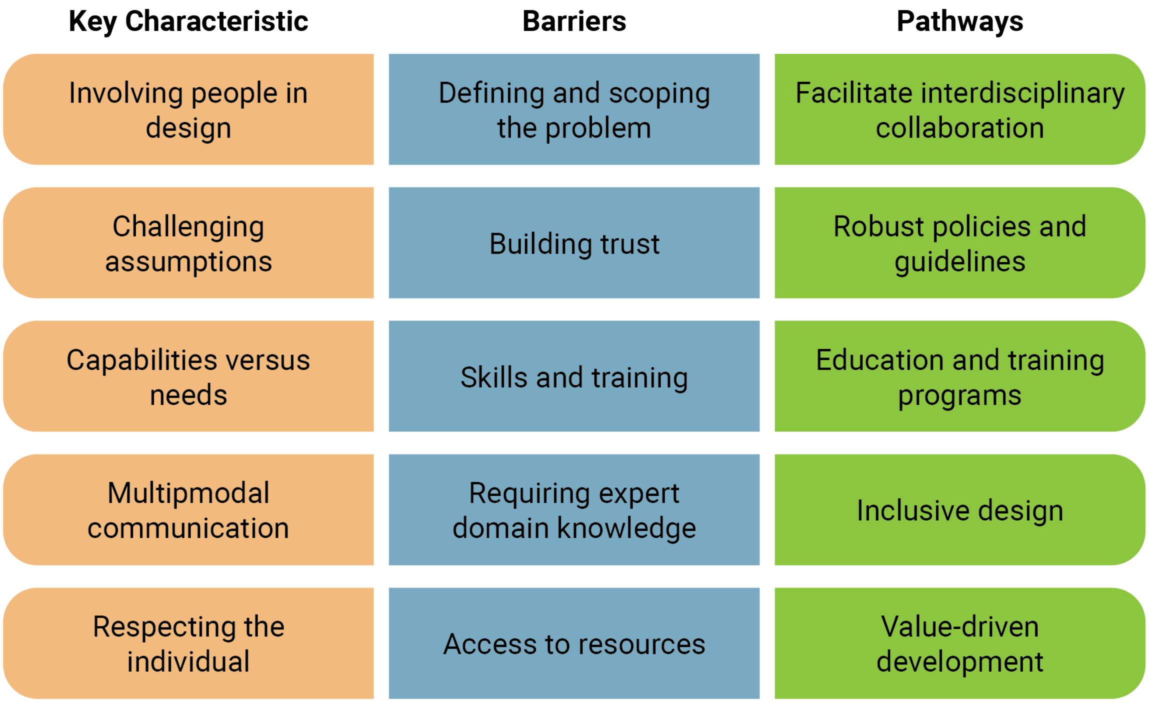

Fig. 4. This diagram summarises our findings in terms of (1) key characteristics that were identified through the analysis, (2) barriers towards enabling these characteristics, and (3) pathways for future research.

to produce solutions that extend human capabilities and enable individuals to achieve more than they could alone. As a background to this findings, much human-robot interaction research adopted a "techno-centric" or "robot-centric" approach [23]. By adopting human-centred design approaches, researchers can analyse the needs and requirements of the end-users and ensure that robots are not only technically proficient but also deeply integrated into human workflows, thus enhancing overall productivity and user satisfaction that complement human skills, researchers and system developers can create systems that foster human decision-making and cultivate creativity. As an example, one post-it note said: "From Dull, Dirty, Dangerous => to: Creative, Collaborative, inClusive?".

4.1.2 Challenging Traditional Assumptions. Empowerment involves challenging the existing assumptions of stakeholders, including developers, users, and policymakers. For example, one post-it note said: "misalignment between academic research (futuristic), media (hype), real world (market)". Some views emphasise artificial intelligence (AI) and robots as solutions to human shortcomings. However, our workshop participants emphasised that a shift is needed to view this advanced technology as an enhancer of human capabilities. Furthermore, they highlighted the importance of designing cobots–collaborative robots–that are customisable and can be modified by their end users for different tasks. This customisation promotes flexibility and user empowerment through making robots adaptable to varying needs and contexts. Moreover, it is essential to understand that robotics is not solely an engineering discipline. There is a need for integration between engineering, social sciences, design, and other disciplines. Multidisciplinary perspectives can investigate robotic systems holistically, considering both the technical and social aspects of robotics. By embracing new perspectives, stakeholders can promote the development of robots that not only support but also amplify human capabilities. This perspective shift can lead to robots being designed to enhance human potential, rather than replacing human work.

