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Where Are *We At?* A Review of the State-of-the-Art of the Ethical Considerations in Human-Robot Collaboration

Tiziana C. Callari[1], Anne-Marie Oostveen[2], Ella-Mae Hubbard[1], Sarah Fletcher[2], and Niels Lohse[1]

[1]Intelligent Automation Centre, Wolfson School of Mechanical, Electrical and Manufacturing Engineering, Loughborough University, Loughborough, UK
[2]Centre for Robotics and Assembly, School of Aerospace, Transport, and Manufacturing (SATM), Cranfield University, Cranfield, UK

ABSTRACT

Human-robot collaboration (HRC) is revolutionising the future of manufacturing and service industries. Ethical research on HRC regards all issues of safeguarding humans from unintended and potentially unethical risks and hazards associated with collaborative robots (also known as cobots). Within the cobots domain, the term Roboethics has been coined to refer to the social and ethical aspects of the design, development, and employment of collaborative and intelligent robots, which could be clustered into four typologies: (1) robots as machines; (2) robots may have an intrinsic ethical dimension and be able to trigger emotions and feelings from users; (3) robots are seen as moral agents; (4) robots are an evolution of a new species, having a conscience and greater intellectual dimensions. This paper aims to provide a review of the available literature in the field to map the ethical aspects and concerns that are discussed in the HRC domain, taking into account the above Roboethics typologies. The paper will conclude by outlining an agenda for future ethical research in HRC.

Keywords: Collaborative robots, Ethics, Social robots, Industrial robots, Psychological well-being

INTRODUCTION

Robots are automating a wide range of professional activities in contemporary industries and services, such as healthcare, manufacturing, military operations and service industries. This trend is also reflected by steady growth in robot installations in industries around the world, with a prevalence in China, followed by Japan, USA, and then Europe (IFR, 2022).

Alongside the installation of new robots, industries are changing and challenging how work is going to be performed. Critically, unlike traditional industrial robots in Industry 3.0 where robots operated in separate spaces on the shop floor with minimal physical interaction with humans, in the so-called Industry 4.0, industries are moving towards cyber-physical systems integration and human-robot collaboration (HRC). HRC requires humans and robots to interact closely and collaborate with shared tasks in shared (physical) spaces towards a common goal. Collaborative robots (or cobots) are robots designed to assist workers in performing shared tasks in the same workspace, 'intelligently' interacting through either gesture or speech recognition (Cohen, Shoval, Faccio, & Minto, 2022). Ergonomic, as well as productivity and efficiency benefits are expected in future industries thanks to the synergic collaboration of humans robots. However, a number of ethical concerns are raised in HRC with impacts at micro-, meso-/organisational, and macro-/societal levels.

Ethical research on HRC regards all issues of safeguarding humans from unintended and potentially unethical risks and hazards associated with cobots (Decker, 2008). Within the HRC domain, the term Roboethics has been coined to refer to the social and ethical aspects of the design, development, and employment of collaborative and intelligent robots (Steinert, 2014; Veruggio & Operto, 2017). Four different typologies have been suggested. The first typology regards robots as machines, although sophisticated. In the second typology, robots may have an intrinsic ethical dimension to do good acts; ethical considerations in this classification are particularly relevant in the healthcare and social sectors. Humanoid and pet-type robots fall into this category. In the third typology, robots are seen as moral agents, and therefore have the ability to make decisions on their own. The last typology – fortunately, played only in the science fiction blockbuster movies – sees robots as an evolution of a new species, having autonomy, conscience, and greater intellectual dimensions (Steinert, 2014; Veruggio & Operto, 2017).

Although we are well aware that there is still no universal agreement as to what is ethically or morally correct, there is growing interest in developing – and even standardising – robot ethics (BS8611:2016). This paper aims to provide a review overview of available literature in the field to map the ethical aspects and concerns that are discussed in the HRC domain, taking into account the above Roboethics typologies. Methodologically, it will employ a narrative approach to identify which ethical concerns are discussed within each typology. The paper will conclude by outlining an agenda for future ethical research in HRC, specifically where current gaps emerge.

