



Tensions and antagonistic interactions of risks and ethics of using robotics and autonomous systems in long-term care

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ABSTRACT

The dwindling informal care support structure for the older population and the shortage of skilled nursing care staff propelled the rise of robotics and autonomous systems as potential solutions to meet the rising demands in long-term care. However, the nascent development in the governance of their applications could predispose older people to the negative ramifications of technological risks and ethical issues. This systematic review maps out four technological risks and five ethical issues in the deployment of robotics and autonomous systems in long-term care. Safety, privacy, liability, and adverse employment consequences to the existing nursing care workers were identified as major technological risks; while loss of autonomy, loss of human interaction and social connectedness, objectification and infantilisation, deception and social justice were identified as five major ethical issues related to the deployment of robotics and autonomous systems in long-term care. This review also identified antagonistic interactions between some of the technological risks and ethical issues that could offset each other. Findings from the review have implications for advancing knowledge on the governance of robotics in long-term care. Policy formulations and implementations would need to account for intricate issues that could arise from technological risks, ethical issues and their paradoxical interactions.

1. Introduction

Population ageing has become an existential issue in many countries, with the lack of trained manpower to care for the elderly being a long-standing issue that threatens the sustainability of long-term care provisions for the governments. Technologies such as robotics and autonomous systems are increasingly being deployed to address this issue. However, policies and regulations that could effectively govern these technologies remain opaque and unexplored in the current literature. This review seeks to address these gaps in the literature by understanding the nature of risks and ethical issues in the use of robotics and autonomous systems in long-term care as well as their tensions and antagonistic interactions.

To depict the extent of population ageing, Europe, North America, Latin America and East Asia, for instance, have seen rising life expectancies, advancement in medical care provision, falling total fertility rates, and increased dependency ratios facilitated by gradual retirement of the baby boom generation since 2010 (Guerin et al., 2015). It is projected that the world's older population (aged 65 and above),

including the 'oldest old' population (aged 80 and above) is going to triple from 8% in 2010 to nearly 25% by 2050 (World Health Organization 2011; United Nations 2017). In Europe, the old age dependency ratio is projected to increase by 21.6 percentage points from 29.6% in 2016 to 51.2% in 2070 (European Commission, 2018). While the increase of the older population in North America is projected to be less pronounced than Europe (United Nations 2017), emerging economies such as China, India, Mexico and Brazil will likely face the same fate as developed countries as the proportion of older people aged 65 and above is expected to triple from 2010 till 2050 (World Health Organization 2011; Angel et al., 2017). As countries and societies age, governments can no longer depend on the socio-economic advantages achieved during the demographic transition when countries can reap a demographic dividend from having a disproportionately larger young and thriving population at the bottom of population pyramid supporting the frail and old at the top. As the bottom of the pyramid shrinks and the dependency ratio increases, the demand for social security and social services inevitably increases, suggesting that more long-term care needs of the older people are likely to be left unmet.

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Long-term care is a wicked problem that intertwines with the demographic structure and labour market conditions of a country, with complex intermingling demand-side and supply-side forces that are constantly recalibrating to achieve equilibrium. The dwindling informal care support structure would imply that the state will have to strengthen long-term care provisions by increasing the capacity of formal institutions such as care centres and nursing homes (Bao et al., 2017). Nevertheless, these institutions are constantly struggling to adequately recruit and subsequently retain skilled nursing care staff (Stone and Harahan, 2010). To address this problem, robotics and autonomous systems are now actively implemented, experimented with and considered as potential solutions for long-term care in many countries to counter the double whammy of dwindling informal care support as well as the shortage of nursing staff in the formal institutions (Bonaccorsi et al., 2016). In addition, research and development in care robotics that took root since the 1970s in the US and EU have also intensified in recent years, with the most active player being Japan (Goeldner et al., 2015). For instance, Japan is one of the earliest adopters of robotics and autonomous systems in long-term care across the developed world where humanoid robots receive relatively higher public acceptance and positive ratings from the users and care personnel (Coco et al., 2018).

To date, the types of robotics and autonomous systems that have been deployed for long-term care range from social robots such as care robots for both personal physical assistance and cognitive and social help, monitoring robots, mobile servant robots, rehabilitation robots and therapy robots in both humanoid and non-humanoid forms; and assistive technology such as virtual assistants (Sharkey and Sharkey, 2012). Each of the above systems plays different care roles like monitoring interactions and emotional states, providing physical help and rendering rehabilitation support. They can also be used for helping healthcare experts complete mundane tasks to free them for better and more useful activities in holistic care that enable longer and more meaningful engagement with older people. Besides, these autonomous systems can also help to perform sophisticated tasks with greater precision and accuracy such as administering the right medication dosage and perform high-level rehabilitation activities for older people (Sharkey and Sharkey, 2012).

The use of robotics and autonomous systems in long-term care are generally perceived as an autonomy-enhancing tool for older people and burden-relieving assistant for the caregivers. Physically, robotics and autonomous systems can empower older people to be more independent, support the older people in the process of rehabilitation, preserve physical privacy and dignity of the older people, and enable them to maintain their normal routines and handle activities of daily living (Sharkey and Sharkey, 2012; Draper and Sorell, 2017; O'Brolchain, 2017). If the frailty levels of older people are still not overly compromised, the use of robotics and autonomous systems enable them to make basic care choices for themselves and remain community-mobile. For instance, robotic wheelchairs enable older people to take some control over their environment and they can be summoned anytime to carry older people to the toilet without having to depend on their caregivers all the time (Sharkey and Sharkey, 2012). The ability to maintain a sense of control is especially empowering for older people in the face of physical body degeneration. Emotionally, robotics and autonomous systems can also help to alleviate prolonged loneliness and distress feeling of older people who lack sufficient human contacts beyond those provided by their caregivers due to their infirmity and mobility constraints, especially for those admitted to formal care institutions (O'Brolchain, 2017). Psychologically, assuming that robotics technology has been programmed to act ethically, employing robotics and autonomous systems to deal with some of the caregiving tasks for the older people could potentially reduce the likelihood of psychological and emotional abuse and neglect which often stem from caregiver fatigue (O'Brolchain, 2017). Socially, robotics has also shown to allow older people to maintain social engagement. For instance, an observational study conducted in Australia that spanned five years in which

researchers recorded more than 10,000 behavioural reactions from the persons with dementia when they come in close contact with voice- and face-activated social robots. This study found improved care quality, emotional well-being and social engagement for older persons diagnosed with dementia (Chu et al., 2017). Besides empowering older people who need close supervision and assistance in long-term care, robotics and autonomous systems can help to ameliorate the care burden of caregivers as well. For example, assistive technology such as virtual assistants could help to free up some time for caregivers to leave home and tend to other tasks as it allows close monitoring and supervision of the older people to be conducted from a distance. Virtual assistants also enable the enhancement of human contacts between home-bound older people and their family members or friends (Sorell and Draper, 2014).

Nevertheless, like all other robotics and autonomous systems which have been deployed in other industries such as transport, medical care, emergency response, as well as in the police force and military (Pratt, 2014; Royakkers and van Est, 2015; Loh, 2018; Taeihagh and Lim, 2019), robotics and autonomous systems in long-term care can pose unforeseen and unintended consequences that could put the safety and security of patients or residents at the care facilities at risk. Human-robot interactions in care environments might also include "non-users", namely all people sharing the robot's space and not directly using the robot (Salvini et al., 2010). Another issue is robots altering their behaviours through algorithmic learning which can potentially pose risks and harms to human recipients (Li et al., 2007).

Empirics or reviews that dive into the discussion of immediate technological risks and long-term unintended social consequences to both individuals, as well as the institutions, have been limited to date. From the governance and public policy perspectives, risks could be consequential, organisational and behavioural. As such, it entails not only the immediate consequences of a novel technology to the users when it is not operating as per its designed standards, but also the wider implications and uncertainties that it could bring to the organisation and community (Brown and Osborne, 2013). A recent systematic review has consolidated arguments-based ethics literature to investigate various ethical issues that could emerge from robotics deployment in aged-care (Vandemeulebroucke et al., 2018). Albeit comprehensive, this review did not focus on the discussion of many direct and indirect technological risks in the deployment of robotics and autonomous systems that could manifest during the production process. Besides, primary studies that account for the perception and acceptability of the users towards robotics and autonomous systems were not included.

This systematic review aims to address the above literature and knowledge gaps by theorising and advancing the understanding of technological risks and ethical implications of robotics and autonomous systems in long-term care, besides teasing out their possible interactions. This endeavour is important to consolidate clear insights regarding the technological risks and ethical issues involved in the deployment of robotics and autonomous systems in sectors within and beyond health and long-term care, and help governments to design appropriate policies to govern these issues. To achieve our research aims, we designed the following review questions: "What are the technological risks and ethical issues that could emerge in the deployment of robotics and autonomous systems in long-term care? To what extent do some of the technological risks and ethical issues complement or contradict one another?" We employed a systematic review protocol to answer the above questions.

2. Theoretical background: risks and ethics in the context of emerging technology deployment in long-term care

In this review, we adopted established definitions of technological risk which is described in the literature as the potential for physical, economic and/or social harm/loss or other negative consequences stemming from adoption of a technology over its lifecycle (Renn and Benighaus, 2013; Li et al., 2018; Taeihagh and Lim, 2019). The

definition of risk that we chose to adopt in this review is akin to the conceptualisation of risk from the public policy and governance perspectives, in the context of emerging technology such as robotics and autonomous systems in sectors such as transport, long-term care and healthcare (Li et al., 2020; Tan and Taihagh, 2020). Hence, we considered not only direct consequence of an emerging technology to human when it is not functioning according to its projected standards or intended product designs, but also the larger sectoral risk to the health and long-term care industry, as well as wider risk to the community at large (Li et al., 2020; Brown and Osborne, 2013). In terms of ethical issues, we drew definitions and findings derived from emerging themes reported in a primary study that examined ethical concerns for emerging technology use in long-term care among various stakeholders in the US (Dorsten et al., 2009). See Table 1 for a brief explanations of technological risks and ethical issues associated with the applications of robotics and autonomous systems in LTC.

