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Developing social robots for aging populations: A literature review of recent academic sources

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Abstract

The perception of aging populations is a major factor driving the social robot development movement. A growing body of research reflects the expanding interest in social robots. This paper synthesizes research on the development of social robots with a literature review of academic articles with publication dates ranging from 2006 to 2017. The review is divided into three themes: (a) robots as an aid in treatment; (b) robots as social assistants and home companions; and (c) robots as custodial caregivers that are viewed in terms of ethical implications. This paper outlines the issues surrounding social, commitment, assistive, and companion robots for use in medical treatment, mental health therapy, physiotherapy, care facilities, and private homes. It describes some of the ethical concerns raised by researchers and media, including questions of control, privacy, consent, and the issue of simulated versus human compassion in caregiving. The research also points out that a rhetoric of urgency concerning aging populations drives the development of robots, which frames citizens who will benefit from robots in reductive ways. We argue that the contribution of humanities and social science research, including age studies and critical gerontology, should be better integrated with discourses of social robot development, largely from technical fields.

1 | INTRODUCTION

Population aging is occurring worldwide. In the United States, the number of citizens 65 years and older is estimated to double by 2050 (Pew Research Centre, 2015). Japan is considered a "super-aging" society, with a populace aging at

a faster rate than any other country due to low birth rates and long life expectancy (Ries & Sugihara, 2017). Currently, low- and middle-income countries are experiencing the greatest leaps in longevity and population aging; by 2050, Chile, China, the Islamic Republic of Iran, and the Russian Federation will have a similar ratio of older people to Japan (World Health Organization [WHO], 2015). The United Nations Population Fund (2015) reports that people aged 60 and older currently comprise 12.3% of the global population; by 2050, that percentage is predicted to rise to nearly 22%, with 80% of older people living in low- and middle-income countries (WHO, 2015). Based on these facts, there is a perceived urgency to accommodate these numbers and account for health care needs (Pfadenhauer & Dukat, 2015; Richardson, 2017; Trynacity, 2015). As economic and social pressures increase with aging populations, countries worldwide are exploring the potential of social, assistive and commitment robots as caregivers and companions for older adults. A growing body of research reflects this interest.

Working in parallel with demographic and empirical research on aging populations are voices from other disciplines. Critical gerontology and age studies caution that alarmist pronouncements on demographics are not productive images of aging (Marshall, 2015). These humanities and social science disciplines promote a broader, culturally infused viewpoint to analyze the concept of aging (Gilleard & Higgs, 2013; Hendricks, 2008; Katz, 2003; Marshall, 2015). Katz (2014, p. 21) writes, "From the social sciences, age studies elucidates the new cultural processes redefining later life and old age." This perspective reveals the effects of ageist cultural determinants that minimize the lived experiences of citizens. Important research from humanities and social science fields deals with technology for elders, some specifically on social robots (Joyce, Loe, & Diamond-Brown, 2015; Neven, 2010; Suchman, 2017). Neven (2010, p. 344) writes "age-based assumptions lay at the heart of technology design and implementation, both for technology designers and prospective users." Joyce et al. (2015) address gerontechnology by focusing on the use of robots as an ambient assistive technology. They make the argument that the technology often further isolates elders rather than encouraging more interaction. Finally, from the field of anthropology, work on humanoid robots and how they figure in relevant technocultural imaginaries and material practices contributes to understanding rhetorical predictions about robots and the lives of citizens who will interact with them (Suchman, 2017).

As neutral pronouncements about growing aging populations are declared by governments and international organizations, necessitating the implied need for social robots, social science, and humanities researchers critique and challenge the reductive terms upon which these declarations are made. This paper contributes to synthesizing research on the subject of "social robots" with a literature review of academic and popular media articles on social robot development with publication dates ranging from 2006 to 2017. The limited timeframe is deliberate. The intent is to reveal a discursive snapshot of current academic work on social robot development to inform the broader abstract, cultural concept of "aging." In addition, the collection of popular news sheds light on the primary discourse, academic research, in order to reveal how the research is accommodated for a general public. We explore the following research questions: (a) How is current research on the development of social robots justifying the need for aging populations? (b) As robot prototypes are designed for elderly persons, upon what terminological categories are they proposed?

