At the Forefront of HF/E

Maximizing the Benefits of Participatory Design for Human–Robot Interaction Research With Older Adults

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Objective: We reviewed human–robot interaction (HRI) participatory design (PD) research with older adults. The goal was to identify methods used, determine their value for design of robots with older adults, and provide guidance for best practices.

Background: Assistive robots may promote aging-in-place and quality of life for older adults. However, the robots must be designed to meet older adults' specific needs and preferences. PD and other user-centered methods may be used to engage older adults in the robot development process to accommodate their needs and preferences and to assure usability of emergent assistive robots.

Method: This targeted review of HRI PD studies with older adults draws on a detailed review of 26 articles. Our assessment focused on the HRI methods and their utility for use with older adults who have a range of needs and capabilities.

Results: Our review highlighted the importance of using mixed methods and including multiple stakeholders throughout the design process. These approaches can encourage mutual learning (to improve design by developers and to increase acceptance by users). We identified key phases used in HRI PD workshops (e.g., initial interview phase, series of focus groups phase, and presentation phase). These approaches can provide inspiration for future efforts.

Conclusion: HRI PD strategies can support designers in developing assistive robots that meet older adults' needs, capabilities, and preferences to promote acceptance. More HRI research is needed to understand potential implications for aging-in-place. PD methods provide a promising approach.

Keywords: human–robot interaction, participatory design, older adults, aging-in-place, assistive robots

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In its broadest sense, technology is the harnessing of knowledge to support/enable/augment human activities and goals. Robots are one form of technology being developed to support a range of activities including manufacturing (e.g., Baxter, a multipurpose industrial manufacturing robot; Elprama et al., 2017); search and rescue (e.g., Boston Dynamic's Atlas robot; Kohlbrecher et al., 2015); delivery services (e.g., Relay, an assistive robot that delivers room-service in hotels; Tussyadiah & Park, 2018); and domestic tasks (e.g., robotic vacuums such as iRobot's Roomba; Willow Garage's PR2; Smarr et al., 2014). Increasingly common are assistive robots that can potentially support the daily activities of older adults (reviewed in Wiczorek et al., 2020) or individuals with disabilities (e.g., Hello Robot's Stretch; Kadylak et al., in press).

Broadly defined, a robot is a programmable machine that can sense the environment, compute, and perform tasks autonomously (Beer et al., 2014; Guizzo, 2020). Given the increasing number of older adults in the world (World Health Organization, 2015); age-related changes in motor, perceptual, and cognitive abilities (Czaja et al., 2019), and reductions in healthcare workforce to support older adults (Flaherty & Bartels, 2019), robots seemingly have much potential to fulfill a societal need.

Human factors and ergonomics (HF/E) as a discipline plays a central role in assuring that robots are designed to support older adults' needs, are easy to use (i.e., to interact with and control), and will be accepted by the older adults and integrated into their home environments. Standard HF/E methods and tools can engage older users and guide the design process (Boot et al., 2020). For example, exploratory design methods include literature reviews of older adults' needs and capabilities, observations of daily activity challenges, and task analyses of everyday activities that need support. These methods will provide valuable guidance for the design of robots. Critically important as well will be the engagement of older adults in the design process to ensure usability and accessibility (Mitzner et al., 2015).

Participatory design (PD) methods provide opportunities to harness the experiences, capabilities, limitations, and preferences of older adults for design of robots that will support successful aging. We consider successful aging very generally, as goal attainment; that is, being able to do what you want, when you want, with whom you want, where you want, and how you want. How might older adults provide insights about robots that could support these goals?

Defining Participatory Design

PD approaches draw on various research methods with the goal of eliciting tacit knowledge that individuals have about their own activities and facilitating the expression of that knowledge to inform design (Spinuzzi, 2005). For example, older adults can be *co-designers* throughout the design process to ensure that their activity needs and preferences are represented in resultant robot designs. Generally, PD uses a range of quantitative, qualitative, and ethnographic research approaches, along with a mix of concept generation and co-design activities, to iteratively develop novel robot prototypes. Because HRI PD research with older adults is a nascent and emerging field, there is a need to understand how PD is being used in this context to guide specific recommendations.

