PODER: A Robot Programming Framework to Further Inclusion of People with Mild Cognitive Impairment in HRI Research

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***Abstract*—Many HRI researchers have engaged in participatory research to include users in robot design processes. However, to our knowledge, people with mild cognitive impairment (PwMCI) and early stage dementia have yet to be included in developing and programming robots, and the HRI community lacks tools to facilitate their inclusion. We bridge this gap by introducing PODER (PrOgramming framework to Develop Robot behaviors), which enables a lived technology experience for PwMCI via scaffolding, peer programming, and development tools to support them as key developers of social robots. We conducted a study where PwMCI and early stage dementia used PODER to program robot interactions, and found that participants were highly engaged and deeply enjoyed their experience, creating programs for robots that reflected their interests, experiences, and needs. Our results show the impact of including participants with MCI and early stage dementia in robot programming, including an increased understanding of technology, shifting their perceived role from technology users to programmers, and desire to be involved with the end-to-end process. By releasing PODER to the community, we hope this work can facilitate the intentional inclusion of people with cognitive impairments in further HRI research.**

***Index Terms*—Human-robot interaction, robot programming, assistive robotics, inclusion, people with cognitive impairments**

I. INTRODUCTION

Socially assistive robots have emerged as a promising means of delivering health interventions for people with cognitive impairments [1,2]. As with other longitudinal digital health interventions, their success depends on engaging users over time to support adherence [3–7]. Personalizing a robot's behaviors and interaction to an individual's preferences, abilities, and interests is crucial to promoting its acceptance, adoption, and engagement [6–8]. However, to our knowledge, people with MCI and dementia have not been involved as programmers in the development of assistive robots. This may be due to incorrect assumptions made about their cognitive abilities and digital literacy to contribute as co-designers of technology [9–12]. Inclusion of people with cognitive impairments in robot design and development is vital for personalizing these systems. This is also necessary to prevent ableist narratives from making their way into the development process [10,13].

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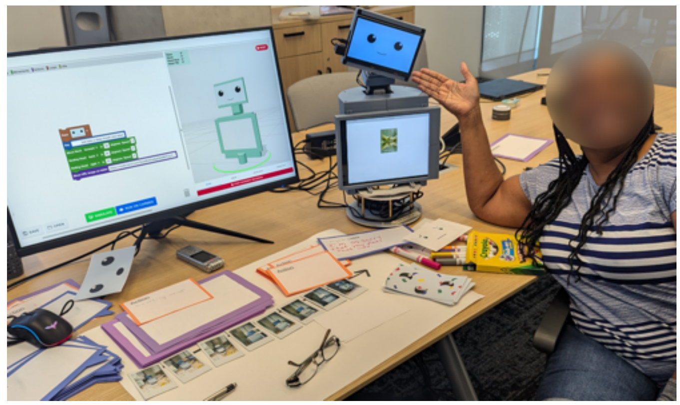

Fig. 1: PODER supports inclusion of PwMCI in robot programming via scaffolding strategies, tangible objects, a programming interface, and a physical robot. A participant with MCI presents the robot interactions she designed and programmed with PODER.

The HRI community has explored co-designing robots with older adults [14–19] and PwMCI [8,20–25]. While these works have made great strides in identifying how to broadly design robots for these populations, robots will still need to be personalized to a person's preferences and abilities. It is infeasible for roboticists to manually personalize robots to each user, and it may take time for robots to autonomously learn personalized behavior for a particular user.

End user programming (EUP) tools have effectively supported a range of novice programmers to personalize robots, including older adults, teenagers, caregivers, and clinicians [17,26–34]. However, several gaps limit the accessibility of existing EUP tools to support PwMCI with programming robots. First, most EUP tools require users to think abstractly about robot behaviors without clear connections to a physical robot. MCI can affect cognitive functioning, including memory, attention, and executive functioning, which may impact how PwMCI learn and process concepts [35,36]. Thus, PwMCI may require tools that minimize cognitive demand [8].