4.1.3 Balancing Capabilities and Needs. When it comes to empowerment, there is a delicate balance between developing a robotic system that performs tasks beyond human capabilities and designing robots that actually meet user needs. Instead of focusing solely on addressing perceived human challenges, developers should aim to understand user requirements and design robotic systems to enhance user's quality of life, enabling them to achieve personal and professional goals. This requires a deep understanding of human needs from a holistic perspective–not just the physical or financial, but also considering social and emotional dimensions.

4.1.4 Multimodal Communication Systems. The workshop discussion emphasised that effective communication is critical for successful collaboration between humans and robots. Robotic machines often lack effective communication capabilities. The group discussion suggested using context-appropriate multimodal communication (*e.g.*, visual, gesture, haptics, speech) could improve how robots communicate with human operators. By incorporating a bidirectional multimodal communication system, robotic machines can also effectively detect, interpret, and respond to human signals. Such multimodal communication could enhance the user experience and make robots more accessible and useful to a broader range of users, including those with different sensory abilities or language skills.

4.1.5 Respecting What is Innately Human. Recognising and respecting what is innately human is crucial to empowering HRC. It is important to acknowledge human traits such as creativity, empathy, and the need for meaningful work. Robots should be designed to further augment these human qualities. For instance, robots can perform repetitive tasks, allowing human operators to focus more on the creative aspects of their work. Similarly, robots can take on physically demanding tasks, reducing the risk of physical strain for workers and improving user safety.

4.2 Barriers to Empowerment

Our workshop discussions pinpointed five main barriers to empowerment in HRC, as detailed below.

4.2.1 Defining and Scoping the Problem in HRC. The first step in overcoming barriers to empowerment is accurately defining and scoping the problems that HRI researchers and interaction design can address. One post-it note from participants said: "Lack of domain knowledge integrated into design". This involves identifying specific areas where interaction design can significantly impact HRC. For example, determining how robots can augment rather than replace human tasks requires an in-depth understanding of job roles and human strengths. HRI specialists must conduct thorough assessments to identify where robots can add the most value, ensuring that robotic technology supports rather than disrupts existing workflows. This problem-scoping phase is critical because it sets the parameters for design and development, focusing efforts on areas where HRI can make a meaningful difference. Another note from the workshop noted: "Identify when and when not to motivate from human-human collaboration, and define new collaborative approaches depending on use case".

4.2.2 Building Trust through HRC System Development. Trust in HRC is a complex, multifaceted issue that encompasses both the interaction level and broader societal impacts. At the interaction level, users must appropriately trust the robots' ability to perform tasks reliably and safely. This can be addressed through thoughtful design by creating interfaces that are intuitive and provide clear feedback about robot actions and status. Ensuring transparency in robot operations and consistent performance can further build user confidence in using cobots and intervening at the right time. Furthermore, transparent communication about the goals of robot integration and active involvement of end-users in the development and implementation processes can address the fears and concerns about robots potentially displacing jobs. By engaging with end-users and ensuring they understand the benefits as well as limitations of robotic systems, we can foster a collaborative environment and expect improved adoption and acceptance of robotic technologies.

The design of HRC systems should emphasise on the enhancement of human capabilities and ensure that the robots are used appropriately and not relied upon excessively. This balanced approach helps maintain human oversight and decision-making, ensuring that the integration of robots supports and augments human work rather than replacing it entirely. Furthermore, our workshop participants highlighted that the advent of robotics will not just displace certain jobs but will also create new types of employment opportunities. Building public capacity to critically engage with and assess the potential benefits and harms of robotic integration is an essential step towards empowerment. This framing can help to inform our shared narratives to better reflect the double edged sword of robotics that, on the one hand, robots can displace and replace but, on the other hand, the goal should be to support work and not replace it.

4.2.3 Skills and Training of People. The introduction of robots into the workplace or home environments introduces a need for new skills and training. People not only need to learn how to operate these new tools but also how to effectively collaborate with them. HRI, HCI, and interaction design can play a crucial role in this by designing educational interfaces and training programs that are accessible and engaging. These training programs should cater to diverse users with varying levels of technical proficiency, using adaptive learning methods to customise the training experience. By empowering users with the knowledge and skills to use robotic systems, we can create a foundation for well-informed and critical engagement with HRC.

4.2.4 Designing Interfaces from Expert Domain Knowledge. A significant barrier to empowerment in HRC is that, on the one hand, systems should have intuitive and natural communication between humans and robots but, on the other hand, many robotic systems are not designed as such. This makes it challenging for users to understand the robots' intentions or actions. This communication gap can lead to user frustration. Furthermore, when robots encounter issues or malfunctions, the lack of straightforward troubleshooting methods or clear diagnostic feedback can exacerbate user frustration. It is important to acknowledge that most users do not possess the technical knowledge required to diagnose these robotic issues. To overcome these barriers, it is essential to design robotic systems that communicate more effectively with users through user-friendly interfaces and provide clear, actionable feedback that makes sense to non-experts. In addition, incorporating more intuitive and natural interactions and simplifying maintenance procedures could improve the user experience and foster greater empowerment by fostering users' confidence, agency, and capability when collaborating with robotic systems.