Our review focused on research using PD methods with older adults as the stakeholders for robot design. Our goals were as follows: explore how PD is being used for robot co-design with older adults, elucidate the benefits and challenges of different PD methods for use with older adults, provide guidance for future research, and design efforts to maximize PD for robot design. The design process is iterative and relies on multiple sources of information (e.g., Kumar, 2012), and PD holds promise as an informative tool. However, there may be unique challenges in using PD with older adults, given age-related motor, sensory, and cognitive changes, as well as their typically lower technology experience (Czaja et al., 2019).

PARTICIPATORY DESIGN STUDIES

We searched academic journal databases and Google Scholar to identify all HRI research studies (journal papers and conference proceedings) that included older adults (age 60 and above) and domestic robots; we identified 329 articles. From this set, we selected articles that explicitly conducted PD research with older adults. Each article was evaluated by three research assistants to determine inclusion of PD methods. The research assistants were iteratively trained by a postdoctoral research associate and the director of the laboratory to establish agreement for the keywords, inclusion, and exclusion criteria. When discrepancies emerged, the research team reviewed and discussed the article to determine inclusion.

Our evaluation yielded 26 research articles that explicitly used PD with older adults in the context of robot design (see Appendix). Figure 1 shows the frequencies of each PD method used in the articles; note that every article reported using multiple methods. Most common were workshops (defined as a series of interviews and focus groups that involved co-design or concept generation activities), followed by focus groups and interviews. Concept generation activities, such as drawing, storyboarding, or card sorting were less common.

PARTICIPATORY DESIGN METHODS

We next describe each PD method, benefits of using, and potential challenges for older adults. Note that although some methods have been infrequently used in the literature, we included them in our discussion. They may have heretofore been underutilized, but they have potential to support PD for design of robots with older adults.

Card Sorting

In the card sorting tasks, older adults arranged cards that reflected various features of a robot/system, or related design concepts, into categories. One strategy was to use cards with

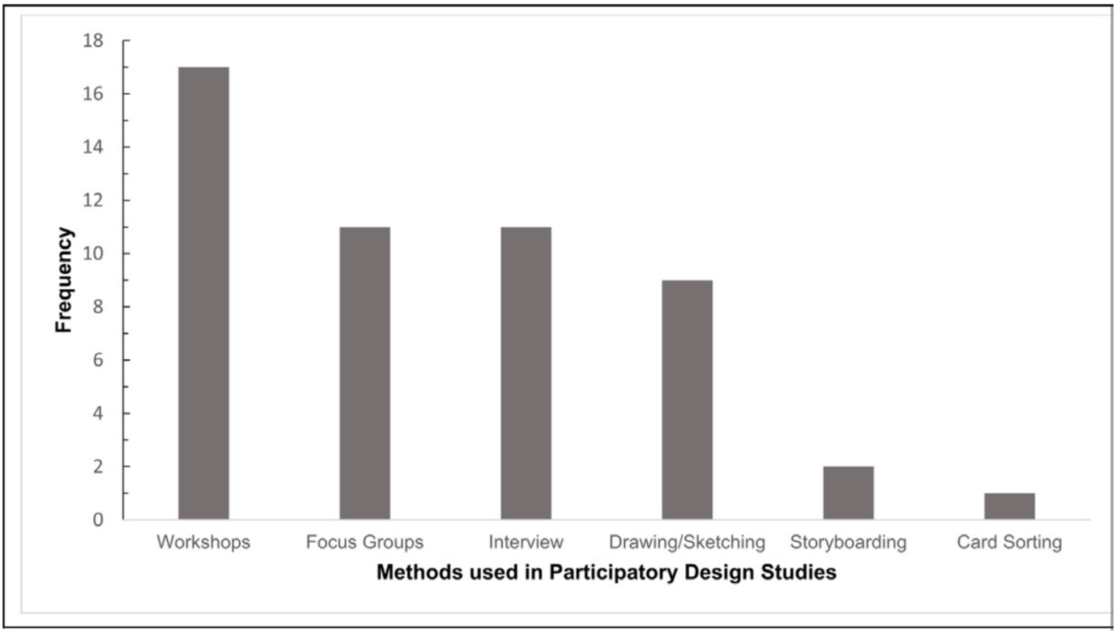

Figure 1. Total number of times each participatory design method was used. N = 26 articles. All of the articles reported using multiple methods; thus, the sum is > 26.