Second, people without lived technology experience (e.g., interacting with or programming a robot [16]) may not know

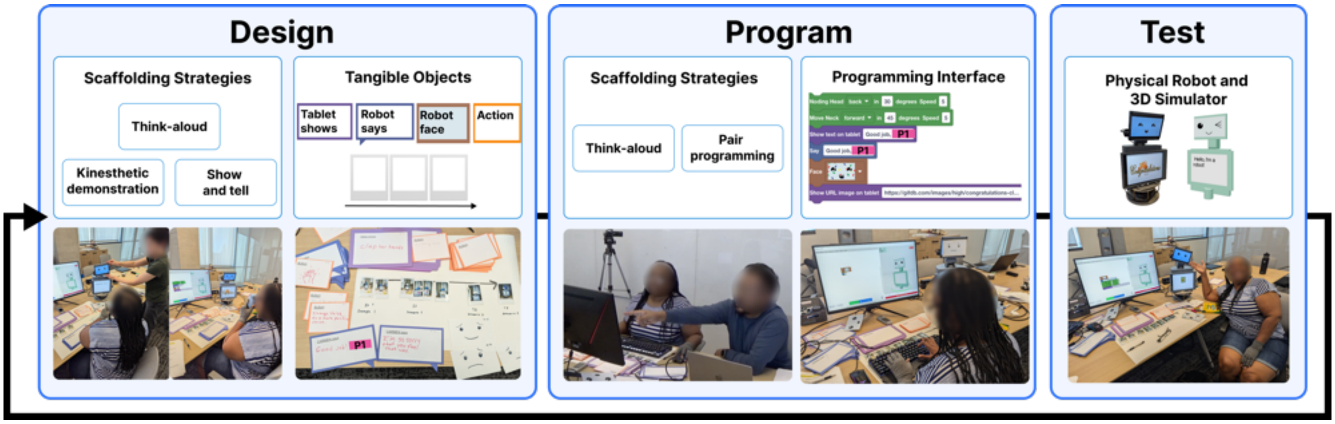

Fig. 2: An overview of PODER. The **scaffolding strategies** enable an active collaboration between PwMCI and researchers to design and program a robot. PwMCI can envision and design behaviors and interactions using **tangible objects**. Then, PwMCI and researchers program together using PODER's **programming tools** to translate their ideas into programs. Finally, PwMCI can test and view a physical **robot** performing their programs in real time, and iterate until they are satisfied with their program.

of the full abilities or limitations of a robot. Thus, they may be unable to effectively communicate how they want robots to behave without sufficient scaffolding. Ideation activities that promote concrete thinking (e.g., tangible objects, sensory experiences) may enable PwMCI to better express their ideas and be more included in robot design and development [37,38].

These gaps often limit robot design and implementation because HRI research lacks the means to support PwMCI to conceptualize, experience, program, and prototype their desired social robots. It is crucial to provide opportunities for PwMCI to experience robots, build knowledge about them, and use that knowledge to create more informed and personalized robot interactions. Thus, there is a strong need for programming frameworks that engage PwMCI in the prototyping and programming stages of creating robots.

In this work, we introduce PODER, a PrOgramming framework to DEvelop Robot behaviors (Spanish: *poder*: be able to *verb*, power *noun*) (see Fig. 1). PODER allows PwMCI to collaboratively program a robot and its interactions; express their preferences, experiences, and needs; and create their desired robot behaviors. PwMCI can collaborate with roboticists to create interactions using verbal and nonverbal robot features.

PODER facilitates inclusion of PwMCI in robot programming via pair programming [39,40], promoting peer-to-peer collaboration and a lived technology experience [16]. PwMCI can ideate robot interactions with *scaffolding strategies* and *tangible objects*. Then, PwMCI and researchers pair program the robot using PODER's block-based *programming interface*. PwMCI can test their programs on a simulated and/or physical robot to view them in real time, and iterate as desired.

The contributions of this work are four-fold. First, we present PODER, a collaborative robot programming framework that promotes concrete thinking, allowing people with cognitive impairments to collaborate with roboticists to develop personalized robot programs, including how a robot communicates, interacts, and behaves with users. Second, we introduce recommendations for promoting a deeper involvement and engagement of people with cognitive impairments in programming and creating social robots. Third, we provide insights on the social cues, elements, and robot features that PwMCI used in their programs, which can help other HRI researchers designing robots with this population. Finally, we plan to publicly release PODER as open source, so other researchers can use it in their work. Our work lays the groundwork for more meaningful inclusion of people with cognitive impairments in robotics research, design, and development, and ultimately positions these individuals to understand and shape technology to support their own priorities.