METHODOLOGY

We adopted a narrative approach for organising and analysing the literature, to highlight the state-of-the-art on ethical research in HRC. Narrative reviews are suited for understanding the status of knowledge of the researched phenomenon, identifying gaps and inconsistencies, and highlighting the significance of new research (Fan, Breslin, Callahan, & Iszatt-White, 2022; Paré, Trudel, Jaana, & Kitsiou, 2015).

The review was carried out considering studies published in peer-reviewed journals, books, and grey literature using the following relevant keywords: ethics OR roboethics OR "moral agency" AND "human-robot collaboration" OR "human-robot interaction" OR cobot* OR "collaborative robot*" OR "social robot*" OR "assistive robot* OR "military robot*".

The databases searched were: Web of Science, Scopus, Science Direct, Ebsco, American Psychological Association databases (PsycARTICLES), Medline, Journal Storage (JSTOR), and Google Scholar. The paper results were screened from the abstract, and the selected papers were saved in the reference management software EndNote^{x9} (©Clarivate Analytics) and then uploaded in NVivo (v.12 Pro for Windows, ©QSR International) for analysis. The Qualitative Content Analysis method (Schreier, 2012) was employed to code the literature material into a concept-driven coding frame mirroring the suggested Roboethics typologies. The analysis was performed collaboratively by this paper's co-authors.

Typology 1 – Robots Are Mere (Intelligent) Machines

This typology refers to considering the robots as mere machines, although sophisticated. This approach takes an instrumental view of the human-robot interaction (HRI), and therefore robots are conceived with "amoral robot agency" (Asaro, 2006, p. 11). Roboethics within this frame can be compared to Engineering Applied Ethics (Veruggio & Operto, 2017). In this section, we will address HRC in the manufacturing and military sectors.

Within the manufacturing industry, specific ethical questions that blue-collar workers are facing with regard to shop floor HRC are still under-explored (Fletcher & Webb, 2017; van Wynsberghe & Roeser, 2022). Most of the ethical debates around the industries of the future (4.0 and 5.0) centre around the concern of robots creating a jobless society, with labour displacement and/or replacement. Critically, the installation of robots will mainly aim to release the human workforce from those repetitive, heavy, and dangerous tasks, replacing manual tasks with more sophisticated cognitive and supervisory roles that will improve the efficiency and quality of industrial production (Moniz & Krings, 2016; Murphy, 2022). This trend will accelerate the need for novel HRC business models, requiring more qualified and skilled workers to accomplish complex and collaborative task configurations. Therefore, human operators will need to improve their technical and non-technical skills to keep up with the work demands (Rangraz & Pareto, 2020). Indeed, the literature is advocating for new roles involving workers in more creativity and problem-solving capabilities (Holford, 2019). Ethical considerations are posed on whether we shall assume that the employees of the future industrial robotics factories must all engage in more creative activities to retain their jobs, instead of being comfortable performing routine and non-creative tasks (van Wynsberghe & Roeser, 2022). Additionally, in the future, flexible working schedules might require specific training to support employees in managing their workloads and improving work-life and well-being (Martinetti, Chemweno, Nizamis, & Fosch-Villaronga, 2021).

Another well-known ethical concern in the HRC domain in industrial settings regards workers' physical well-being and safety. ISO standards that cover HRC (ISO10218:2011 parts 1 and 2; ISO/TS 15066:2016) and industrial applications of Human-Machine Interaction (HMI) research are challenged to advance theoretical and methodological models able to integrate and predict the complex safety-related relationship and collaboration of humans and robots at the factory floor. This includes not only the physical safety outcome of the actual human-robot dynamics, but also the psychological well-being of humans during the task-sharing interaction with robots (Fletcher & Webb, 2017). This regards the feelings and experiences human operators encounter in their relationship with robots, for which trust has been found to be an underlying key factor (Charalambous et al., 2016). Indeed, cobots may pose psychological harm (Fletcher & Webb, 2017), such as burnout and/or anxiety when interacting with them (van Wynsberghe & Roeser, 2022; Yam et al., 2022). In line with this, recent research is attempting to comprehend the role of emotions and embodied experiences associated with a subjective/perception of HRC (van Wynsberghe & Roeser, 2022).