Table 1
Brief explanations of technological risks and ethical issues associated with the applications of robotics and autonomous systems in LTC.

Technological risks/ethical issues	Brief explanations
1. Safety	<ul style="list-style-type: none"> Robots and autonomous systems veering away from what they have been programmed to do as a result of autonomous learning, especially when deployed in an unstructured environment externally, or when experiencing mode transition internally.
2. Privacy and data security	<ul style="list-style-type: none"> Privacy entails both physical privacy and informational privacy. It relates to the extent to which surveillance functions of robotics and autonomous systems are infringing the personal spaces of carers and care recipients. Data security encompasses detailing the purpose and types of data collected, stipulating the level of access to the data by different stakeholders, and ascribing ownership of the data.
3. Liability	<ul style="list-style-type: none"> The right allocation of responsibilities and compensation risks in the event of accidents and harms imposed by robotics, autonomous systems during the caregiving process.
4. Effects to the incumbent workforce	<ul style="list-style-type: none"> The disruptive employment consequences created by the potential replacement of the existing social care workers by robotics and autonomous systems.
5. Autonomy and independence	<ul style="list-style-type: none"> The ability of care recipients to exhibit self-determination and assert preferences regarding the extent to which robotics and autonomous systems should be deployed in the caregiving process.
6. Social connectedness and human interactions	<ul style="list-style-type: none"> The possibility of compromising social interactions and human touch, which are needed to ease loneliness and preserve the well-being of the older people during the caregiving process, when robotics and autonomous systems are applied.
7. Objectification and infantilisation	<ul style="list-style-type: none"> Undermining the dignity of the care recipients by subjecting them to the command and control of robots and through robot behaviours that potentially infantilise them.
8. Deception and anthropomorphisation	<ul style="list-style-type: none"> Counterfeiting authentic social engagement and mislead care recipients to falsely believe that robotics solutions deployed to facilitate their care deliveries are genuine social companions.
9. Social justice	<ul style="list-style-type: none"> Preserving social equity by ensuring that the level of access to and mechanisms of distribution of robotics and autonomous systems in LTC benefit all segments of the older population.

3. Methods

Using a systematic review approach, this study systematically identified, analysed and synthesised literature that addresses technological risks and ethical issues that intersect with artificial intelligence and long-term care in the medical, bioethics and social sciences journal. A protocol was developed by first identifying the inclusion and exclusion criteria. These criteria help us to systematically exclude irrelevant studies and include the highly relevant ones by scanning the titles and reading the abstracts of each study generated from the search process. Thereafter, we developed a search string through multiple rounds of brainstorming and discussion among the review team members and executed the search on the relevant social sciences and public health academic databases. After identifying the studies that fulfil our initial inclusion and exclusion criteria, we developed a data extraction frame and performed data extraction for all included studies. All studies were also critically appraised for their quality. Finally, we analysed the data from the data extraction table using a thematic synthesis approach. The types of autonomous systems that this review seeks to examine are autonomous and intelligent social robots, care robots and their progenitors which are capable of deep learning and may not have been extensively deployed in most countries. We did not examine other more commonly deployed assistive technologies because the risks and uncertainties involved in the deployment of autonomous and intelligent social robots would be far greater than assistive technologies such as wearable devices.

3.1. Inclusion and exclusion criteria

Three inclusion criteria and four exclusion criteria were stipulated in the process of evidence search in identifying studies that are relevant to the scopes of this systematic review. The first inclusion criteria entails searching for the literature that either entirely or partially discuss technological risks and ethical issues of autonomous systems within the context of long-term care and/or social care for older people. The second inclusion is related to study types, under which it was decided that journal articles, book chapters and conference proceedings would be included in the review. These studies included both empirical studies and conceptual studies that discuss the various technological risks and ethical issues that arise as a result of autonomous systems deployment in long-term care. Third, we included only studies published since 2000 and in English language, on the notion that studies published prior to 2000 and in other languages are scarce. The exclusion criteria, are as follows: Firstly, we exclude studies that merely examine the applications of robotics and autonomous systems in long-term care without discussing risks and ethical issues of autonomous systems in long-term care are excluded. Secondly, studies that discuss risks and ethical issues of robotics and autonomous systems not within the contexts of old age and long-term care are excluded. Thirdly, opinion pieces, commentaries, op-eds and letters to editors were excluded. Finally, we excluded studies published prior to 2000 and not in English language.

3.2. Search strategy and information sources

The evidence search process first entailed the development of a comprehensive search string that aims to capture literature that is partially or entirely focusing on the discussion of risks and ethical issues concerning the implementation of robotics and autonomous systems in long-term care. Two sets of keyword searches are developed (see Table 2). The first set of keywords captured various concepts and progenitors of autonomous systems and artificial intelligence, while the second set of keywords captured various types of old age concepts and long-term care. All the authors collectively develop these two comprehensive sets of keywords through ongoing discussion. In addition, the development of the first set of keywords is based on a taxonomy of artificial intelligence that has been developed based on synonyms of

Table 2
Search string developed for the systematic review.

The first set of keywords (Concepts and progenitors of AI)	The second set of keywords (Concepts related to old age and long term care)
"autonomous system" OR "autonomous systems" OR "artificial intelligence" OR "AI" OR "distributed artificial intelligence" OR "computational intelligence" OR "neural network" OR "cybernetics" OR "machine learning" OR "deep learning" OR "expert systems" OR "random forest" OR "random decision forest" OR "bayesian network" OR "reinforcement learning" OR "ambient intelligence" OR "artificial systems" OR "colony optimization" OR "colony optimisation" OR "agent based model" OR "agent-based model" OR "evolutionary learning" OR "evolutionary strategy" OR "evolutionary strategies" OR "evolutionary programming" OR "feedforward networks" OR "fuzzy logic" OR "fuzzy rule" OR "fuzzy rules" OR "fuzzy system" OR "fuzzy systems" OR "genetic algorithm" OR "genetic algorithms" OR "genetic programming" OR "hybrid intelligent system" OR "hybrid intelligent systems" OR "intelligent agent" OR "intelligent agents" OR "support vector machine" OR "swarm intelligence" OR "swarm optimization" OR "social robots" OR "socialrobots" OR "social robot" OR "socialrobot" OR "care robot" OR "carerobot" OR "care robots" OR "carerobots" OR "botcare"	"long term care" OR "longterm care" OR "social care" OR "socialcare" OR "dementia care" OR "dementia care" OR "palliative care" OR "palliativecare" OR "assistive care" OR "assistivecare" OR "old age" OR "oldage" OR "retired" OR "older people" OR "olderpeople" OR "elder" OR "terminally ill" OR "senile" OR "end of life"

"artificial intelligence" available in the literature and the computational techniques used in building autonomous systems (Davis et al., 2016; Abbas et al., 2015). Following this, we conducted a systematic database search (Scopus and PubMed) based on the search strings developed. We also searched Web of Science and all its constituent databases (Science Citation Index, Social Sciences Citation Index, Arts & Humanities Citation Index, Conference Proceedings Citation Index, Book Citation Index and Emerging Sources Citation Index). In addition, we performed a hand search of relevant literature from four key Artificial Intelligence (AI) journals (*AI & Society*, *International Journal of Social Robotics, Ethics and Information Technology*) that focus on the social sciences aspect of AI, including risks and governance.

3.3. Data extraction and data charting process

A data extraction framework that includes information/items such as the objectives and, methods/design of the research, types of robotics and autonomous systems examined, technological risks and ethical implications was constructed. This framework was created by the first author based on ongoing discussion with the second and third authors until a unanimous agreement is reached. Relevant information within the literature that fit within the scopes of this review were extracted in a data table to aid the data analysis process. The first and second authors were involved in data extraction and charting the information into a spreadsheet. Both authors subsequently cross-check a random selection of papers to ensure consistency and validity of the data extracted to the spreadsheet based on the above data extraction framework.

3.4. Critical appraisal of individual sources of evidence

All the included studies were critically appraised to evaluate the

quality of the evidence as well as to ascertain the extent of rigour for each individual study. As the pool of evidence in this review is highly heterogeneous—comprising single country and multiple countries case studies through the use of qualitative techniques such as focus group discussion, participant observation, analysis of secondary information, observational studies (cross-sectional surveys and mixed-method surveys), comprehensive literature review and conceptual studies—the challenge was to identify a generic critical appraisal tool that would be applicable when evaluating the quality of the above stated studies. After referring to various types of tools used for evidence appraisal in systematic reviews, we utilised the Crowe's critical appraisal tool (CCAT) as it enables a diverse range of research design to be evaluated and offers a high degree of reliability (Crowe et al., 2011, 2012). The CCAT has eight category items (Preliminaries, Introduction, Design, Sampling, Data Collection, Ethical Matters, Results and Discussion), with each category item scoring five points and a total aggregate score of 40. The CCAT User Guide offered a detailed descriptions and references on how each category item can be scored (Crowe, 2013). (See Supplementary Data for details).

3.5. Synthesis of results

A thematic synthesis was employed as the data analysis frame in this systematic review, and the data analysis went through three-stages – line-by-line coding, formulation of descriptive themes and development of analytical themes (Thomas and Harden, 2008). Major themes were first derived through an intense and thorough line-by-line reading of all the relevant narratives on technological risks and ethical issues of robotics and autonomous systems in long-term care extracted from the primary studies and organised in a data table by the first author. Thereafter, descriptive themes were formulated from a direct interpretation of the narratives and categorised as either technological risks or ethical issues. After the formulation of descriptive themes, analytical themes were developed through a closer examination of the symbolic meanings and relationships between each of the descriptive themes. It was during this analytical stage that we discovered inherent tensions and dilemma between some categories of technological risks or ethical issues that warrant closer examination and deeper analytical reflection. While these categories of risks and ethical issues are well justified in their own right, they resulted in certain contradictions when practised and applied concurrently and has various implications to long-term care. To study how these interaction effects, we examined how paradoxical relationships were formed between different categories of risks and ethical issues when they are applied concurrently in the actual care setting in order to determine their points of contention. This process enabled us to understand the underlying complexities of risks and ethical issues related to the deployment of robotic and autonomous systems in long-term care under various unique care circumstances. Besides, analysing these interactive dynamics also helped us to frame various dilemmic situations that might create repercussions to the care recipients, care givers and care providers. Throughout the data synthesis process, the first and third authors independently conducted the preliminary round of data analysis. The second author audited the analysis to ensure coherence. This process went through several iterations of refinement through several rounds of discussion among the three authors to first categorise the narratives and the underlying meanings under different individual themes of risks and ethical issues, before determining the dilemmic situations and tensions identified from different categories of risks and ethical issues.