words, images, or visual stories to encourage older adults to imagine the benefits of robots for other people, even if they did not think they would find them useful for themselves. Card sorting was utilized to hierarchically visualize and map concepts to investigate users' mental model of a given system (Stone et al., 2017). This technique is useful for establishing user requirements, improving user interfaces, and to provide insights on how older adults imagine interacting and communicating with robots (Vines et al., 2012). Card sorting approaches can facilitate subsequent focus group discussions (Frennert et al., 2012).

Older adults may find it particularly difficult to brainstorm design recommendations or preferences if they have limited experience or exposure to robots (e.g., Lee et al., 2017). Therefore, when using blank cards that participants have to fill in, it is supportive to provide instructional guidelines. Potential solutions to the technology limitation could include showing examples of contemporary robot capabilities and form factors to encouraging imagination.

Further, sensory impairments (vision loss) or fine motor movement declines can pose barriers to this method of PD testing, which can make reviewing cards or design of cards difficult. Solutions for the sensory/motor limitations include an online format: persons with visual limitations could use assistive technologies, and persons with motor limitations could use a range of predetermined selected shapes. In addition, older adults' preferred rankings of already designed robots can provide insights about what aspects of a robot should be included for the specific task they wish to support.

Storyboarding

Storyboarding helps older adults envision how new technologies could be integrated into their daily lives (Lupton, 2017). We identified two main techniques used for storyboarding with older adults: unassisted and assisted. Unassisted storyboarding involved creating a narrative by filling in a sequence of boxes with their own drawings, or images provided by study personnel. This allowed older adults to brainstorm use cases and explore preferences for the steps involved in robot commands and input methods for specific tasks.

Assisted storyboarding, whereby researchers guided participants through a scenario, can help participants visualize HRIs. Assisted storyboarding may also alter the perceptions of older adults by increasing their understanding of potential robot use cases and robot appearance preferences (Bedaf et al., 2019; Iacono & Marti, 2014). For example, Bedaf et al. (2019) incorporated a multinational sample (Netherlands, France, United Kingdom) and three different groups of stakeholders (older adults, clinicians, informal care partners), all of whom had diverse exposure to and limited experience with domestic robots. By using a storyboarding and scenario activity with their domestic robot (Care-O-bot 3) prior to each focus group, the researchers were able to provide all participants with a realistic mental model of domestic robot capabilities, appearance, and size to ground their discussion.

Drawing/Sketching

Drawing and sketch methods can afford older adults an opportunity to influence novel robot form factors from the inception of the design process (Frascara, 2002). Although drawing and sketch components of PD studies place low demands on working memory, some participants may be apprehensive or unable to draw or sketch their preferred robot by themselves (DiSalvo et al., 2008; Ng et al., 2012). In some studies, participants drew or sketched a robot that looked and functioned in a manner that they deemed appropriate (e.g., Rose & Björling, 2017). In other studies, researchers sketched or drew the robot, while the older adult participants described what they would like their robot to do (e.g., Lee et al., 2017). With the latter approach, researchers can ask participants to do a cognitive walk through of some of their daily routines, and then try to identify activities the robot might be able to support as well as identify any modifications the participants would want to make to their initial drawings and designs.