Finally, the ethical issues of data sharing (regarding confidentiality and privacy) and performance data monitoring are pivotal in HRC in manufacturing settings (Fletcher & Webb, 2017; van Wynsberghe & Roeser, 2022). Industry 4.0 implies an ongoing exchange of data captured from sensors and robotics in interaction with humans on the factory floor and transferred to the middle and top management. How these data (involving human and robot performances at individual and collaborative levels) are managed still needs to be fully understood. Indeed, the ethical implications are to be fully represented to ensure that the captured human data not only comply with data protection protocols regarding informed consent, but also for which performance monitoring purposes these data are collected. The ethical implications of performance data monitoring warrant additional research and policy guidelines within manufacturing/industrial settings to help clarify the extent of the trade-off between performance, quality and well-being resulting from HRC.

The academic literature on the use of robots in the military sector predominantly addresses ethical questions focused on Lethal Autonomous Weapons Systems (LAWS), which are autonomous weapon systems that use robotics and artificial intelligence to identify, select, and kill targets without human intervention. These weapons have already been deployed on the battlefield (Rossiter & Cannon, 2022; Hwang & Song, 2022).

In contrast, other military robotic applications require collaboration with humans. Examples regard remote-controlled ground robots, in which robots are deployed for dull, dirty, and dangerous tasks such as saving lives by moving into potential danger zones ahead of or instead of humans and are changing modern warfare (Lin, Abney, Bekey, 2014). They perform tasks such as neutralising explosive devices, search and rescue in disaster areas and battlefields, equipment supply, surveillance and reconnaissance (through automated facial or image-recognition and object-detection capabilities), chemical, biological, radiological, and nuclear (CBRN) detection, or sniper detection. Indeed, disarming and disposing of bombs is one of the most potentially hazardous professional activities, and therefore was one of the first practical applications for robotics. Since their implementation in the 1970s, bomb disposal robots have undergone a considerable transformation, especially in their user control methods. Critically, modern Explosive Ordnance Disposal (EOD) robots are progressing towards virtual reality and advanced haptic sensory feedback controlled remotely to keep the operator safe.

These military robots offer great opportunities for different mission sets to improve soldier safety and reduce their cognitive burden. However, this might pose a danger: "*the more we rely on machines to relieve ourselves of cognitive responsibilities, the more we forget how to do important things*" (Jordan, 2016, p. 225). As an extent of military troops, the robots must not impose any extra workload on the team (Sanaullah, Akhtaruzzaman & Hossain, 2022).

Moral and ethical considerations in the HRC domain in military settings concern the worry that military operators can put too much trust in the robots. Those systems might not be able to adapt to the inevitable complexities of war. Critically, it is hard to differentiate an anomaly from a threat, distinguish valid from invalid targets and decide who is accountable for mistakes. Further, sensor data might be imperfect, with errors of both systematic and random nature (Ha, Yen & Balaguer, 2019). Robot safety and security are also vital concerns. Because a robotic system has sensors, actuators, drivers and controllers, it is vulnerable to hardware failure or intrusions such as virus attacks, hacking, or robot worms that block sensitive parts of the sensors and produce fake signals (Sanaullah, Akhtaruzzaman & Hossain, 2022). Finally, with fewer casualties among the own servicemen and servicewomen, robots could lower the cost of warfare, making the conflict between nations more likely.

Overall, the opinion in the literature is that no matter what kind of military robots we deal with (manual, semi-autonomous, autonomous), they must be supervised and human-controlled.

Typology 2 – Robots Have Ethical Dimensions

Ethical considerations of HRC in this classification are particularly relevant in the healthcare and social sectors, involving target patients, healthcare operators, and caregivers.

Socially assistive and companion robots are conceived and designed to engage on an emotional level because they are able to trigger social and emotional responses from their human users (de Graaf, 2016; Steinert, 2014). Indeed, they are often referred to as "affective humanoid social robots" (Shaw-Garlock, 2009; Steinert, 2014). Humanoid and zoomorphic robots (or robopets) may fall into this second typology (Steinert, 2014). Humanoid robots with anthropomorphic features can mimic various social interactions with humans, including natural communication, social learning and cooperation (Breazeal, 2004). Critically, they are designed based on the rules of human–human interaction to behave as if they have mental states, personalities and intentions (de Graaf, 2016; Steinert, 2014), and as such, be able to simulate feelings and act accordingly (Veruggio & Operto, 2017). For this reason, they may be considered "ethically considerable beings" (Steinert, 2014, p. 252).