II. Background

HRI researchers have explored EUP frameworks to include non-expert end-users in robot programming. For example, Code3 allows users to control robot primitives to create more complex actions for a manipulator [26], and other researchers developed robots that let novice programmers synthesize emotions on robots [27]. Kubota et al. [30] developed JESSIE, which enables novices program complex, high-level social robot behavior via a tangible interface and control synthesis.

Other HRI researchers have explored inclusion of older adults in robot programming. For example, Hsu et al. [17] conducted a co-design study with older adults to program movements, expressions, and sounds for a humanoid robot. Ajaykumar [28] used a kinesthetic teaching approach and web interface to enable older adults to learn and program a robot arm. Ostrowski et al. [31] created a rapid prototyping tool for older adults to program social robot interactions.

While this work is exciting, PwMCI have unique cognitive needs and are a distinct population from older adults; it is important not to conflate the two populations [10]. For instance, they may require tools which leverage concrete ideation techniques rather than the abstract and complex nature of existing EUP tools. Thus, more work is needed to include PwMCI and early stage dementia in robot development. Our work draws from crip technoscience [41], disability studies [13,42,43], and critical dementia studies [9,11] to highlight PwMCI as "knowers and makers", and position them as expert designers and developers to have greater say in technology development processes [13,41]. This means designing "by" or "with" disabled people, not just designing "for" them [13,41,44]. These approaches help us avoid technoableism, or the belief that disability is a "problem" solvable by technology [45].

III. PODER: A COLLABORATIVE ROBOT PROGRAMMING FRAMEWORK

The goal of the PODER framework is to further the inclusion of people with cognitive impairments (and no programming experience) in the development of social robots. PODER enables a lived technology experience for PwMCI on three levels: 1) interacting with a social robot, 2) designing new robot behaviors, and 3) programming and testing their creations in real time. PODER provides structure to enable a collaborative relationship between a PwMCI and researcher, which centers the creative ideas of the PwMCI.

PODER is a collaborative framework that consists of a robot, scaffolding strategies, tangible objects, and programming tools (see Fig. 2). PODER uses CARMEN (Cognitively Assistive Robot for Motivation and Neurorehabilitation), an open-source robot developed by our team which can be modified to support additional functionalities [20]. We use scaffolding strategies so PwMCI can freely express what they want the robot to do, and actively collaborate with researchers to design and program robot behaviors. PODER also includes tangible objects that enable end-users to express and generate ideas without familiarity of robots or programming experience. Additionally, PODER has visual accessible programming tools so end-users can code and test their creations in real time.

A. CARMEN

While PODER is extensible to other robot platforms, we demonstrate it using CARMEN, whose interaction modalities include speech, a tablet to display content, and a screen to show facial expressions. It has four degrees of freedom, including torso and neck movement, and head nodding and tilting. PwMCI can utilize these modalities in their programs. CARMEN has ROS (Robot Operating System) nodes to enable these features. We used the Mozilla SpeechSynthesis interface [46] to synthesize voices on the tablet. To protect user privacy, PODER runs offline, and all cameras and microphones on CARMEN and the computer are disabled.

B. Scaffolding strategies

We incorporated four scaffolding strategies [47] to promote active collaboration between PwMCI and researchers to imagine, design, and program CARMEN.

Think-aloud and **show and tell** are successful strategies to demonstrate a new concept [47]. In think-aloud, PwMCI verbally express how they would design new robot interactions, including how the robot should communicate and behave with users, and what factors affect these interactions. With show and tell, the researcher steps through how to translate PwMCI's ideas into a robot program as an example before inviting PwMCI to use the programming tool themselves.

The essence of **pair programming** is pair learning, in which two people collaboratively program on one computer [48]. Using PODER, a PwMCI generates ideas for their desired designs with tangible programming objects (see Sec. III-C). Then, researchers concretize their ideas into programs with PODER's programming tools (see Sec. III-D). A PwMCI iteratively gives feedback until the robot behaves as envisioned.