Though participants may depict a range of robot form factors (e.g., machine-like, anthropomorphic, or animal-like), the drawing process can elicit specific needs and help older adults to express social meaning and social practices (Rehm et al., 2016). For example, Rehm et al. (2016) showed that the drawing method can be used to identify daily routines/tasks, such as meal reminders for older adult residents of assisted living facilities, and help elicit how older adults feel about those tasks. Based on this identified need, they developed a social robot prototype that provided reminders to residents that staff used to do manually, which lessened the demands on staff and helped the older adults gain back independence. Moreover, drawing and sketch methods can be positioned within a multistep design workshop—typically, either preceding or following semistructured interviews or focus groups (Lazar et al., 2016).

Interviews

Semistructured interviews are commonly used in PD studies. Typically, researchers ask participants a series of open-ended questions, with the intention of asking clarifying, or probing, follow-up questions. HRI PD interviews can be performed with a range of stakeholders such as older adults, clinicians, therapists, care providers (e.g., Lee et al., 2017).

A key benefit of semistructured interviews is that they provide participants with the chance to express feelings, thoughts, or brainstorm intimate use cases that they may be inhibited to share in group settings (e.g., using a social robot companion to cope with loneliness or an assistive robot to support health concerns; Sabanović et al., 2015). In addition, novel themes that emerge from initial stakeholder interviews can inform discussions in subsequent PD focus group interviews.

Focus Groups

Focus groups are another staple of PD research. Focus groups are commonly used to explore older adults' attitudes and perceptions, uncover ethical/privacy related apprehensions, and learn about how older adults would expect the robot to move throughout their home environment (Leong & Johnston, 2016; Smarr et al., 2014). These types of discussions place older adults at the center of the design process. When

HRI PD focus groups occur in independent and assisted living facilities, the discussion groups may afford an opportunity for social engagement between residents, which could foster novel design ideas. Moreover, HRI participatory design workshops with older adults usually include a series of focus groups. Focus group discussions can inform future PD activities (e.g., storyboarding scenarios or card sorting activities; Frennert et al., 2013).

Workshops

PD workshops commonly include focus groups and other concept generation and design activities. Workshops are a useful way to engage multiple samples of stakeholders, such as older adults with cognitive impairment, care partners, and clinicians (Nicholas et al., 2012), and they can offer multiple opportunities for co-design activities. Depending upon the specific user population, robot form-factor, and task type, different workshop configurations may be applicable (Karasti, 2014).

In general, workshops tend to consist of two phases: (1) initial interviews and (2) focus groups with concept generation/co-design activities. Some workshops also included a third PD phase: prototyping/presentations. Of the 17 PD workshop studies, 42% included an initial interview phase, 100% included at least one focus group, and 19% included a presentation phase. The workshops that included focus groups often had multiple iterations (from 1 to 6). Figure 2 shows the sequence of workshop phases and design activities in a subsample of workshop studies. This representation highlights both the variability and commonality across workshop configurations. The inconsistency in standardization could, in part, be due to the need to address the potential challenges of different age-related barriers to PD methods.

CONCLUSIONS

PD Methods for Obtaining Design Insights

Our review of the HRI PD literature with older adults yielded several insights. First, these studies consistently highlight the importance of mutual learning and engagement with stakeholders throughout the design process. The more designers, researchers, and older adults engage during the design process, the more likely robots will be appropriately designed to meet older adults' needs and preferences (Merkel & Kucharski, 2019). Different types of mutual learning can occur throughout PD activities and phases (Lee et al., 2017).

Our brief review revealed that less common PD activities, such as card sorting and storyboarding, can give older adults a chance to express the types of challenges or difficulties they routinely encounter and then consider how a robot could be designed to support those activities. These methods have thus far been infrequently used but might be very valuable to compensate for the lack of direct robot interaction experience for most older adults (Smarr et al., 2014).

Potential Challenges of Using PD With Older Adults

Older adults may face challenges engaging in certain PD activities. When designing HRI PD activities or workshops, it is important to consider potential motor, sensory, and cognitive limitations (Boot et al., 2020; Czaja et al., 2019). Pilot testing activities and materials may help designers develop PD workshops that accommodate a range of older adults' capabilities and needs. For example, it is common practice to engage older adults with visual impairments using PD interviews or storyboarding activities. Physical prototyping, though feasible, with individuals who have visual impairments, may require additional rounds of materials testing to ensure the usability of prototyping objects, Braille labels, and the layout of the PD environment/location.