For the sake of clarity, in ideal terms, a robot can be defined as a machine that resembles a living creature with the ability to move independently and perform complex actions and/or interactions. The technical field is human–robot interaction. Most of the articles in the review referred to robots that physically move, although not all robots were actually ambulatory, e.g., they only moved their heads. The notion of autonomous activity or autonomous decision making is stated or implied in many articles in the review. Many of the technologies and/or robots were associated with artificial intelligence. We acknowledge that decisions made by robots that are automated or include artificially intelligent algorithmic systems need to be contextualized in broader research forums, one being international law (Wachter, Mittelstadt, & Floridi, 2017).

We considered the term *social* when limiting the review to social robots. Relevant research discusses the use of robots in determining the "relations people establish with and through health care technologies meant for home use" (Pols & Moser, 2009, p. 162). We adopt this clarification on the social dimension of a social robot as those that "are

explicitly designed to establish social and affective relations with their users" (Pols & Moser, 2009, p. 162). Related to this area, but quite different, is a "social bot." This refers to a social software robot, which "is a computer algorithm that automatically produces content and interacts with humans on social media" with a goal to emulate or even alter human choices (Ferrara, Varol, Davis, Menczer, & Flammini, 2017, p. 96). This review focuses particularly on robots that have some ability to behave in a social manner for an audience or demographic group that is classified as aging or elderly. Search terms were developed accordingly; these are listed in the Section 2.

The literature review is divided into three main themes, which arose from the articles:

1. robots as an aid in treatment,
2. robots as social assistants and home companions, and
3. robots as custodians for the elderly redefining ethical implications of care.

The research and reporting on social robots is weighted towards emergent design and uses. The sampled literature generally promotes the integration of assistive robots in elderly caregiving contexts. In our Section 4, we question discourses that unequivocally promote developing social robots without due consideration for broader life issues leading to the reductive treatment of elderly persons. We argue that the critical contribution of humanities and social science researchers must be better integrated into engineering and media discussions of social robots and elderly care.

2 | METHODOLOGY

Articles were collected from the Association for Computing Machinery database, the Institute for Electrical and Electronics Engineers database, ProQuest database, SpringerLink database, Scholars Portal Journals database, and Academic OneFile database. A total of 31 academic articles were collected and categorized with publication dates ranging from 2006 to 2017.

In addition, news and industry articles were collected during a period of 9 weeks (January 1, 2017–March 8, 2017). A total of 11 relevant news or industry articles were analyzed. The online articles were retrieved through Google News and are therefore specific to the search algorithms of the researcher, who was located in Canada.

All articles were collected based on the following criteria: the presence of content related to social robots or content on social robots and elderly/aging persons or elderly assistance/caregiving. Search terms included "social robots," "social robots; elderly," "social robots; aging," and "social robots; elderly care."

3 | LITERATURE REVIEW

3.1 | Robots as an aid in treatment

Aging populations are a major factor driving the social robot movement (Flandorfer, 2012). There has been an increased focus on the use of robotics as treatment aids for elders as this population increases and is set to increase in the coming years. It is perceived that robotics will provide potential solutions for some of the economic and social challenges of aging populations, acting not to replace health care providers, but to provide support (Ries & Sugihara, 2017; Trynacity, 2015). Researchers, designers, and engineers focused on developing assistive robots are considering age, gender, and the education of users as relevant factors in the design process (Flandorfer, 2012; Heerink, 2011; Lee, Tan, & Šabanović, 2016). Researchers and critics, including cognitive scientists, involved in the development of assistive robots for older persons note that there are risks in the use of robots for elderly users. For example, they emphasize that the robots must be designed to address real issues of aging not stereotypes that often surround the

concept of aging (Lee et al., 2016; Weiss, Beer, Shibata, & Vincze, 2014). It is helpful to include elderly users in research, design, and usability processes and that the designs be highly user-centered (Ries & Sugihara, 2017).

The simulation of social interaction is a central concern in the development of assistive or companion robots. Compassion, for instance, is a crucial element of geriatric care, and assistive robots must be able to convey compassionate qualities (Mordoch, Osterreicher, Guse, Roger, & Thompson, 2012). Studies have found that elderly individuals are more likely to interact with a humanoid or simulated animal object than a screen (Mordoch et al., 2012).

Customization is another key to users' comfort with robots; it is important for robots to be able to learn the behavior of the individual patients and adapt to future encounters (Agrigoroaie & Tapus, 2016). Examples of customization might include robots learning to initiate games or to alter behavior to reflect the sources of enjoyment of particular individuals, by responding to verbal and nonverbal indicators (Agrigoroaie & Tapus, 2016; Turk, 2017).