People without experience programming robots might struggle to understand motor movement concepts such as rotation, degrees, and speed. Thus, PODER also includes **kinesthetic demonstration**, where users guide the robot through movements by hand [28,49,50]. Users can manually manipulate the robot (e.g. CARMEN's 4 DOFs) to concretize complex body gestures without needing to understand robot kinematics.

C. Tangible objects

To provide accessible options to design robot interactions, we created tangible objects. These tangible objects allow users to express their ideas in a familiar format, such as through writing, drawing, or thinking aloud, which do not require experience with programming or robots [24,51–53]. Tangible objects have been used to facilitate robot programming with novice programmers [30,54,55] and older adults [56,57].

We created **paper blocks** (i.e., big paper cut-outs with large text for users to specify different behaviors and interactions), including drawing the robot's facial expressions, writing what the robot should say, and what the tablet should display. We also created "action" paper blocks to enable users to express ideas for new features, behaviors, and interactions that the robot does not currently support to avoid limiting participants to the robot's current capabilities. Users can prototype interactions by positioning paper blocks directly on the physical robot to modify it. For example, they can affix the paper with the desired facial expression onto the robot's face.

PODER also allows taking photos with a Polaroid camera to support ideation, aligned with HCI work [51,52]. Users can use the photos to convey programming sequences on a **timeline**, akin to stop motion animation frames, to show how the robot will move (e.g., via kinesthetic demonstration) and interact (e.g., via paper blocks) over time.

D. Programming tools

The PODER framework includes visual programming tools to provide accessible means for people with cognitive impairments to translate their ideas into robot programs (see Fig. 3).

Programming interface: PODER includes a block-based programming interface, which has been shown to be accessible to novice programmers, older adults, and people with cognitive disabilities [26,40]. PODER's programming interface is based on Blockly [58], a visual programming editor. The programming interface contains the following custom blocks:

- *Say block:* Specifies what phrase the robot will say using its speech synthesizer.
- *Show on-screen block:* Defines the content to be displayed on the tablet screen.

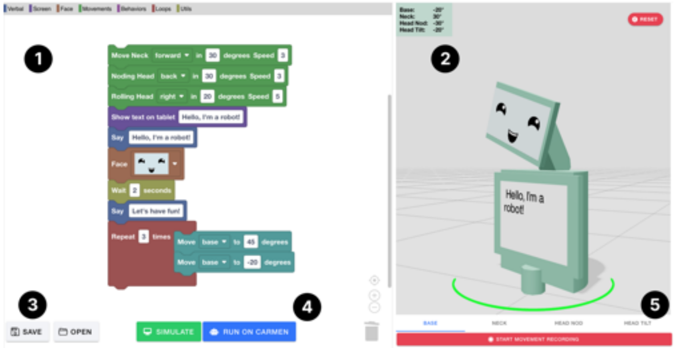

Fig. 3: PODER's programming interface has: 1) A block-based programming interface, 2) A 3D robot simulator, 3) Program saving and loading, 4) Running and debugging programs via the simulator or physical robot, and 5) Moving the 3D model to generate code blocks automatically.

- *Face block:* The user can select from 8 preprogrammed facial animations (normal, smile, grin, wink, surprise, nod, cool, celebration) to display on the robot's face.
- *Relative position movement block:* Moves the physical robot or 3D model (base, neck, nod head, and tilt head) to a relative position based on the current position using three parameters: direction (forward/back, left/right), degrees, and speed.
- *Absolute position movement block:* Moves the physical robot or 3D model to an absolute position, specifying a goal position in degrees and speed.
- *Saved program block:* Loads a previously saved program into a block.
- *Loop block:* Repeat other blocks.
- *Delay block:* Delays the execution of other blocks.

Users can combine these blocks to program robot interactions, with the option of saving and reusing their creations.

Simulator: The simulator includes a 3D robot model with all its features (speech, tablet, movements, and face). We used Three.js [59], a 3D Javascript library, to create and manipulate a 3D model of the robot. Users can instantly test and view their program on the model before running it on the physical robot. Users also can manipulate (drag and drop) the model to program robot movements, and the simulator automatically generates the appropriate code blocks.