4. Findings

4.1. Study contexts and characteristics

This review identified a total of 33 studies that fulfilled the inclusion criteria and were included in the final synthesis. Fig. 1 reported the

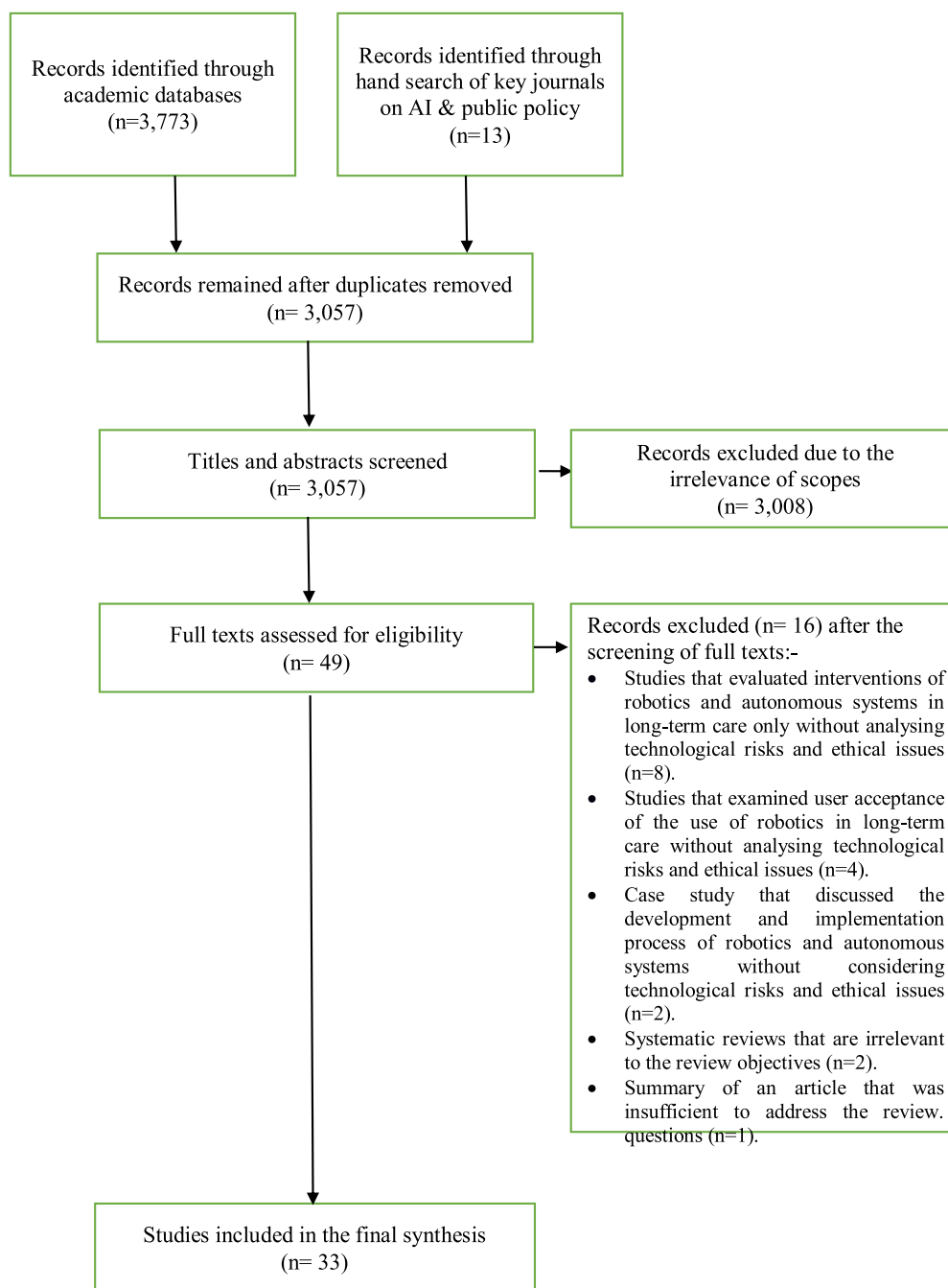


Fig. 1. PRISMA flow diagram of the literature search, selection process and reasons for exclusion.

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart that documented the details of evidence search processes at various stages. The PRISMA statement was developed to guide the reporting of systematic reviews and meta-analyses (Moher et al., 2009).

Among the included studies, 11 studies are primary studies that involved data collection methods such as qualitative interview, focus group discussion, questionnaire survey or participant observation, while the other 22 studies are secondary studies that include country-level case studies, review studies or conceptual studies of technological risks and ethical discussion. All 33 studies are mainly reported in 11 countries, namely, the US, Canada, the UK, Germany, Finland, France, The Netherlands, Australia, Italy, Japan and Taiwan. In terms of the population of interests or perspectives in which these studies are adopting, seven studies surveyed older people with dementia or

institutionalised older people (Pfadenhauer and Dukat 2015; Moyle et al., 2016; O'Brolchain, 2017; Ienca et al., 2018; Metzler et al., 2015; Ienca et al., 2016; Moro et al., 2018), three studies surveyed older people from the general population (Laitinen et al., 2016; Frennert and Östlund, 2014; Etzioni and Etzioni, 2017), nine studies surveyed either care personnel or a combination of formal/informal caregivers and older people (Rantanen et al., 2018a; Rantanen et al., 2018b; Jenkins and Draper, 2015; Jenkins and Draper, 2014; Draper et al., 2014; Draper and Sorell, 2017; Khaksar et al., 2016; Sorell and Draper, 2014; Bedaf et al., 2016), while 14 studies examined various stakeholders from the entire long-term care system (Scheutz, 2013; Fosch-Villaronga and Virk, 2017; Chou et al., 2018; Fosch-Villaronga and Roig, 2017; Vandemeulebroucke et al., 2018; Matsuzaki and Lindemann, 2016; Sharkey and Sharkey, 2012; Sedenberg et al., 2016; Sharkey, 2014; Royakkers and van Est, 2015; Stahl and Coeckelbergh, 2016; Salvini et al., 2010; Decker, 2008;

Nambu, 2016). In terms of the nature of long-term care settings, slightly more than half of the studies examined a wide range of aged care settings from home-based, community-based to residential-based (Pfadenhauer and Dukat, 2015; Rantanen et al., 2018a; Rantanen et al., 2018b; Moyle et al., 2016; O'Brolchain, 2017; Ienca et al., 2018; Fosch-Villaronga and Virk, 2017; Metzler et al., 2015; Ienca et al., 2016; Fosch-Villaronga and Roig, 2017F; Khaksar et al., 2016; Vandemeulebroucke et al., 2018; Sharkey and Sharkey, 2012; Moro et al., 2018; Sharkey, 2014; Royakkers and van Est, 2015; Bedaf et al., 2016), while the other half of the studies do not clearly specify the type of long-term care setting in which the research was based on (Scheutz, 2013; Jenkins and Draper, 2015; Laitinen et al., 2016; Jenkins and Draper, 2014; Draper et al., 2014; Draper and Sorell, 2017; Frennert and Östlund, 2014; Etzioni and Etzioni, 2017; Chou et al., 2018; Sorell and Draper, 2014; Matsuzaki and Lindemann, 2016; Sedenberg et al., 2016; Stahl and Coeckelbergh, 2016; Salvini et al., 2010; Decker, 2008; Nambu 2016) (See appendix for details).

Table 3 outlined the studies that examined various technological risks and ethical issues identified in this review.

Table 3

Evidence reporting on various technological risks and ethical issues identified in the systematic review.

Technological Risks / Ethical Issues	Evidence
Safety	(Sharkey and Sharkey, 2012; Draper and Sorell, 2017; Salvini et al., 2010; Etzioni and Etzioni, 2017; Fosch-Villaronga and Roig, 2017; Fosch-Villaronga and Virk, 2017; Ienca et al., 2016; Jenkins and Draper, 2014; Khaksar et al., 2016; Matsuzaki and Lindemann, 2016; Stahl and Coeckelbergh, 2016)
Privacy and data security	Sharkey and Sharkey, 2012; Draper and Sorell, 2017; Royakkers and van Est, 2015; Etzioni and Etzioni, 2017; (Fosch-Villaronga and Roig, 2017; Fosch-Villaronga and Virk, 2017); Ienca et al., 2016; Jenkins and Draper, 2014; Matsuzaki and Lindemann, 2016; Stahl and Coeckelbergh, 2016; Bedaf et al., 2016; Chou et al., 2018; Ienca et al., 2018; (Jenkins and Draper, 2015); Sedenberg et al., 2016; Sharkey 2014
Liability	Sharkey and Sharkey, 2012; O'Brolchain, 2017; (Fosch-Villaronga and Roig, 2017; Fosch-Villaronga and Virk, 2017); Matsuzaki and Lindemann, 2016; Chou et al., 2018; Nambu, 2016
Impact on the incumbent workforce	Khaksar et al., 2016; Stahl and Coeckelbergh, 2016; Chou et al., 2018; Metzler et al., 2015; Pfadenhauer and Dukat, 2015
Autonomy and independence	Draper and Sorell, 2017; Vandemeulebroucke et al., 2018; (Fosch-Villaronga and Roig, 2017; Fosch-Villaronga and Virk, 2017); Ienca et al., 2016; Stahl and Coeckelbergh, 2016; Bedaf et al., 2016; Chou et al., 2018; Ienca et al., 2018; Jenkins and Draper, 2015; (Draper et al., 2014); Rantanen et al., 2018a
Social connectedness and human interaction	Sharkey and Sharkey, 2012; Draper and Sorell, 2017; O'Brolchain, 2017; Vandemeulebroucke et al., 2018; Etzioni and Etzioni, 2017; (Fosch-Villaronga and Roig, 2017); Stahl and Coeckelbergh, 2016; Sharkey 2014; Laitinen et al., 2016; Rantanen et al., 2018b
Objectification and infantilisation	Sharkey and Sharkey, 2012; (Fosch-Villaronga and Virk, 2017); Ienca et al., 2016; Chou et al., 2018; Moyle et al., 2016
Deception and anthropomorphisation	Sharkey and Sharkey, 2012; Royakkers and van Est, 2015; Vandemeulebroucke et al., 2018; Etzioni and Etzioni, 2017; Chou et al., 2018; Sharkey, 2014; Laitinen et al., 2016; Frennert and Östlund, 2014; Moro et al., 2018
Social justice	Vandemeulebroucke et al., 2018; Ienca et al., 2016; Khaksar et al., 2016; Chou et al., 2018; Ienca et al., 2018; Laitinen et al., 2016