According to some researchers, it is most important that the process involves a smooth integration with elderly care facilities, and that staff, patients, and robots work together to ensure a fluid exchange of information (Sabelli, Kanda, & Hagita, 2011). One ethnographic study within an elderly care facility began with a human-centric research question, "How do people understand and interact with the robot?" (Sabelli et al., 2011, p. 37). This research question becomes extremely important for assessing robots as effective agents in treatment scenarios.

One identified path for assistive social robots is in aiding in the dispensing of medication and providing reminders to patients (Keay & Silicon Valley Robotics, 2017). One robot, Mabu, has been designed to learn about patients' medications, note their side effects, and remember dispensing schedules in order to assist staff in providing care (Keay & Silicon Valley Robotics, 2017). Pepper Robot, another assistive social robot, has been designed to be able to communicate through speech and gesture, move independently, and interpret signs that elderly individuals are in pain or unwell (Richardson, 2017).

3.1.1 | Mental health—Dementia

Robots have been specifically designed to serve elderly persons who suffer from a range of cognitive impairments including dementia (Agrigoroaie & Tapus, 2016; Molestina, 2017; Roger, Guse, Mordoch, & Osterreicher, 2012). These robots encourage elderly individuals to engage with people, the arts, and activities they may have begun to ignore (Molestina, 2017; O'Keeffe, 2017). Many studies have shown increased pleasure, happiness, and involvement among users with motivational and emotional disorders such as dementia (Perugia, Diaz, Barakova, Català, & Rauterberg, 2017).

PARO, a robotic baby harp seal (see Figure 1), and Matilda are the best known examples of successful social or mental commitment robotic prototypes that have had trial runs in elderly care facilities (O'Keeffe, 2017). Commitment

FIGURE 1 PARO, Seal-Type Therapeutic Robot

robots are designed to create emotional attachment in users (Intelligent System Company, 2006). PARO, which has been used in care homes since 2005, was observed to be helpful to individuals who participated in preliminary studies (Roger et al., 2012; Wada & Shibata, 2007). The individuals' families also found PARO to provide helpful interactions; a positive emotional outlet for the patients; a source of dialog among family members beyond the usual topics; a source of comfort, joy, humor, and play; and an opportunity to reduce loneliness through tactile stimulation (Roger et al., 2012; Wada & Shibata, 2007). These preliminary results are promising for the use of social commitment robots in senior care facilities. Further goals include a reduction in agitation among persons living with dementia, as well as targeting other major challenge areas involved with aging in general (Pfadenhauer & Dukat, 2015; Roger et al., 2012; Trynacity, 2015).

Another assistive robot, Matilda, is a social commitment robot that recognizes voices, faces, and emotions among users (O'Keeffe, 2017). Matilda is able to dance, play music, and call bingo numbers as well as make Skype calls and tell patients about the news and weather (Khosla & Chu, 2013; O'Keeffe, 2017). Matilda showed promise in preliminary trials, where 90% of participants indicated they felt comfortable in the presence of Matilda and 75% felt relaxed while talking to Matilda (O'Keeffe, 2017). Two percent of participants felt uneasy around Matilda (O'Keeffe, 2017). Engagement with Matilda in early studies has shown a reduced level of restlessness among patients with dementia and a reduced reliance on certain dementia-related medications (Khosla et al., 2012; Khosla & Chu, 2013; O'Keeffe, 2017).

3.1.2 | Physical health—Physiotherapy

It has been suggested that robots might someday replace humans in conducting physiotherapy. Humanoid robots hold a great potential for exercise coaching and the delivery of information to elderly individuals (Shen & Wu, 2016). One study observed that elderly participants respond better to humanoid robots that mimic their speed of motion than they do to human instructors or instructional videos, whose movements may be too vigorous; in this study, the robots' slower pace led to an improvement in the technical quality of patients' movements (Recio, Segura, Segura, & Waern, 2013). Another example of a responsive robot is the portable TechTech, which encourages elderly people to take a walk (Kumahara & Mori, 2014). TechTech can judge the weather outside, count users' steps, and recognize images and voice commands (Kumahara & Mori, 2014). There is a momentum in the field of assistive robotics for physiotherapy and a drive towards further implementation in senior care facilities.