Program synthesizer: The program synthesizer is responsible for generating the code implementation corresponding to the block-based program, to control either the simulator or the physical robot. If the user runs their program on the simulator, the program synthesizer generates Javascript code to control the 3D robot model. If the user runs it on the physical robot, the program synthesizer generates a Python implementation that maps to ROS nodes, and sends it to CARMEN to execute.

IV. Feasibility Study

We aimed to understand how PwMCI perceived PODER and the robot, and their experiences programming it. PwMCI collaborated with us to use PODER over a 1.5-2.5 hour long session, held either at the participant's home or in our lab. Our study was approved by the UC San Diego IRB.

A. Participants

We recruited seven participants with MCI from a previous study which included PwMCI. 6 participants had an MCI diagnosis, and 1 was just diagnosed with dementia. All participants were retired, ages between 62 and 91 years (mean: 75.57, s.d.: 9.96). Two were female, five were male. One identified as Black, one as Asian, and five as white. P4 had prior experience in software development, but no other participants had experience using robots or programming computers.

B. Measures

All participants completed a demographics form, the modified Computer Self Efficacy (mCSE) scale [60], and the System Usability Scale (SUS) [61]. The mCSE questionnaire formally measures the self-efficacy of older people or people with disabilities when using technologies [60], which we used to explore how confident PwMCI felt using PODER to program robots. SUS measures user perceptions of a system's usability through aspects such as the need for support, required training, and system complexity [61]. We conducted semi-structured interviews after sessions to understand participants' experiences using PODER to program robots. All sessions were audio and video recorded to collect participants' comments and impressions. Finally, we collected artifacts: the programs created by the participants and all tangible objects, including photographs, paper blocks, and sketches.

C. Materials

Researchers and participants with MCI collaborated using the PODER framework via scaffolding strategies (see Section III-B), using tangible objects (see Section III-C) and programming tools (see Section III-D) to program CARMEN.

D. Procedure

We welcomed participants and answered any questions. Then, we introduced the robot via a short video that described how it works and its context of supporting PwMCI [62]. Next, we asked participants about their experiences with cognitive training for MCI, attitudes towards technology and exposure to it, and feelings of inclusion in its design and development.

We then introduced participants to the PODER framework, demonstrating how to use the tangible objects and programming tool. We started with a "Hello, World" example and demonstrated how to program the robot, including changing its display, moving its head, and specifying its speech. After participants felt comfortable programming the robot, we shifted to the main part of the study.

We presented three hypothetical scenarios wherein participants created robot behaviors that reflect how they might want the robot to respond. These included 1) performing well on a memory game with the robot, 2) working with the robot for a week but not getting the outcomes they expected, and 3) having a difficult or stressful day, and how they might want a robot to help them relax. The first two scenarios are drawn from previous work and aim to address major questions in social robot behavior for longitudinal intervention contexts, including providing positive feedback and maintaining engagement during periods of frustration [63,64]. The third scenario was suggested by our clinical collaborator as a corollary to an activity they conduct in a human-led intervention.

Participants could use whichever PODER materials they wanted to program, and we supported them through scaffolding and peer programming strategies, including helping to see their programs come alive on the robot. Once participants felt the programs they created adequately aligned with their desired response to the scenario, we asked follow-up questions to understand what they thought of their program and what inspired them to create it that way. After completing all three scenarios, they completed SUS and mCSE. Finally, we asked about their experience programming the robot using PODER.

E. Analysis

We analyzed mCSE and SUS following their scoring methods. To analyze the interview transcripts, we used Reflexive Thematic Analysis (RTA) [65,66]. We divided them between three coders, ensuring two per interview. Each coder analyzed the interviews individually and generated themes. We then met to share, iterate, discuss, and frame our individual findings. We were cognizant of our potential biases as researchers so we engaged in a reflexive research practice and consciously avoided framing using the deficit model of aging [67–69] and technoableism [13]. We did not calculate inter-rater reliability as we aim to identify recurring themes and new concepts of interest through iterative discussions, and Braun and Clarke's perspective that inter-rater reliability does not align with RTA [70,71].