One of the more physically challenging PD activities for older adults is the drawing method; one solution is to use surrogate drawers such as care partners or study personnel to draw for the older adult participants (e.g., Lee et al., 2017). Moreover, it is important to consider the physical layout of PD workshops, which could hinder interested older adults from being able to access certain PD study materials (e.g., Bråthen et al., 2019).

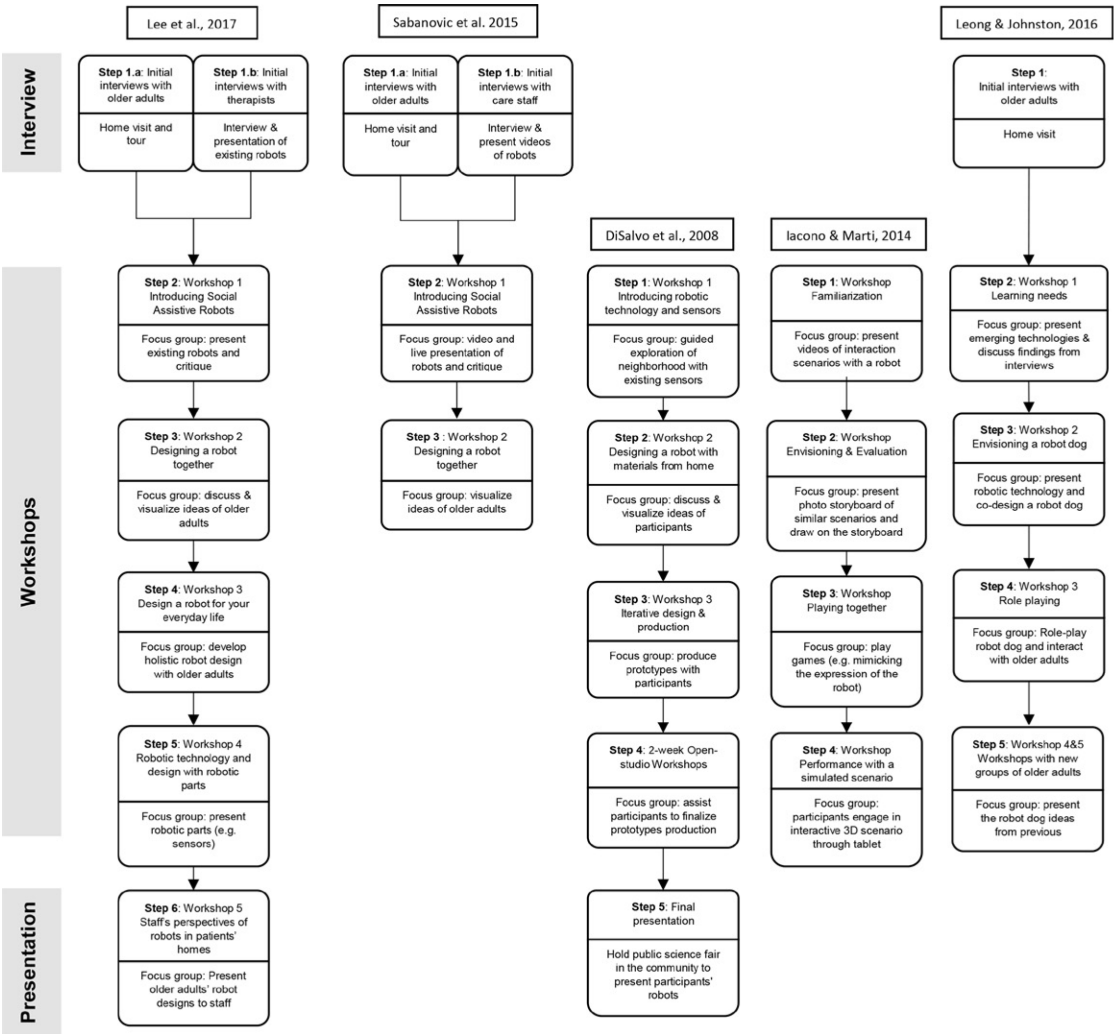

Figure 2. Examples of HRI participatory design workshop formats with older adults.