These robots have started to be introduced in recent years to (1) aid patients in medical treatments, which could include interventions both in residential and in-home settings targeting healthcare patients, and/or adults with cognitive impairments such as dementia (Hebesberger *et al.*, 2016; Pedersen, Reid, & Aspevig, 2018). Furthermore, (2) robots are developed to help minimise older adults' social isolation and as such, act as home companions (Ienca, Jotterand, Vică, & Elger, 2016; Pedersen, Reid, & Aspevig, 2018).

In relation to (1), socially assistive robots as an aid in treatment may be further classified in: rehabilitation robots (used mainly in the physical rehabilitation of patients) (Mohebbi, 2020); service robots (used to complement the human caregivers in several direct cares, e.g. support of patients affected by dementia in memory-related activities of daily life) (Ienca, Jotterand, Vică, & Elger, 2016); and telepresence robots (used to provide remote monitoring through telephony and long-range remote control). The primary human-robot interaction (HRI) functions of these robots encompass all service-related requirements, such as dealing with emergencies, nutritional support, physical and memory-related assistance through cognitive or emotional stimulation, logging daily activities, and collaboration with healthcare staff, including exchanging data (Kim et al., 2021).

Regarding (2), social companion robots have been implemented to remediate social isolation among older adults and, therefore, enhance communicational and emotional capabilities with their users. Additionally, robopets are able to elicit and develop affective social interactions (see, for example, studies around companion-dog robots: (Konok, Korcsok, Miklósi, & Gácsi, 2018;) Krueger, Mitchell, Deshpande & Katz, 2021; Miklósi & Gácsi, 2012). Thus, human-animal interactions have been used as inspirations to recreate and build behaviour models for robopets (Miklósi & Gácsi, 2012). Indeed, animal behaviour is regarded to be simpler than human behaviour, and as such easier to design and implement in companion social robots.

The benefits of employing these assistive and companion robots are reported in the literature, both for the caregivers themselves (Persson, Redmalm, & Iversen, 2022) and for patients, especially targeting vulnerable people (such as patients affected by dementia). Agitation reduction, loneliness decrease, and improvement in social interaction are the main results that have been published to date (e.g., Bemelmans, Gelderblom, Jonker, & de Witte, 2012; Van Orden et al., 2021). Additionally, they could support older adults in increasing their sense of control and autonomy (Sharkey & Sharkey, 2012).

Ethical considerations with regard to privacy and surveillance issues are extensively discussed in the literature. Here, the focus mainly centres on the possibility of assistive robots monitoring, following and storing the patients' daily activities around the home. Additional concerns are raised in cases where the patient's mental state deteriorates further, and they become confused and/or panic in the presence of the robot (Sharkey & Sharkey, 2012).

Another ethical concern regards the problem of '*objectification*' of older adults, especially when involving assistive robots carrying out care tasks (Vandemeulebroucke et al., 2020). Indeed, greater attention should be given to prioritising older patients' welfare and health, besides the additional interest of reducing the caregivers' workload (and costs) (Decker, 2008; Sharkey & Sharkey, 2012).

Ethical concerns have been raised in relation to the feelings and emotions of attachment/detachment that users may experience in their interaction with companion robots. This issue was specifically investigated in patients affected by dementia, where the ethical challenge of deception emerged. Some patients misperceived the robopets as real animals and displayed feelings of attachment towards them (Koh, Ang, & Casey, 2021; Sharkey & Sharkey, 2012). The potential for deception should be minimised wherever possible, and caregivers should clearly present the robopet as a robot and refrain from referring to it as a real animal (Koh, Ang, & Casey, 2021).

Typology 3 – Robots Possess Moral Agency

This typology refers to those semi or fully autonomous robots that are designed, and have the ability to make decisions on their own, with no human intervention to take over (Floridi & Sanders, 2004; Steinert, 2014; Veruggio & Operto, 2017). Examples here may include the autopilot in aircraft, Lethal Autonomous Weapon Systems (LAWS), and self-driving cars.