4.2. Critical appraisal of the sources of evidence

Of the 33 studies included in this review, nine studies were assessed to be of high quality, with a total score of at least 36 or above (Rantanen et al., 2018a, 2018b; Jenkins and Draper, 2015; Ienca et al., 2018; Draper and Sorell, 2017; Frennert and Östlund, 2014; Vandemeulebroucke et al., 2018; Moro et al., 2018; Bedaf et al., 2016). Based on the CCAT appraisal guidelines, these studies have clear stipulation of study background, objectives, research design and methods that fully or partially address the issue of biases, sampling and data collection method, results that interpret the analysis and explain both expected and unexpected outcomes, discussion that situate the analysis in the context of the current evidence, and conclusion that highlights strengths, limitations and future research directions. However, not all nine studies thoroughly reflect on ethical matters related to the participants (informed consent, privacy and confidentiality) and the researchers (researcher biases and their relationships with the participants), and all nine studies also failed to discuss the generalisability of their research findings especially to other socio-cultural contexts, which are some of the limitations. The other 24 studies that scored lower than these nine studies do not thoroughly address all the above issues, particularly issues related to biases, design, data collection and sampling in their methods sections. This difference is inevitable and will be reflected in the total score as CCAT is a critical appraisal tool that account for diverse studies that employ different design (Crowe et al., 2011, 2012), and lower scores are especially prevalent for conceptual studies and literature reviews that do not emphasise on design and data collection protocol (Scheutz, 2013; Laitinen et al., 2016; O'Brolchain, 2017; Frennert and Östlund, 2014; Metzler et al., 2015; Etzioni and Etzioni, 2017; Ienca et al., 2016; (Fosch-Villaronga and Roig, 2017); Sorell and Draper, 2014; Sharkey and Sharkey, 2012; Sedenberg et al., 2016; Sharkey 2014; Royakkers and van Est 2015; Stahl and Coeckelbergh 2016; Salvini et al., 2010; Decker, 2008). Despite this, we have decided to include all 33 studies in the synthesis process as they offer important insights to the review questions posed, not only based on the empirical data, but also the authors' strong expertise in the field of robotics and autonomous systems (for details regarding the score for each study, see Supplementary Data)

4.3. Functional analysis of robotics and autonomous systems in long-term care

The robotics and autonomous systems discussed in all the included studies can be categorised into five types. These include companion robots, rehabilitation robots, mobility robots, mobile servant robots and tele-operated monitoring robots. Table 4 summarises the different examples, activities performed, and functions for each of the identified robotics or autonomous systems.

4.4. Technological risks in the application of robotics and autonomous systems in long-term care

4.4.1. Safety

Safety of the applications of robotics and autonomous systems in long-term care settings is one of the most significant risk concerns for the carers and care recipients (Sharkey and Sharkey 2012; Draper and Sorell 2017; Salvini et al., 2010; Etzioni and Etzioni 2017; Fosch-Villaronga and Roig, 2017; Fosch-Villaronga and Virk, 2017; Ienca et al., 2016; Jenkins and Draper 2014; Khaksar et al., 2016; Matsuzaki and Lindemann 2016; Stahl and Coeckelbergh 2016). Participatory research conducted in long-term care settings in three European countries highlighted that the harm that could be inflicted by social robots is a risk factor that older people and carers are highly concerned with (Draper and Sorell 2017; Jenkins and Draper 2014). Due to the greater physical vulnerability of older people, non-maleficence is suggested to be the foremost principle that needs to be upheld when deploying robotics and

Robotics/ Autonomous systems	Examples	Activities performed	Functions
Companion robots	Paro (Chou et al., 2018; Frennert and Östlund 2014; Ienca et al., 2016; Jenkins and Draper 2015; Khaksar et al., 2016; Laitinen et al., 2016; Moyle et al., 2016; O'Brolchain 2017; Sharkey 2014; Sharkey and Sharkey 2012; Sorell and Draper 2014; Vandemeulebroucke et al., 2018; Royakkers and van Est 2015), AIBO ((Draper et al., 2014); Frennert and Östlund 2014; Khaksar et al., 2016; Jenkins and Draper 2014; O'Brolchain 2017; Royakkers and van Est 2015; Sharkey 2014; Sharkey and Sharkey 2012; Vandemeulebroucke et al., 2018), Care-O-Bot (Bedaf et al., 2016; (Draper et al., 2014); Draper and Sorell 2017; Ienca et al., 2016; Sharkey 2014; Sorell and Draper 2014; Vandemeulebroucke et al., 2018), NeCoRo (Khaksar et al., 2016; Sharkey 2014; Sharkey and Sharkey 2012), iRobot (Sharkey and Sharkey 2012), Pleo (O'Brolchain 2017; Sharkey 2014; Sharkey and Sharkey 2012), Primo Puel (Sharkey 2014; Sharkey and Sharkey 2012)	<ul style="list-style-type: none"> • Verbal or non-verbal interactions with older people. • Elicit emotive responses. 	Companionship
Rehabilitation robots/ manipulator arms	Hybrid Assistive Limb (Sharkey 2014; Sharkey and Sharkey 2012)	<ul style="list-style-type: none"> • Automatically move a muscle based on the nerve signals detected. 	Rehabilitative
Wheelchair/ mobility robots	RIBA (Royakkers and van Est 2015; Sharkey 2014; Sharkey and Sharkey 2012; Sorell and Draper 2014)	<ul style="list-style-type: none"> • Pick up humans and carry them from bed to the wheelchair. 	Assistive
Mobile servant robots	“My Spoon” automatic feeding robot (Sharkey 2014; Sharkey and Sharkey 2012; Sorell and Draper 2014; Vandemeulebroucke et al., 2018), “Sanyo” electric bathtub robot (Sharkey 2014; Sharkey and Sharkey 2012; Vandemeulebroucke et al., 2018), uBot5 (Sharkey and Sharkey 2012) uBot5 (Sharkey and Sharkey 2012) Pearl (Frennert and Östlund 2014; Sharkey and Sharkey 2012; Vandemeulebroucke et al., 2018) Care-O-Bot (Bedaf et al., 2016; (Draper et al., 2014); Draper and Sorell 2017; Ienca et al., 2016; Sharkey 2014; Sorell and Draper 2014; Vandemeulebroucke et al., 2018)	<ul style="list-style-type: none"> • Assist older people with activities of daily living (feeding, bathing). • Pick up and move objects around. • Remind older people about routine activities. • Delivery of medicine. 	Assistive
Tele-operated monitoring robots	RP-6 (Sharkey and Sharkey 2012), RP-7 (Sharkey and Sharkey 2012) uBot5 (Sharkey and Sharkey 2012) Care-O-Bot (Bedaf et al., 2016; (Draper et al., 2014); Draper and Sorell 2017; Ienca et al., 2016; Sharkey 2014; Sorell and Draper 2014; Vandemeulebroucke et al., 2018) RoboLAB10 (Sharkey and Sharkey 2012)	<ul style="list-style-type: none"> • Facilitate doctor-patient interactions remotely. • Monitor older people for falls. • Check for signs of stroke. • Remote video monitoring. • Provide verbal reminders of medical appointments for the older people at pre-determined times and dates. • Render physical assistance to immobile older people and perform physical tasks for them. 	Monitoring

autonomous systems in long-term care settings (Ienca et al., 2016; Stahl and Coeckelbergh 2016). For instance, some of the most common sources of danger that could be exposed to person carrier robots are unstructured environments that are extrinsic to the device; and mode transition that is intrinsic to the device (Fosch-Villaronga and Roig, 2017). This principle of non-maleficence is usually paired with the principle of beneficence, i.e. promoting what is in the best interest of the user. In the context of the application of robotic devices in long-term care settings, the application of this principle requires a careful assessment of the balance between medical and psychosocial benefits, and potential risks or distress (Ienca et al., 2016).

Other aspects of safety in the applications of robotic devices that need to be accounted for in the long-term care settings include safety in communication, presence and behaviour as well as the accessibility of an emergency alarm for the users in the event of crises (Khaksar et al., 2016). As care robots are learning robots, there are concerns pertaining to the unintended consequences that could result from the incessant pace of autonomous learning of robots from the surroundings (Salvini et al., 2010; Etzioni and Etzioni 2017; Fosch-Villaronga and Roig, 2017; Fosch-Villaronga and Virk, 2017; Ienca et al., 2016; Matsuzaki and Lindemann 2016). As some machines and robots possess deep learning capabilities,¹ and when they are trained continuously by the massive amount of input from trolls, they could veer from what they have been originally programmed to do in the care settings (Etzioni and Etzioni 2017). The ability to adapt and learn in the face of new input received

¹ Deep learning is an ability of machines to perform inferential analysis and pick up recurrent patterns in digital representations of numbers, texts, audio, images and other forms of data through iterative exposures and trainings using big data (Hof, 2018).

and changing norms and circumstances in the interactive care settings with human users can lead to emergent modes of robot behaviours that are unpredictable. Hence, robot designers, engineers and programmers, hence, will not be able to fully predict the full gamut of responses of these learning care robots. Though safety design principles such as collision avoidance, tipping over prevention and safe navigation can be inherently fixed, autonomous robot behaviours resulting from emerging circumstances can lead to unpredictability in risk assessments (Salvini et al., 2010; Fosch-Villaronga and Virk, 2017). Furthermore, open software programmes that crowdsources for third-party innovation will face infinite possibilities of robot behaviour modifications, and hence pose even more concerns when these autonomous systems are deployed in residential and non-residential care facilities (Matsuzaki and Lindemann 2016). Therefore, with thorough risk identification, risk analysis, risk elimination and consistent risk management efforts that account for both the technical and ethical-social considerations, machines and autonomous systems in long-term care settings should first obey the non-maleficence principle and not increase risks and harms (Ienca et al., 2016).