Another challenge to HRI PD is that older adults' initial perceptions of robot capabilities and appearance can be influenced by popular Hollywood depictions of robots/fictional media (Sundar et al., 2016). Hence, it is common in PD to start off by exposing older adults to a diverse range of existing and/or developing robots to provide a realistic sense of robot capabilities and appearance (e.g., Sabanović et al., 2015). This can provide a foundation for older adults to brainstorm their own robot designs and use cases. When introducing older adults to commercially available and developing robotics technology, it is important not to provide overly complex technical knowledge as this can potentially hinder older adults' engagement with PD activities (e.g., Randall et al., 2018).

The PD studies we reviewed primarily occurred with collocated participants (e.g., focus groups). However, we encourage designers and researchers to consider alternative methods of engaging older adults throughout the PD process (e.g., telephone interviews, online questionnaires, interviews, focus groups via videoconference). A broader range of PD methods could increase engagement (e.g., rural older adults, people with disabilities, those without transportation), resulting in richer input to the design process.

PD Potential

HRI PD research tools hold great promise for developing future domestic robots for older adults. Researchers should deliberately plan PD workshop activity-sequencing, taking into consideration the needs and capabilities of their specific target population of older adults and/or other stakeholders that they intend to involve in the design process (e.g., care partners). Although outside of the scope of the present review, future HRI PD systematic literature reviews and meta-analyses could investigate the efficacy of specific mixed-method HRI PD procedures and evaluate whether they foster a holistic understanding of HRI for older adults with diverse needs and capabilities.

Human factors researchers are uniquely equipped to develop HRI design frameworks with older adults (e.g., Rogers & Mitzner, 2017) and evaluate the efficacy and efficiency of PD method configurations (e.g., identify points of saturation where components of a PD workshop become redundant and/or identify workshop designs that may fatigue older participants). Human factors expertise could also lead the way for developing new HRI PD methods to support remote data collection (e.g., online card-sorting activities) and enable inclusion of broader samples.

Though many of the articles assessed in our brief review were not published in human factors journals, we posit that human factors researchers are well suited to contribute to HRI research with older adults by integrating traditional human factors evaluation techniques (e.g., heuristic analysis, task analysis, naturalistic observation), PD co-design activities/workshops, and applied quantitative and qualitative research methods. We encourage human factors researchers to consider how their expertise and skills can be applied to investigate open-research questions in the context of HRI with older adults (see also Sheridan, 2016). Taken together, we maintain that HRI PD research with older adults can be deployed to co-design, or even optimize robot form-factors for specific target populations, but also as a research tool that can be used to advance scientific knowledge on HRI with older adults.

APPENDIX. PARTICIPATORY DESIGN ARTICLES INCLUDED IN REVIEW (*N* = 26)

Bråthen, H., Maartmann-Moe, H., & Schulz, T. W. (2019, February). *The role of physical prototyping in participatory design with older adults*. The Twelfth International Conference on Advances in Computer-Human Interactions, Athens, Greece. https://www.duo.uio.no/bitstream/handle/10852/68794/achi_2019_9_10_20110.pdf?sequence=2&isAllowed=y

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KEY POINTS

- Assistive robots have the potential to support older adults with everyday activities in their homes.
- Participatory design methods are valuable tools to engage older adults in the robot design process, from conception to implementation.
- Participatory design workshops may be most effective as they incorporate multiple methods (e.g., survey, interview, design exercises) to elicit the perspectives of older adults.
- Age-related changes in motor, sensory, and cognitive capabilities must be considered in the instantiation of participatory design methods to maximize their effectiveness.

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