3.2 | Robots as social assistants and home companions

Social assistance robots are growing in popularity for both use in senior care facilities and home use (Hurrell, 2017). Home companion robots might address the growing issue of loneliness and isolation among the elderly (Hurrell, 2017; N.A., 2017; Trynacity, 2015; Turk, 2017).

Ethnographic research of social robots in senior living facilities may provide important information for the development of home companions. Researchers have found that elderly individuals are willing to engage with robots placed in the care facilities as companions; they are willing to talk to them socially and tell them stories (von der Putten, Kramer, & Elmer, 2011). Studies of robots in elderly care facilities suggest that robots must be adept at interpersonal communication in order to be accepted as companions by users. In particular, robots must understand basic social and conversational conventions, such as saying 'hello'; be able to recall information told to them by patients; be able to provide positive feedback to patients; and have clear auditory and verbal feedback (Sabelli et al., 2011). Other researchers have found that social robots must be able to behave and socialize at a level suitable to the individuals they are interacting with (Lorenz, Weiss, & Hirche, 2015). Several researchers concentrated on social reciprocity, the principle of social 'give-and-take,' a fundamental human–robot interaction concept (Khosla & Chu, 2013; Lorenz et al., 2015). In another study, elderly individuals indicated that they would accept a companion robot in their homes provided that it did not seem completely human-like and was not overly invasive in size (Prakash, Kemp, & Rogers, 2014).

A Pennsylvania State University study determined that elderly people found cheery robots to make good assistants and serious robots to make better companions (Sundar, Jung, Waddell, & Kim, 2017). Another study found

that elderly participants viewed assistive robotic companions as child-like, i.e., something to take care of and teach things to (Sabelli et al., 2011). Other researchers have found that social robots must be useful, inspire trust, be socially acceptable, and not impede on the user's privacy (de Graaf, Allouch, & Klamer, 2015; Ezer, Fisk, & Rogers, 2009). Users may need time to adjust to the presence of robots but, after an initial integration period, would likely accept and begin to communicate with a robot naturally (de Graaf et al., 2015). Researchers have found that, while there are variances due to age and experience of technology, robots would eventually be accepted and supported by most users (Ezer et al., 2009).

3.3 | Robots as custodians for the elderly, ethical implications of care

3.3.1 | General public perceptions of robots

Exposure to and acceptance of social robots varies globally. Japan is considered to be at the forefront of social, economic, and medical advances in aging and in creating and using robots for companionship, therapy, safety, and treatment (Ries & Sugihara, 2017). Alongside Japan, the EU is pursuing research in the area of social robots. Social Engagement with Robots and Agents is a European Union project that aims to understand how people will react to robots in their homes and implement research designs to accommodate these concerns (von der Putten et al., 2011). Reports suggest that Finnish citizens hold a high opinion of robotics, with 75% believing that robots are good and 47% believing they are good for elderly care and companionship (N.A., 2017). Very little research has been conducted on social commitment robots in long-term care facilities in Canada (Sabelli et al., 2011).

As the North American public generally has little real-world exposure to robots, depictions in film become a source for assessing and judging them as potential caregivers. These fictional depictions of robot caregivers increasingly deal with real-life social scenarios such as a robot's capacity to care, love, entertain, hold legal rights, and interact with humans (Pedersen, 2016).

3.3.2 | Ethical concerns: Control, privacy, consent, true compassion

The review revealed that the autonomy and agency of robots is often taken for granted. The assumption that robots *can* care was often a given in the language of description. It was common to see sentences such as "Robots in care of the elderly are hoped to bring benefits for everyone involved" (Körtner, 2016, p. 304). To categorize this theme, we use the concept of *custodianship* when it intersects with companionship over issues of responsibility.

The issue of *control* is often at the center of ethical concerns. The point has been made concerning ethics and Internet of Things technologies for care-based surveillance that control or the means for control is a key consideration when aiding individuals and families (Abbas, Michael, & Michael, 2014). Researchers and critics argue that artificial robot companions need to be under the user's control and able to follow the user's instructions at all times. It is important that the robot does not control the user (de Graaf et al., 2015; von der Putten et al., 2011).

Additionally, issues of *privacy* need to be considered, especially considering that social robots may have access to medical and personal information (Körtner, 2016; N.A., 2017). This issue is exacerbated due to the auditory and visual capabilities of most robots (Caine, Šabanović, & Carter, 2012; Körtner, 2016; Turk, 2017). For face-to-face interaction with robots, cameras and facial recognition capabilities are required.