4.4.2. Privacy and data security

Privacy of both carers and recipients of care emerged as another major risk in the use of robotics and autonomous systems in long-term care (Sharkey and Sharkey 2012; Draper and Sorell 2017; Royakkers and van Est 2015; Etzioni and Etzioni 2017; Fosch-Villaronga and Roig, 2017; Fosch-Villaronga and Virk, 2017; Ienca et al., 2016; Jenkins and Draper 2014; Matsuzaki and Lindemann 2016; Stahl and Coeckelbergh 2016; Bedaf et al., 2016; Chou et al., 2018; Ienca et al., 2018; Jenkins and Draper, 2015; Sedenberg et al., 2016; Sharkey 2014). While data sharing by robotics and autonomous systems are necessary to ensure that care recipients receive seamless and effective care, they introduce

many privacy concerns (Bedaf et al., 2016). In various focus group discussions conducted across three European countries, elderly participants voiced their fear and concern of being monitored in an intrusive manner (Jenkins and Draper 2015). As robots could potentially make continuous video and sound recordings of the users, older people voiced robotic applications as a form of forceful intrusion and 'Big Brother' surveillance of every snippet of their lives (Draper and Sorell 2017). Intrusive monitoring can violate personal privacy and pose discomfort to the recipients of care (Sharkey 2014). Carers discussed privacy in relation to formulas and routines that they took to be embedded in their professional codes of conduct and good practices, and raised concerns regarding unwelcome intrusion or surveillance (Draper and Sorell 2017). In the context of long-term care, most privacy issues pertain to the violation of physical privacy and informational privacy (Sharkey and Sharkey 2012; Draper and Sorell 2017; Royakkers and van Est 2015; Etzioni and Etzioni 2017; Ienca et al., 2016; Matsuzaki and Lindemann, 2016; Stahl and Coeckelbergh 2016; Bedaf et al., 2016; Chou et al., 2018; Ienca et al., 2018). Physical privacy is defined as 'capacity to demarcate one's personal physical space' while information privacy is defined as 'capacity to seclude sensitive, confidential or private information' (Ienca et al., 2018). The ability of high-performance sensors and video cameras to transfer real-time data to anyone who is monitoring the systems pose concerns about invasion of physical privacy (Matsuzaki and Lindemann 2016). Also, robots intruding the personal space of care recipients when they are bathing or dressing are seen as a violation of physical privacy for older people (Sharkey and Sharkey 2012). As regards to informational privacy, the advent of much larger server capacities nowadays such as cloud computing for sensor fusion and the disproportionate amount of sensitive data and video recordings collected from users and recipients could predispose care recipients to privacy breaches more easily (Fosch-Villaronga and Virk, 2017; Ienca et al., 2018). Adjacent issues related to such extensive and widespread surveillance include reasons behind the recordings being made or data that are collected, content of the recordings and data, ownership and access of these recordings and data, as well as the duration of data storage in the system's platform (Sharkey and Sharkey 2012; Draper and Sorell 2017; Royakkers and van Est 2015; Stahl and Coeckelbergh 2016; Chou et al., 2018). The data captured by robotics and autonomous systems deployed in long-term care settings cover a significant amount of an old person's life at the end of the developmental curve. This information is highly sensitive and intimate especially when it comes to data collected towards the end-of-life of the care recipients. If these data are breached for unsolicited purposes that are detrimental and malicious, it will result in strong distrust from the care recipients and their families, as well as negative publicities for the care institutions (Ienca et al., 2016). Apart from informal carers, the privacy of visitors can be undermined as the data recorded by sensors and internet-of-things devices on robots will capture private conversations and activities held in these homes, generating unprecedented knowledge about both the care recipients and their visitors (Sedenberg et al., 2016). Further complicating the privacy issues are complex situations such as collecting information from persons with Dementia and Alzheimer's Disease who are not aware of the information being collected from them, despite consent given by their next-of-kin (Sharkey and Sharkey 2012; Royakkers and van Est 2015), and who should be given the right to access their collected data as far as abuse and negligence are concerned (Etzioni and Etzioni 2017). The intricate issues concerning privacy to both carers and care recipients are also reflected in the tensions that exist in the care triad which comprises the formal carers, informal carers and robots. The extensive personal and sensitive health information that formal carers can access from care robots in the long-term care settings may risk being leaked to other residents in the facilities. Besides, the information advantage possessed by formal carers may also exacerbate power differences between formal and informal carers, creating unnecessary hierarchies where robots possess much more information about older people as opposed to informal carers. The risk of strained relations

between formal carers, informal carers and users are compounded by the nature of information management in healthcare settings, where confidentiality and non-disclosure of information are strictly adhered to (Jenkins and Draper 2014).

4.4.3. Liability

The third major technological risk that was widely discussed is liability (Sharkey and Sharkey 2012; O'Brolchain 2017; Fosch-Villaronga and Roig, 2017; Fosch-Villaronga and Virk, 2017; Matsuzaki and Lindemann 2016; Chou et al., 2018; Nambu 2016). The most salient issue in liability is about which party should be held responsible for accidents or harms imposed by care robots on the care recipients and carers (Sharkey and Sharkey 2012; Fosch-Villaronga and Virk, 2017; Chou et al., 2018; Nambu 2016). For instance, there are no clear rules and guidelines to date in specifying which party should be held responsible should robots inflict harm on the older people (Chou et al., 2018). For example, in case of a false alarm, the care robot could call for an ambulance, but the cost to the hospital or insurer will most likely be borne by the person being cared for. This is a classical scenario of a moral hazard, in which one party controls decisions about resources, but another party bears most of the benefits or burdens (O'Brolchain 2017). This is closely related to the principal-agent problem, in which one group or person (the principal) appoints another (the agent) to act in the former's interest. There is always a risk that the agent will not act in the principal's interest. Besides, if an older person in an exoskeleton inflicts harm on or injures the carers, should the older people, formal care institution, or robot manufacturers bear the brunt of compensation (Sharkey and Sharkey 2012)? The rapid development of robotics technology is making classifications and the governance of liability to be extremely intricate (Fosch-Villaronga and Roig, 2017), with both civil and criminal liabilities involved in the deployment of social robots becoming more complex (Nambu 2016). The fundamental principle of product liability rules asserts that robot manufacturers or producers should be primarily accountable for the robots' behaviour and the resulting damages as these are shaped by the robots' programming rules during the production process, but it does not address liability for robot behaviours that result from unpredictable internal and external factors that manufacturers have no control over (Matsuzaki and Lindemann 2016). The complicated situations of robots capable of autonomous learning and alteration of circumstantial behaviours imply that conventional liability ascription is no longer sufficient to govern the concept of negligence in fulfilling the duty of care (Matsuzaki and Lindemann 2016). To protect users of robotics and autonomous systems from harm, correct categorisation of the types and nature of robots through risk assessment and posterior legal compliance is deemed necessary in the deployment process (Fosch-Villaronga and Roig, 2017). As legislations in governing robotics and autonomous systems in long-term care will take time to firm out, there have been various proposals and discussion related to the governance of liability in robotics and autonomous systems in long-term care (Fosch-Villaronga and Roig, 2017; Chou et al., 2018). One study opined that medical device legislation should play a prominent role in governing the attribution of liability in the meantime (Fosch-Villaronga and Roig, 2017), while another study suggested a shared liability framework that delineates the rules and responsibilities clearly to each party from programmers to manufacturers, retailers, and the end users (Chou et al., 2018).

4.4.4. Impacts on the incumbent workforce

The applications of robotics and autonomous systems in long-term care also have both positive and negative employment implications to the incumbent nursing and health workforce in the future (Khaksar et al., 2016; Stahl and Coeckelbergh 2016; Chou et al., 2018; Metzler et al., 2015; Pfadenhauer and Dukat 2015). There have been ongoing debates on whether social robots should serve as a care assistant or care replacement (Pfadenhauer and Dukat 2015), and the extent to which economic reasoning that inevitably advocates for workforce efficiency

and cost reduction should dictate the deployment of robotics and autonomous systems in long-term care (Khaksar et al., 2016). Studies that have discussed this issue tend to favour the view that care robots ought to be deployed as assistants to the nursing care staff to ease their care burden and free up more time for them to perform more specialised and personalised caregiving tasks, rather than replacing them to assume the role of companionship and many other nursing assistive tasks directly (Khaksar et al., 2016; Metzler et al., 2015; Pfadenhauer and Dukat 2015). Another pertinent question being raised is whether robotics and autonomous systems should be deployed to solve the problem of workforce shortage in nursing care, or to reduce operating costs of the long-term care institutions by replacing the nursing care staff (Stahl and Coeckelbergh 2016). Even if humans remain as prominent actors in the care delivery process, there are questions regarding how distinctive their roles and tasks should be as opposed to robots and autonomous systems (Stahl and Coeckelbergh 2016). It is projected that the demand for human carers would shrink substantially should both routine nursing care tasks and therapeutic tasks be delegated on a large-scale basis to robotics and autonomous systems. This could reduce the employment opportunities for the existing health and nursing care workforce in the long-term (Metzler et al., 2015).