4.2.5 Accessibility to Resources. In HRC, economic barriers such as high entry costs, ongoing maintenance expenses, and limited access to training and technical support significantly hinder the potential of robotic technologies to enhance productivity and quality of life. These challenges pose substantial difficulties, particularly for small businesses and those in developing regions. In addition, research institutions often struggle to engage suitable users for developing HRC technologies in practical, real-world settings.

Collaboration between industry and academic institutions offers a promising solution to these barriers. Such partnerships not only combine practical applications and insights from industry with the theoretical knowledge and research capabilities of academia, but they also provide industries with access to innovative robotic equipment and facilities. Access is crucial for companies that otherwise could not afford such technology, allowing them to participate in cutting-edge development and application. These collaborations could lead to the development of more affordable and accessible robotic technologies and prototyping toolkits, as well as the creation of tailored training programs that bridge the skill gap in end-users. By equipping more individuals to effectively operate and maintain robotic systems, these partnerships enhance end-user capabilities. By leveraging the strengths of both sectors, industry-academic collaborations can facilitate HRC innovation and empowerment across various sectors.

To further enhance accessibility, our workshop attendees envisioned that establishing a public database of robotic suppliers and manufacturers can provide valuable resources to those interested in incorporating robotic technology into their workflows. This database would help small businesses and research institutions identify and engage with suppliers that prioritise inclusive design, making it easier to find and implement suitable robotic solutions.

4.3 Pathways towards Empowerment

During the workshop discussion, we also explored the pathways towards empowerment in HRC, as it has become crucial for ensuring these technologies enhance human capabilities and the work environment. This section elaborates on the strategic approaches to promote empowerment.

4.3.1 Emphasising Interdisciplinary Collaboration. The vision of integrating HRC within the workspace is clear, but the path ahead remains complex and challenging. Interdisciplinary collaboration is crucial for developing empowered HRI. By combining insights from robotics, HCI, psychology, ethics and design, we can create robotic systems that are not only technically proficient but also ethically sound and intuitive. Ethical considerations, such as privacy and autonomy, also must be integrated from the design phase to ensure the robots enhance human work without infringing on rights or dignity. Additional funding schemes should be allocated for interdisciplinary work. Such incentives can encourage more institutions to conduct research in HRC, driving innovation and fostering the development of advanced, user-friendly robotic systems.

Engaging with end-users throughout the development process is also essential as it provides insight into their needs and expectations, ensuring the technology support their workflows and enhance their productivity. Involving end-users in the early development stage provides an opportunity to help them make better decisions by directly comparing collaborative robots with other options in terms of their capabilities, costs, and ease of integration into current operations.

4.3.2 Establishing Robust Policies and Guidelines. Establishing robust policies and guidelines is essential for governing HRC practices. These policies should ensure that ethical standards are maintained and that the benefits of robotic application are distributed equitably across society. Regulations affecting the deployment and use of robots should be informed by empirical research and engagement with a broad range of stakeholders, including end-users, engineers, and the public.

Apart from that, global knowledge exchange between research environments and industry as well as understanding the socio-economic pressures that researchers in some countries face can offer valuable insights. By studying how robotic technologies have been successfully adopted in the past, we can identify best practices and avoid common pitfalls. These success stories can guide the development of policies that promote fairness and accountability in HRC. By shaping policies that reflect diverse inputs and experiences from around the world, we can ensure that HRC practices are not only effective but also equitable and inclusive.

4.3.3 Education and Training Programs for both Humans and Robots.

To harness the full potential of HRC, it is essential for human users to recognise that the working dynamic between human operators and the robotic system will be different. The user would have to be adequately prepared through targeted education and training programs. For humans, this means developing curricula that focus on managing and optimising interactions with robots, including understanding the limitations and capabilities of robotic systems. Implementing adaptive training programs that cater to unique aspects of HRC will foster a more fruitful collaboration and empowerment. In addition, artificial intelligence or computer vision can be integrated within the robotic system to enhance their ability to interpret and respond to human behaviours and emotions to facilitate more effective human-robot interaction.