V. FINDINGS

A. Attitudes towards technology, mCSE, and SUS

All participants regularly used personal technology, and 5/7 expressed positive attitudes towards it. Even though participants expressed liking and curiosity towards technology, they also experienced problems such as burnout, feeling lost, that they were not good at using it, or that it was complicated without assistance. Additionally, participants did not consider themselves to be designers or developers of technology, only end-users. Participants had a mean mCSE score of 71.86/100 (s.d. = 13.48), suggesting medium confidence using PODER [60]. Participants had a mean SUS score of 68.21/100 (s.d. = 8.38), indicating average usability [72].

B. Experience using PODER

Enjoyment and engagement. All participants indicated that they had a good experience using PODER. PwMCI reacted very positively to the robot performing the programs they created. For instance, P1 was very enthusiastic about the robot, "See that's cute [laughs], that's cute, that's contagious." P6 expressed surprise and amazement throughout the session, saying, "Oh look at that [robot performing a behavior] [...] It's wonderful [...] I love it, I think it's great [...] Oh, it's marvelous." Additionally, during sessions, participants expressed their enjoyment when interacting with PODER elements, by clapping their hands, frequent laughter and smiles, and asking to take selfies with the robots to share with friends and family.

While we originally planned for one-hour sessions, they largely lasted at least 1.5 hours because PwMCI wanted to try different behaviors with the robot. Some participants even wanted to design and program behaviors for different scenarios, beyond those we provided, that were more integrated with their lives. For instance, P7 showed us games she plays on her computer, and wanted the robot to play the game with her.

Programming was easy and pleasant. No participants had experience programming robots. However, they all stated that PODER provided an easy way to work with and program the robot. For instance, P6 noted how easy it was to use after a few examples, "I think it was easy. I didn't think it [would be. . .] Once you explain it to me, look at how quickly, how much we did in just [...] 10 minutes of learning, right? We'll able to do all this." P2 stated, "If it's simple enough for me to do, I mean anybody ten years younger than me, [programming the robot would] be [a] no brainer, but for us older guys, it might be more difficult, but I even found it easy."

Participants expressed that working with PODER was exciting and fun, which suggests that participants could freely express their ideas. As P1 said, "It was fun, it was interesting. I've never done this before, so I can always say 'Hey [...] I built a robot to help me get my feelings out."' This sentiment extended beyond our session with participants. For example, P6 called one of the researchers two days later, saying, "It was a delightful time [...] what a pleasant experience [programming the robot]." When asked if they had additional comments about the study, P7 responded, "I would really like to play with it more. It really has a lot of possibilities in there."

A sense of ownership and accomplishment. Participants stated they felt part of the development process by programming the robot. P2 commented, "It stimulates my desire [...] to look more into it, and I feel like I'm a part of the robot now [laughs]." They also felt a sense of accomplishment when they saw their programs being performed by the robot. P2 said, "I like the results of [using the system]. When you do it right, it's very satisfying to get something accomplished with it." As P6 said, "So now we've done two programs [...] [I'll] get an [Associate's] degree pretty soon [laughs]."

Appreciating scaffolding and pair programming. All participants noted PODER's ease of use, and saw the value of pair programming to assist with generating ideas for interactions for CARMEN. For example, P7 had trouble envisioning CARMEN's behaviors on his own, but with our help, it was easier to bring out his ideas, "It's just difficult to imagine what I'm doing. I don't have a lot of imagination, but what you've shown me gives me a lot of ideas that I could use in the future." P2 agreed about the importance of peer programming and having more time to use and explore PODER, saying, "It's particularly easy, I'd say with your assistance snapping those guys [programming blocks] together. I think a few more times, and I would actually know which one to point at [...] the image, the verbal, and other stuff."