4.5. Ethical issues in the application of robotics and autonomous systems in long-term care

4.5.1. Autonomy and independence

Across studies, the ability to retain autonomy and independence appears as the most fundamental concern in the deployment of robotics and autonomous systems in long-term care (Draper and Sorell 2017; Vandemeulebroucke et al., 2018; Fosch-Villaronga and Roig, 2017; Fosch-Villaronga and Virk, 2017; Ienca et al., 2016; Stahl and Coeckelbergh 2016; Bedaf et al., 2016; Chou et al., 2018; Ienca et al., 2018; Jenkins and Draper 2015; Draper et al., 2014; Rantanen et al., 2018a). Autonomy is defined as 'the capacity to make choices and lead one's life as one chooses' (Draper and Sorell 2017), and is grounded on the philosophical view that 'humans are ends in themselves rather than a means to an end' (Vandemeulebroucke et al., 2018). A number of conceptual and empirical studies expressed that autonomy and independence of older people in making care and life choices, regardless of their frailty states, should not be compromised (Draper and Sorell 2017; Fosch-Villaronga and Roig, 2017; Fosch-Villaronga and Virk, 2017; Chou et al., 2018; Ienca et al., 2018; Rantanen et al., 2018a). Free will and self-determination of older people even in the face of their increasing dependence on robotics and autonomous systems for companionship and in performing daily tasks should be thoroughly examined especially when robots are also involved in the decision-making process (Fosch-Villaronga and Virk, 2017; Ienca et al., 2018). Older people should be treated as proactive consumers and be consulted on decisions including the timing of deployment, cost and the extent to which robotics and autonomous systems should be making choices for them (Chou et al., 2018). At the same time, it is important to keep in mind the interests of the carers. Different carers may have different desires or interests regarding how to care for older people and may disagree about how care should be discharged, including the care roles that a robot should assume (Jenkins and Draper 2015). What is beneficial for one type of carer may be detrimental to another. However, this consideration results in another challenge arising from the tensions among the elder person being cared for, their human carers and the robots. As there may be conflicting views about the method of care and what is good for the older person, it is unclear who the robots should respond to. As social robots get more complex and multi-faceted, these tensions are going to become more prevalent (Draper et al., 2014).

One of the unintended long-term consequences of robotics and autonomous systems deployment in long-term care to older people is their over-dependence on these systems and thereby, inactivity (Fosch-Villaronga and Roig, 2017; Bedaf et al., 2016). Besides, tricky

ethical issues ensue when ascertaining whether the choices made by older people with cognitive disabilities should be given less consideration, assuming that they are not making those decisions in their best capacities (Draper and Sorell 2017). One study highlighted the challenge in obtaining unbiased informed consent to introduce robotics and autonomous systems in long-term care, especially in the context of obtaining informed consent from older people who have dementia and Alzheimer's disease (Ienca et al., 2016). Very often, advance directives and proxy decision-making by the legal representatives of older people with cognitive limitations become alternatives to ascertain care decisions (Ienca et al., 2016). Unless the older people's preferences are stated clearly in advance directives, or the proxy decision makers genuinely have the interests of the former at heart, it is unlikely that unbiased informed consent can be obtained from the older people. When robots are making too many choices for the care recipients, it also raises issues regarding moral agency and coercion. For instance, delegating too much autonomy to robotics and autonomous systems in dictating long-term care arrangements for the older people is perceived to be problematic as machines do not possess the capacity for ethical reasoning and hence, are devoid of moral agency to reason like human beings (Stahl and Coeckelbergh 2016). In addition, older people have also voiced concerns about the danger of robot interference and coercion that could potentially compromise their autonomy and independence. Concern was raised pertaining to robot controls of humans when permission is given for robots to monitor and alter human behaviours (Draper and Sorell 2017).

4.5.2. Social connectedness and human interaction

Social connectedness and compromised human interaction emerged as a major ethical issue faced in the deployment of robotics and autonomous systems in long-term care (Sharkey and Sharkey 2012; Draper and Sorell 2017; O'Brolchain 2017; Vandemeulebroucke et al., 2018; Etzioni and Etzioni 2017; Fosch-Villaronga and Roig, 2017; Stahl and Coeckelbergh 2016; Sharkey 2014; Laitinen et al., 2016; Rantanen et al., 2018b). Several empirical and conceptual studies have highlighted dehumanisation of care resulting from robotics and autonomous systems deployment to be an ethical concern (Etzioni and Etzioni 2017; Stahl and Coeckelbergh 2016; Laitinen et al., 2016; Rantanen et al., 2018b). Machines and technologies that are deployed in long-term care settings may do so at the expense of human to human interactions (Etzioni and Etzioni 2017; Sharkey 2014). Reduced social interactions with humans and the replacement of human touch by robots could result in social isolation and reduce the opportunities to form social affiliations with others (Fosch-Villaronga and Roig, 2017; Laitinen et al., 2016). It will be precarious if older people choose to spend time with robots instead of human beings as this would exacerbate social isolation (Vandemeulebroucke et al., 2018; Rantanen et al., 2018b). One conceptual study described prolonged social isolation as not only unethical but almost an act of cruelty (Sharkey and Sharkey 2012). Another equally important issue in long-term care is of physical human touch. Robotics may help elder people perform their personal hygiene autonomously but decreasing human touch in care situations may endanger a profound human need, the very need for care recipients to receive human touch in the process of care (Laitinen et al., 2016). People who suffer from dementia still have capabilities to communicate through gestures and touching, and for people with severe dementia, touch may be their most effective way of communicating. In fact, the long-term deprivation from regular human contact could predispose older people to increased stress and cognitive decline, impacting their health and well-being negatively (Sharkey and Sharkey 2012). Participants from a series of focus group discussion involving formal carers, informal carers and older people opined that human contact is irreplaceable by technology in many situations (Draper and Sorell 2017). The dominance of technology in long-term care could also result in the decline of meaningful human relationships that centre on physical presence and face-to-face communication (O'Brolchain 2017). Massive deployment of robotics and autonomous

systems in long-term care will result in less exposure towards physically and cognitively dependant older people by non-disabled independent persons. The implication to society as a whole could be dire in the long-term as this would mean that the society, especially the younger generation, will be less cognizant about the challenges one faces at old age, including having less exposure to the vulnerability and infirmity that may inflict the older generation. The changing nature of social relationships might also erode opportunities to extend virtues such as care and empathy to functionally dependant older people (O'Brolchain 2017). Echoing this sentiment, one study casts doubt as to whether humanoid robots could ever be programmed to be as emphatic and genuine as human (Stahl and Coeckelbergh 2016).

4.5.3. Objectification and infantilisation

Objectification and infantilisation of older people by using social robots has also been highlighted in several studies as an ethical issue (Sharkey and Sharkey 2012; Fosch-Villaronga and Virk, 2017; Ienca et al., 2016; Chou et al., 2018; Moyle et al., 2016). In a participant observation of interactions of robotic pets and companion robots with older adults with dementia and living in a nursing home, video analysis of their engagement and emotional responses showed limited effectiveness. Participants reported that these toy-like robots elicited feelings of stigma and infantilisation and generally did not find them to be appropriate to be used for old folks (Moyle et al., 2016). Furthermore, the application of robotic pets for older people diagnosed with dementia also raised a similar issue of infantilising older people and undermining their dignity as a human being just because their cognitive capacities are undermined (Ienca et al., 2016). Another conceptual study examining various legal-ethical issues of mobile servant robots raised the possibility of robots discriminating against older people, especially those with speech and hearing impairments who could not actively summon the robots to assist them (Fosch-Villaronga and Virk, 2017). Besides infantilisation, objectification of older people through the use of assistive robots without consulting the older people about the level of control that these robots should have in terms of organising their care is also raised as a potential ethical issue (Sharkey and Sharkey 2012). A case study in Taiwan also highlights that the objectification of older people by replacing human nursing care staff with social robots is an issue. Subjecting older people to the auto command and control of robotics without considering their feelings and preferences, especially those who have lost their functional and cognitive capacities, could potentially undermine their well-being (Chou et al., 2018).

4.5.4. Deception and anthropomorphisation

In the ethical discussion of the deployment of humanoid robotics in long-term care settings, deception and anthropomorphisation of older people has also been raised as an ethical issue (Sharkey and Sharkey 2012; Royakkers and van Est 2015; Vandemeulebroucke et al., 2018; Etzioni and Etzioni 2017; Chou et al., 2018; Sharkey 2014; Laitinen et al., 2016; Frennert and Östlund 2014; Moro et al., 2018). Social robots deployed in long-term care settings is seen as counterfeiting authentic social engagement with the older people and misleading them to falsely believe that they are engaged in genuine social interaction when robots are in fact archetypes intended to promote higher efficiencies in old age care (Royakkers and van Est 2015; Vandemeulebroucke et al., 2018; Laitinen et al., 2016). The forgery of such deceptive relationships raised ethical concerns that might be detrimental to the social well-being of the older people and result in unintended emotional consequences (Royakkers and van Est 2015; Etzioni and Etzioni 2017; Sharkey 2014; Laitinen et al., 2016). Besides, there is also an ethical risk of older people developing affection towards social robots, which can mislead them into believing that developing mutual relationships is possible (Sharkey and Sharkey 2012; Chou et al., 2018; Sharkey 2014). The unintended consequence from the deployment of social robots in long-term care is the encouragement of anthropomorphism. Anthropomorphisation of robots by more vulnerable population groups such as the older people

could potentially create a false delusion of robot companionship (Vandemeulebroucke et al., 2018), causing them to develop a strong emotional attachment towards social robots over time (Sharkey 2014). Hence, the deployment of robotics and autonomous systems in long-term care casts deep concerns about the unnecessary stress that could inflict the older people when these systems become faulty (Frennert and Östlund 2014). A qualitative study that entails video analysis and semi-structured interviews with residents in a nursing home revealed that some participants anthropomorphised social robots and perceived them as real persons, and expressed wish that the non-humanoid robots are more human-like (Moro et al., 2018).