4.3.4 Inclusive Design.

Embracing inclusive design is another critical pathway toward empowerment. It is important for robotic technologies to be accessible across a diverse range of users, catering to people with different abilities and enhancing empowerment across diverse communities. One post-it note from participants said: "develop robots/cobots that support people in their tasks, based on an understanding of the task - this might result in robots that achieve a very specific task (as opposed to a "general intelligence" robot)". This strategy focuses on creating systems that can be personalised and adaptable to handle various tasks and cater to different user needs. By advocating for a human-centered design approach, we can ensure that robotic systems are not only technologically proficient but also empowering for every user, thereby reducing entry barriers and improving systems' usability.

5 DISCUSSION AND FUTURE AVENUES

Our findings extend existing research by identifying concrete characteristics of empowerment that traverse disciplines and application domains. Below, we discuss how this can inform future HRC research in terms of (1) the problems we investigate and (2) the methods we employ.

5.1 Problem Scoping for Empowerment

Robots can empower people in many different ways. From our workshop, this surfaced in discussions relating to how robots can complement and augment human capabilities. For physical empowerment, robots can augment human physical capabilities, allowing for the performance of tasks beyond human strength or endurance limits, and often with the intention of reducing the risk of muscle strain [11]. For cognitive empowerment, robots coupled with computer vision or machine learning can provide cognitive support [11, 22], offering information processing, data analysis, and decision support that enhance human judgement and decisions making. For emotional empowerment, robots can improve human emotional well-being, allowing workers to engage in more fulfilling and creative endeavors [22].

These examples show that, at a basic level in research projects, empowerment is supported through problem framing and scoping. While not surprising, prior research mainly focuses on the methodological approaches to empower people. Recently described by Hou et al. [17], few studies directly address the ways that robots affect power dynamics in teams and organisations. In extension to that, there is an opportunity for future research to investigate such power dynamics in relation to types of robots, application domains, and communities of people.

When scoping and framing problems related to human-robot collaboration, researchers should focus on empowering people by leveraging their strengths and capabilities while using robots to compensate for their challenges. This approach has already been observed when designing collaborative systems for people with disabilities or facing unique challenges, *e.g.*, people who are caring for children or who are limited in mobility. Researchers should carefully consider the division of tasks between the human and the robot, assigning responsibilities based on their complementary strengths [13, 24]. For instance, in the case of workers with physical disabilities, robots can be designed to execute physically demanding tasks while the human focuses on cognitive tasks such as decision-making or problem-solving [15]. When working with individuals who have cognitive disabilities, researchers should frame the problem in a way that focuses on using robots to simplify complex tasks and provide step-by-step guidance. This approach allows the human worker to concentrate on the aspects of the job they can perform well and enjoy, such as predictable handwork in assembly tasks [20, 21]. Moreover, researchers should scope their work to prioritise the autonomy and agency of the human worker. Collaborative robots should be designed as tools that empower people to access meaningful work and participate more fully in society [10, 13, 15, 20]. This framing emphasises the importance of boosting the confidence and self-esteem through successful human-robot collaboration for a broad range of users [15, 24].

5.2 Methods for Empowerment

Prior research demonstrates that Participatory Design gives participants feelings of ownership of a design, thereby empowering them as co-creators [3].

Researchers should consider using experimental designs that simulate real-world human-robot collaboration scenarios to capture the complexities of actual work environments. There are a number of supporting technologies relevant to HRC research to enable effective simulations and evaluations with end-users, for example the use of virtual reality and augmented reality. These simulations can help identify specific empowerment factors that enhance collaborative efficiency and user satisfaction. Additionally, mixed-methods approaches, combining quantitative performance metrics and qualitative user experiences, can provide a comprehensive understanding of how empowerment influences human-robot interactions.

From an institutional perspective, researchers should explore collaborations with industries that have minimal exposure to robotic technology, potentially through hubs and incubators that help connect researchers and industry. Such partnerships can offer fresh insights into the challenges and opportunities of introducing robots in diverse settings. Engaging with these industries through pilot programs and field studies can yield valuable data on the practical impacts of empowerment in human-robot collaboration.

Furthermore, industries, institutions, and governments should look to successful models from other countries regarding the implementation of robotic technology. Learning from international policies and practices can help shape strategies that augment human workforce capabilities rather than replace them. This approach can promote a balanced integration of robots, ensuring that human workers feel empowered and valued in their evolving roles.

6 CONCLUSION

In this paper, we have presented insights from an academic workshop where researchers across various HRC research domains came together to outline how collaborative robots can or should empower people. On the basis of the full day workshop and subsequent analysis, we have outlined a first step towards a working framework for empowerment in HRC. This working framework consists of key characteristics, barriers for empowerment, and future pathways. With existing research calling for further investigations on the role of power in human-robot interaction, this working framework gives constructive insights into an expanding area of collaborative robots.

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