How these robots are 'equipped' with a moral agency is not only the responsibility of the researchers/engineers and programmers, who might not master the appropriate ethical knowledge (Gordon, 2020). Many factors are at stake, which need to be modelled (the context, the environment, other relevant conditions, unforeseen circumstances, etc.). Currently, trolley dilemmas have been used to collect human decisions worldwide on several moral preferences and dilemmas, and how cultural differences may influence these decisions (Gold, Colman, & Pulford, 2014). Although there is still disagreement in the literature about whether trolley dilemmas represent the actual ethical challenge (Anderson & Anderson, 2011), these are employed to illustrate the morality concerns the future autonomous robot/automation shall have.

Critically, the design of moral agents should incorporate the dimension of '*autonomy*' (i.e. the possibility of free action), the '*sensibility to values and norms*' to act '*intentionally*' for the greater good, and the '*responsibility*' (Steinert, 2014; Sullins, 2006). The challenges raised concerning the attribution of 'responsibility as accountability' (Smith, 2015; Watson, 1995) are a major concern at professional (e.g., engineers, human factors experts), manufacturer, robot (e.g., if they are built with a 'conscience'), legal and societal levels. Indeed, the ethical liability of artificial moral agents regards answering questions related to *who* is responsible and for *what* and *for whom*. Smith (2015) has argued that responsibility is about *answerability*: "*a morally responsible agent is one who can intelligibly be asked to 'answer for' her attitudes and conduct*" (p. 104).

Typology 4 – Robots Are a New Species

Many early science-fiction films portrayed robots as an evolution of a new species, having autonomy, conscience, and greater intellectual dimensions. These fictional robots would take over the world, turning humans into enslaved people (Coeckelbergh, 2022; Gunkel, 2018). Nowadays, we refer to this type of robotics as depending on Artificial Super Intelligence (ASI), a type of AI that surpasses human intelligence and can perform any task better than a human. It self-learns and evolves with a consciousness of its own. ASI outperforms humans to achieve societal objectives and facilitate space exploration but can also threaten the very existence of the human race (Kanade, 2022). Luckily, these dystopian predictions have not materialised. Instead, we have seen robots being designed to become companions and collaborators. However, consumers may soon find it more challenging to distinguish embodied robots from human employees (Schmitt, 2020).

Recent literature shows that robotic science and engineering evolve rapidly with the expansion of biohybrid robotics research. Robots are being powered by living muscle tissue or cells. These biobots are safer around people and less harmful to their work environment (Webster-Wood et al., 2022; Mazzolai & Laschi, 2020). There is also continued progress in cyborg-type robots (Yokota et al., 2023; Heffernan, 2019).

Philosophers apply a moral approach to robot development, wondering how we should respond to robots that look like humans and behave as if they are alive. Prescott (2018) points out that "*robots are a new kind of entity, not quite alive and yet something more than machines*". Although still in its infancy, these developments will lead to new ethical dilemmas and questions. Is it acceptable to kick a robot? Should robots have rights? (Gunkel, 2018; Gordon & Pasvenskiene, 2021, Lima et al., 2020).

FUTURE RESEARCH AGENDA AND CONCLUSION

Since Asimov's famous novel on the laws of robotics, moral and ethical considerations have been greatly discussed in the literature; however, applications have been sparse. Critically, recent studies have started to investigate the extent to which ethics or moral action are to be designed into systems, whatever the typology considered. Much discussion follows regarding responsibility if something goes wrong (however that is judged), which is shared across autonomous systems and, much like human error, often judged with the benefit of hindsight.

We may reach a point where decisions are made quickly, excluding humans from the process. This will require a new level of trust in those systems. Moving the human to a supervisory role brings familiar challenges in terms of maintaining situational awareness, for example.

We know there is a skills shortage, particularly in tech companies. Work in this area can inform future job roles, work design and skills needed. We know that the future roles will be different to the ones we have now, and we need to start understanding a more appropriate approach to system design rather than simply replacing human roles with robots. They are different, and a successful system will exploit and enhance those differences.

Considering robot ethics should help us reflect on our approach in design, taking a user-centred approach and moving away from 'can we' to 'should we'.

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