4.5.5. Social justice

Like all other healthcare decisions that involved the allocation of scarce medical resources, social justice brings out fundamental ethical concerns of level of access to robotics among the elderly populace and mechanisms of robotics distribution (Vandemeulebroucke et al., 2018; Ienca et al., 2016; Khaksar et al., 2016; Chou et al., 2018; Ienca et al., 2018; Laitinen et al., 2016). One overarching concern about the level of access is social inequality. The question of whether only the affluent older people will be able to reap the benefits of robotics and autonomous systems and whether the less privileged older people will be disproportionately subjected to the unintended consequences of robotics and autonomous systems has been raised (Laitinen et al., 2016). Should the government allows market principle to dictate the distribution of robotics, the access to robotics could require a significant amount of financial resources, giving rise to inequality in the access to robotics, and consequently, social stratification (Chou et al., 2018). Commodification of robotics and autonomous systems with minimum government intervention would result in large-scale formal care institutions and high income households having more access to these technologies as compared to those in the lower economic strata (Vandemeulebroucke et al., 2018; Chou et al., 2018; Ienca et al., 2018). A review study had highlighted cost-control and affordability of robotics and autonomous systems in long-term care as one of the most salient issues raised in the deployment of intelligent assistive technology (Ienca et al., 2018). Since old age care expenses are a major issue for the involved parties, from older people and caregivers (or their families) to governments paying for it, affordability and cost-control are important characteristics that will enable social robots to be adopted widely in aged-care (Khaksar et al., 2016). Healthcare institutions and robot manufacturers must curb the costs by promoting the development of low-cost robots technologies through the dissemination of open-source initiatives for affordable devices so that these devices could be afforded by a large number of elderly adults from all socio-economic classes (Ienca et al., 2016; Ienca et al., 2018). In the longer run, universal access to robotics and autonomous systems will inevitably surface as an issue of fairness and as production and manufacturing costs decline, this will force institutions to incorporate distributive justice in the mechanisms of distribution (Ienca et al., 2016).

4.6. Tensions between various technological risks and ethical issues

4.6.1. Autonomy versus safety

Autonomy and safety are two risk and ethical components that are likely to cause significant tensions in many scenarios (Sharkey and Sharkey 2012; Draper and Sorell 2017; Sorell and Draper, 2014; Jenkins and Draper 2014; Bedaf et al., 2016; Draper et al., 2014; Scheutz 2013). Giving full autonomy and independence for older people could potentially create an ethical or accountability dilemma (Sharkey and Sharkey 2012; Draper and Sorell 2017; Sorell and Draper, 2014; Bedaf et al., 2016). While autonomy is a desirable value to be upheld, it can undermine safety when care recipients or users insist on placing certain commands on robotics and autonomous systems that could potentially compromise their personal as well as environmental safety (Sorell and Draper, 2014). For instance, the question of whether robots should

overwrite human's decisions when those decisions would predispose older people to danger and harm is a subject of debate (Draper and Sorell 2017; Scheutz 2013). However, there has been a counterargument raised along this spectrum of inquiries - as long as the undermining of safety does not lead to a risk of injury, safety should not always trump autonomy when the welfare of care recipients are also taken into consideration (Sorell and Draper, 2014). Autonomous systems and robotics with limited decision-making capabilities might find moral dilemmas in social situations (Scheutz 2013). For instance, the way social robots should be programmed to react to the care recipients' requests or instructions, including employing moral emotions such as empathy and developing a general ethical understanding that could guide their reasoning and decision-making, are often bound by context-specific situations that involve the consideration of safety issues (Scheutz 2013). Beyond immediate physical safety, there has also been query raised regarding the scopes and boundaries of ethics programmers should espouse in the design of the robots. For instance, whether robots should accede to all kinds of human's instructions, including fetching cigarettes and alcohol for them that could jeopardise their health, just to uphold the autonomy of individuals, continues to be an ongoing ethical debate (Scheutz 2013). Likewise, should robots evaluate instructions and undermine one's interest and autonomy by resisting human instructions (Bedaf et al., 2016)? A series of focus group discussion conducted with older people revealed that while they are torn between autonomy and safety, safety will always be prioritised if they are forced to choose between the two (Jenkins and Draper 2014). The efforts to strike a delicate balance between ensuring the immediate and long-term safety of the users while respecting their autonomy will most likely depend on the circumstances that arise and will require ongoing deliberations (Sharkey and Sharkey 2012). Ensuring safety and promoting autonomy are often competing values that cannot be reconciled easily, and it is important to ask the question of whose interests are we having in mind when deliberating on the tensions that arise. Since older people are prospective users of robotics and autonomous systems deployed in the long-term care setting, gauging their perceptions and preferences between these values through scenario analysis and choice experiments might help to yield additional insights for policy-makers and healthcare practitioners to ensure that all decisions are made in the best interests of the older people.

4.6.2. Safety versus privacy

Less common but a legitimate issue is the tension between safety and privacy in the deployment of robotics and autonomous systems in long-term care (Jenkins and Draper 2014; Ienca et al., 2018). It would appear that in the efforts to ensure the safety of the users and the environment in which they reside and navigate, individual privacy for physical space as well as informational privacy for the maintenance of confidentiality would inevitably be compromised. Albeit stemming from the intention to ensure safety, the real-time monitoring and surveillance by carers through video cameras and sensors would require the sharing of information and thus, will compromise individual privacy (Jenkins and Draper 2014). Whether safety or privacy should take precedence in the deployment of robotics and autonomous systems in long-term care is not only an ethical issue but also a cultural issue that is highly context specific. Some older people from cultures that value collectivism may be less uneasy about enabling real-time informational access to their professional and informal caregivers through monitoring and surveillance, but this may not be applicable to older people from cultures that value more privacy and individual autonomy to make independent decisions for oneself. Besides, care robots collect data for security purposes but the more data the robot is capable of collecting and processing, the higher the risk that such data can be used for unintended purposes, including purposes that are malicious and intended to harm the user and/or third parties (Ienca et al., 2018). Thus, it is important to ensure the security of the data collected and especially the devices that can access and process personally identifiable and medical information of the users.

4.6.3. Safety versus social connectedness

Another two components that are in tension in the deployment of robotics and autonomous systems are safety and social connectedness (Sharkey and Sharkey 2012). If care robots can be used to monitor the activities of daily living of the older people by their dependents who live apart, less social visits could be an unintended consequence in the process of leveraging the technology. While safety is ensured, social isolation may be perpetuated (Sharkey and Sharkey 2012). At this point, it is unclear as to whether the deployment of social robots to enhance safety for independent living among older people would compromise social connectedness between them and their caregivers. This is because no empirical studies have examined the impact of social robots intervention in long-term care on the social contact between caregivers or family members and care recipients. However, it is important to bear in mind the potential conflict that could arise between safety and social connectedness when society moves forward to embrace massive deployment of robotics technology in long-term care.

4.6.4. Deception versus autonomy and safety

It seems that deception would be inevitable in the deployment of robotics and autonomous systems in long-term care as far as promoting their well-being is concerned, including raising their autonomy and enhancing their safety (Chou et al., 2018; Sharkey 2014). This dilemma is especially common among older people with cognitive disabilities such as dementia, in which the applications of companion robots with elements of deception is built in to keep them safe and to raise their autonomy by enabling more long-term care choices for them (Chou et al., 2018; Sharkey 2014). The tension that arises between deception versus autonomy and safety could be resolved by considering various individual factors such as medical history, life history, personal preferences of the older people in making decisions on whether or not they would likely benefit from the adoption of robotics and autonomous systems in their care process. While customisation based on individual preferences may not be possible in the residential-based care setting, it is highly possible in the home-based and community-based settings. Making robotics access to be highly individualised to older people also aligns with the spirit of holistic and personalised care whereby medical and social interventions are delivered and sometimes adjusted based on individual circumstances and preferences.

5. Discussion

In the discussion on safety issues of robotics and autonomous systems in long-term care, the question of whether social robots could be safely deployed with minimal human supervision remains a contentious issue. This review found that there are contradictory intentions among some of the technological risks and ethical issues identified that could potentially lead to accountability and ethical dilemmas. For instance, the tension between autonomy and safety will have to be resolved by considering and assessing the unique situations that arise in different contexts. These include gauging the frailty levels and cognitive abilities of the care recipients, understanding the nature and extent of their disease progressions, and assessing the ability of the care recipients to actively communicate with the carers, including the care robots. The question of whether the benefits of the social companionship and the efficiency associated with the implementation of robotics and autonomous systems in long-term care would outweigh the harms and unintended consequences involved necessitates ongoing assessments in different long-term care settings that are facing unique challenges (Vandemeulebroucke et al., 2018). At the same time, it is unclear how to reconcile the trade-offs between the ethical issues of deception and its positive side effects. In case of older people with cognitive disabilities, deception seems inevitable and might even produce positive side effects like promoting well-being, raising autonomy by increasing choice and control and avoiding harm to the elderly (Chou et al., 2018). Should deception then be allowed for its potential positive effects? There is no

clear answer, and it is difficult to take a universal and absolutist ethical approach to address questions about robots and deception (Etzioni and Etzioni 2017).

Besides, the perceptions and social acceptability of deploying social robots in a long-term care setting might differ across various cultural contexts (Stahl et al., 2014). Even though studies have shown that the European and Japanese older populations are generally receptive towards the prospect of deploying social robots as part of the policy solutions to meet the rising social care demand (Nomura et al., 2012; Cavallo et al., 2018), the level of acceptability and receptivity in other cultures with ingrained traditions of prioritising communal living and filial piety may not be similarly expected. Furthermore, in multicultural societies where multiple languages and dialects are used as *lingua franca* and care norms could differ substantially, the deployment of social robots that are only able to communicate with humans in one language may not be an ideal solution. To enable adaptations of social robots across cultures or within a multicultural long-term care setting, many issues need to be accounted for in the design of robotics and autonomous systems. Besides language, the ability to pick up various social cues, cater to personalised care needs of different care recipients within a similar long-term care setting and adapt to different care norms is important in the design of social and care robots in catering to care recipients of diverse demographics. Studies have suggested the potential desirability of designing the robot's personality to complement that of the person it takes care of, and for the robot to be adaptable to the older person's needs (Rodić et al., 2016).