Researchers argue users must be fully apprised of the capabilities of the robots being provided to them so that they are not deceived in any way; trust is fundamental (Körtner, 2016; Lazar, Thompson, Piper, & Demiris, 2016). Individuals build relationships with their robotic assistants/companions and must also be aware that the robots have a limited set of capabilities (Lazar et al., 2016).

As with any process involving human participants, informed consent is fundamental to implementation, both in the trial and test phases (Körtner, 2016). The issue of informed consent requires special attention in considering the use of robots as assistants to dementia patients, who may not have the mental capacity to agree to the use of the robots (Körtner, 2016).

Sparrow R. and Sparrow L. (2006) highlight the limits of social robots and believe that the very concept of robots replacing human socialization or providing partial care for elders is unethical. They claim that robots are incapable of meeting the standards involved in any task related to aged care, where emotional work such as friendship, love, or concern is a crucial part of the role. They aim to draw attention to the discourse forming around aged care and robotics as it reflects broader social attitudes towards older persons. Specifically, they note that older persons are often regarded as problems to be managed, whose desires and opinions are devalued compared to the recommendations of gerontologists, sociologists, and economists. (Sparrow R. & Sparrow L., 2006; Weiss et al., 2014).

4 | CONCLUSION

The first question guiding this synthesis is *how is current research on the development of social robots justifying the need for aging populations?* The literature review revealed that there is a long road ahead before robots will seem or behave like humans or living beings, in the same manner that they seem like them in fictional film portrayals. The development cycle for robots requires instrumentalizing biological, social, and existential aspects of identities in order to create machines that will behave in meaningful ways in relationships with humans. This approach is problematic because it crosses over to treat elderly persons and their lived experiences in reductive and compartmentalized ways (Segal, 2014). Indeed, reducing lived experienced is an issue not only in the development of robots but with most automated decision-making systems. The logic behind development and the envisaged consequences can run counter to the way society understands human value systems. Engineering discourses are not incorporating analysis from humanities and social science fields, specifically age studies and critical gerontology, when it comes to dealing with these issues, even though ethics was one of the main themes that arose.

The rhetoric of urgency was instantiated across the review that *we need robots because international populations are changing dramatically*. Many of the articles provided numerical evidence to kickstart and contextualize the urgency of acting quickly to develop robots before the perceived problem of global aging occurred. The need was attributed to voices from medical, economic, legislative, administrative, professional, nonprofit, and advocacy bodies. Long-term care facilities were positioned to benefit from keeping abreast of recent research and reporting on social robots, in order to properly assess their introduction in care facilities as a response to this rhetoric of urgency.

This paper has synthesized some of the research on the topic of the development of robots to be deployed as social agents geared to aging individuals. It provides a literature review on social and assistive robots for the use of companionship and care for aging persons. In light of the second research question—*as robot prototypes are designed for elderly persons, upon what terminological categories are they proposed?*—the research is classified into three dominant themes. The categories are social robots as an aid in treatment, robots as social assistants and home companions, and robots as custodians challenging the ethical implications of using robots as caregivers for the elderly. The terminological clusters orient technology development and contribute to how elders will be affected in their lived experiences when robots are further commercialized.

Increasingly, social robot development is associated with the field of artificial intelligence, which involves machines imitating the intelligent cognitive behaviour of humans. It is important, then, that robots reflect the complexity of human life, by accounting for human capacities, such as identity, memory, or creativity during robot development. Development also needs to design for elders within spheres that reflect their participation as socially integrated individuals, such as citizen engagement, cultural consumption, participation with global current issues, or historical contextualization. Many of the articles in the review described how robots were trained in direct human to robot interactions: conversational and physical. Few, however, demonstrated the inclination to draw on the rich culturally embedded lives of elder populations. Joyce et al. (2015, p. 159) explain that this is a common conceptualization of aging, "this perspective locates solutions at the individual level rather than the social or structural." In conceptual terms, Katz (2002, p. 48) defines "aging" as having "inspired the human artistic and cultural imagination for millennia" because it makes people confront "the paradoxes of living and dying in time." Early

development of robot prototypes ought to reflect humanities and social science fields that are interpreting aging in profound cultural contexts. The goal for this paper is to provide a foundation from which to begin broadening the research across disciplinary boundaries.

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