While safety, privacy and liability issues are frequently discussed as major technological risks, this review found a noticeable gap in the discussion on cybersecurity as a major technological risk in the deployment of robotics and autonomous systems in the long-term care setting. To date, there have been emerging discussions on cyber-physical threats related to the use of social and service robots (Miller et al., 2018; Lera 2017). One of the biggest cybersecurity threats identified for social robots is the potential of hackers gaining remote access to the robots by tampering the wireless network and taking control of the robots to induce harm on the care recipients (Miller et al., 2018; Lera 2017). In addition, the lack of robust authentication mechanisms, potential stealth attacks by deliberately inducing errors and modifying sensor readings of the robots, false data-injection into the information systems within the social robots that store medical information, covert attacks that discretely share personal data to other third-party applications, and denial of service to hinder the delivery of care services to the recipients are some of the other cybersecurity issues found (Miller et al., 2018). As the discussions and the scientific research endeavours around cybersecurity attacks are gradually intensifying, governance should respond swiftly to the fast-changing prototypes of the exoskeletons to ensure that safety and privacy are not compromised.

To date, no country in the world has enacted specific laws to govern all dimensions of the technological risks and ethical issues that are associated with the implementation and deployment of social care robots in long-term care documented in this review. With the exception of privacy regulation, which has witnessed substantial development in various jurisdictions propelled by the recent implementation of the European Union's (EU) General Data Protection Regulation (GDPR) governing data privacy of all data subjects in the EU (Laybats and Davies 2018), the regulatory developments of most other aspects of technological risks and ethical issues remain nascent. In particular, liability issues such as the allocation of safety risks among carers, care recipients, long-term care service providers, robotics manufacturers and software developers in the event of accidents during the care delivery process remains unclear. In addition, the legal ramifications of errors consequent to the technical faults in robotics and autonomous systems deployed in the long-term care settings have not been widely discussed. These issues are important in regulatory discussion as they would affect liability allocations among different component suppliers, software designers, operators and owners. The lack of a clear decision-making

process framework to interpret potential false judgement and the lack of regulatory responses to handle situations such as those in which false alarms are activated by social robots in lieu of dangerous situations that an older person is facing are some of the unresolved governance challenges.

Albeit lacking in concrete and deterministic regulations to govern the deployment of social care robots at this point, there has been increasing calls by robot ethicists and legal scholars to incorporate ethical discussions and thinking in the design of social robots (Sedenberg et al., 2016; Borenstein et al., 2016; Crnkovic and Çürüklü, 2012; van Wynsberghe 2013). This call echoes the concept of 'ethics by design', which is to ensure that the human-centric nature of social care, privacy, autonomy and the ability to promote social justice are not compromised, but instead, actively considered in the robots' design and development phases (Sedenberg et al., 2016; Borenstein et al. 2016; Crnkovic and Çürüklü, 2012; van Wynsberghe 2013). For instance, the introduction of more dynamic and flexible privacy features in social care robots is a design feature that actively takes user privacy concerns into account, such as through retroactive control of data privacy settings that enable more nuanced control on the consenting procedures on the use of data, instead of using strict binary approaches, and actively alerting the users when data recordings are taking place (Sedenberg et al., 2016). Such design for privacy is now highly encouraged under the GDPR, especially when new features such as the right to be forgotten and the right to erasure have been introduced to allow users to retract their consent at any point in time (Laybats and Davies 2018). Beyond privacy, there are also discussions as to whether social robots should be designed with 'opt-in', 'opt-out' or a 'no way out' design features to nudge users towards espousing personal interest or collective interests of the society (Borenstein et al., 2016). Moreover, a value-sensitive design approach enables care ethics, such as the dignity of the care recipients and the need for human touch to be actively weaved into the design process rather than subjecting robotics development to the sole purpose of promoting efficiency (van Wynsberghe 2013). The incorporation of ethical lens in the design of robots should adopt collaborative spirits from knowledge co-creation and solution co-development among various stakeholders such as robot designers, technology companies or developers, manufacturers, healthcare practitioners and even the informal caregivers. This can be done through prototype simulations during the pilot phase of robotics and autonomous systems deployment, during brainstorming process, and through ongoing programme evaluations to prepare these technologies for mass distribution.

While this systematic review has raised important issues surrounding tensions and antagonistic interactions between some of the technological risks and ethical values, it has not considered the additional complexity that could arise between the tensions between informal caregivers and care recipients during the caregiving process. The literature that incorporate this layer of tension when deploying novel technology in long-term care remains scarce at this point, but this would be an important research endeavour that could be undertaken to shed light to policy and practice in the future.

Furthermore, the integration of robotics and autonomous systems into LTC in the future will mean that the notion of human capital and the way it translates into economic capital (Corolleur et al., 2004), the quality of the jobs (Halteh et al., 2018; Hecklau et al., 2016), as well as the evolving relationships between humans and robots will need to be redefined (Webster and Ivanov 2019). Instead of substitution, the overarching aim for robotics and autonomous systems deployment is to augment its complementarity to human workers ultimately (Decker et al., 2017). To this end, this review has raised important questions with regard to human resource (HR) management and organisation's recruitment strategies in the age of Industry 4.0 that will witness massive automation through deployment of robotics and autonomous systems in various industries. This is set to disrupt the current employment practices and will have profound impacts to the existing workforce. In particular, the displacement of low-skilled human labour and

talent acquisitions in high skilled labour are expected to emerge as some of the new challenges to HR practices (Gan and Yusfo, 2019). According to Sima et al. (2020), the deployment of robotics and autonomous systems in various industries have shifted the technological mode of production from the model of information + knowledge + innovation in the knowledge economy to human intelligence + new information technologies + information + innovations in the Industry 4.0 era. Besides, innovative business models that infuse new strategies on customer engagement, identification and product or services monetisation will also alter the relationships between incumbents and new entrants in the health technology industry (Rose et al., 2017). These transitions will have implications to HR practices from talent onboarding, talent development to talent off-boarding which will have to be transformed through “Smart HR practices” (Sivathanu and Pillai 2018). Notably, the HR will have to equip existing employees with more versatile skill sets, which can be achieved through upgrading and continuous accumulation of new skills and knowledge related to management, risk management, leadership and so forth through periodic trainings (Shamim et al., 2016; Chuang and Graham 2018; Goos, 2018; Pham et al., 2018; Sima et al., 2020). It is postulated that most existing employees, including HR management personnel, will have to upgrade their analytic capabilities to stay relevant in the era of big data and autonomous systems (Angrave et al., 2016). Better labour market policies that facilitate intermediation to assist workers during job transitions and provide social security protections to workers in low-paid jobs will also be necessary to counter the impacts of job loss as a result of automation (Goos 2018). In addition, outdated HR practices will have to make way for new human development strategies that promote technology and digitalisation (Stein and Scholtz 2020; Mangematin et al., 2014). For instance, it is proposed that talent development through the use of technology collaborative tools, the creation of talent incubators via learning platform such as hackathon, and the engagement of digital leaders that focus on innovation are some of the emerging human resource management practices that corporations could adopt in the age of robotics and artificial intelligence (Rana and Sharma 2019; Stein and Scholtz 2020). In the future, flexible employment models which include part-time, on demand, and contractual modes of employment engagement may replace the traditional full time 40-hour work week model (Sima et al., 2020). By and large, reconfiguration of six HR practices, namely, knowledge management, HR policy making, training, recruiting, reward system and job design, is expected to happen in the era of robotics and autonomous systems (Gan and Yusfo, 2019).

Our questions regarding technological risks and ethical implications in the deployment of robotics and autonomous systems in long-term care have been answered using a systematic review approach. Tensions and antagonistic interactions between some of these components were also dissected to demonstrate the intricacy and complexity involved. Developing a concrete understanding of the nature and interactions of the different risks and ethical issues involved in deploying disruptive technologies in the long-term care setting could help governments catch up with regulatory design and bridge the colossal gap between technological innovations and the necessary regulations needed to govern their applications. We think that the advancement of this knowledge would contribute to helping governments to design, implement and enforce regulations that could effectively govern novel and emerging technologies in the near future.

6. Conclusion

This review synthesises the state-of-the-art evidence on the implementation of robotics and autonomous systems in long-term care and pays specific attention to the risks and ethical issues discussed in the literature. Based on multi-disciplinary sources of evidence that encompass engineering sciences, social sciences, gerontology and bioethics, we identify four major technological risks and five ethical issues in the deployment of robotics and autonomous systems in long-term care. Our

analysis further dissects the tensions between some of the technological risks and ethical issues, which is a unique contribution that has not been highlighted in the existing literature. Findings from this review advance the discussion on the governance of autonomous systems and builds on the insights gathered from previous studies that discuss technological risks of autonomous systems deployed in other sectors. These include autonomous vehicles in the transport sector, drones in telemedicine, emergency relief and disaster management, as well as military robots in national security and defence (Taeihagh and Lim, 2019; Royakkers and van Est 2015; Balasingam 2017). Our findings indicate that safety, privacy and data security, liability, and effects to the incumbent workforce are technological risks that associate with the application of robotics in long-term care setting. Our findings raise valid ethical issues in the deployment of robotics in medical and long-term care settings. For instance, autonomy, deception and social justice issues are salient ethical issues that regulators and practitioners have to confront with in crafting policies and guidelines to deploy robotics and autonomous systems as far as individual rights, transparency and social equality are concerned. As the technology in robotics and autonomous systems for supporting long-term care matures, new regulations will need to be in place to ensure that the deployment of these technologies poses minimal risks. Besides, organisations’ HR management practices and strategies will have to move towards continuous skills upgrading and digitalisation to stay relevant in the era of robotics and autonomous systems that are set to disrupt many current employment practices. Creating decent and sufficient jobs to maintain political-economy stability in the age of artificial intelligence will be the key to maintaining sustainability in the new normal with rapid technological change (Alic 1997; Boyd and Holton 2017; Morrar et al., 2017; Webster and Ivanov 2019). Future studies could build on the overall understanding of the governance of risks and ethics in long-term care settings by broadening the range of autonomous systems examined and including the examination of regulatory responses from various governments.

Authors contributions

All authors have contributed to the data collection and data analysis of the article. The first and second authors carried out the research design, wrote and edited the article. The second author conceptualised the research, acquired research funding, and supervised the research.

Declaration of Competing Interest

The authors report no conflict of interest in this manuscript to report.

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Supplementary materials

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