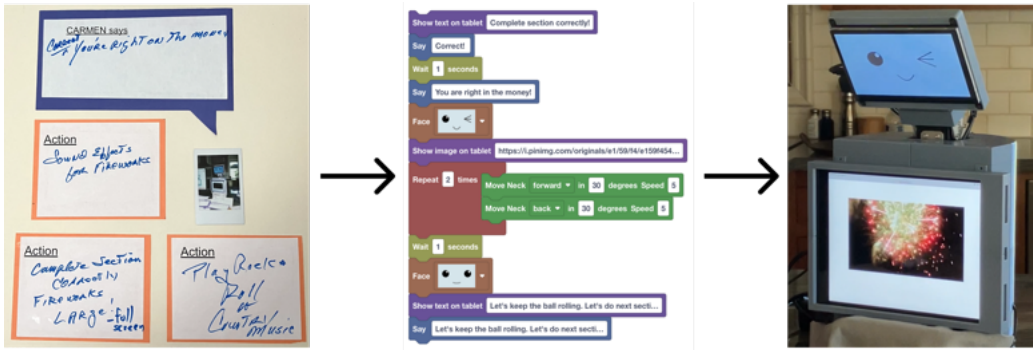

Fig. 4: In P2's program, the robot compliments him when he has done well in a memory game and encourages him to keep going. The robot shows a fireworks image and winks.

C. Advancing inclusion in robot development

Building confidence through learning. Participants expressed that they learned new things about robots and programming. For example, P1 explained how this experience helped her better understand robots, "[I learned] how to set up a robot [laughs] [...] I learned something new today that's interesting." PODER facilitated programming the robot, reducing cognitive load on participants. P5 was surprised, realizing he had programmed the robot. "Researcher: You programmed robots today. P5: I did? [...] You should have told me that before we started, I would have been very nervous. [laughs] Researcher: Did you feel nervous when you were using the system? P5: No, nah, did I look nervous?"

After programming the robot, participants felt more confident using programming tools and robots. P2 expressed, "I'm enthused about it now, so might be very confident [using PODER]." P3 similarly shared, "I'm more confident [programming] now than I was before you guys came."

Changing robot perceptions. Using PODER changed participants' perception of robots. For example, P6 realized robots are machines he can program, saying, "They [robots] are only going to do what you tell them to do. I mean, they're not independent thinking machines. They're program machines, just like your computer." Participants also realized they could personalize robots. As P2 expressed, "Personalizing [a robot] to the individual, I hadn't even thought of that. [...] Even your Roomba will probably talk to you [...] and say your name. [...] The personalization, that's a new one for me. My computer's always been very impersonal."

Envisioning new opportunities. PODER enabled participants to use and program robots, improving their knowledge about robots and technology. With this new knowledge about robot features, participants envisioned opportunities and contexts where the robot could support them. For example, P6 envisioned how the robot could provide daily support for his health, saying, "If [the robot] said, 'Three o'clock, time to take your medication,' and I went back in and said, 'Done, medication taken.' Then [the robot] would say 'Good job.'" Some participants expressed that programming robots could be an interesting cognitive stimulation activity, like P1 saying, "It keeps you wondering and trying to figure things out [how to program the robot], so it is exercising your brain."

As our participants interact daily with their peers, including PwMCI, they suggested some situations where CARMEN could support them. "[Many] people are singles [who live in his building], and you know, when you get older, and especially during COVID [...], people get very lonely and isolated [...], so anything like this that they can interact with [...] would be wonderful. [...] Something to tell them, 'Hey, don't get down,' 'Hey, here's, let's do this.' (P6)"

Feeling included in technology development. After the session with PODER, participants expressed feeling more included in the development process. For example, P6 was excited to feel part of the development and share his experience and knowledge to improve the robot, expressing, "It's very exciting just thinking of the possibilities [...] So that's exciting to be a small, very, very small part of that [the development process] [...] it makes me feel good. So I didn't waste my time coming out here, it was well worth it."

Participants openly stated their desire to continue collaborating with us to help improve our systems and robots. P2 said he wants to stay informed about our research progress and participate in future programming and design sessions, saying, "Let me know how it's going in the future. I'd like to hear, you know, what stage, maybe a picture of [the robot] once in a while, what to various new iterations of [the robot] down the road. [...] I don't know what your timeline is [...], but somewhere down the line, I'd like to try it again."

D. Features of PwMCI's robot behaviors

Reflecting and influencing emotion. Some participants wanted the robot to mirror the emotions they were feeling. For example, in the first scenario, where participants program a behavior for performing well, participants imagined the robot would say something encouraging, such as, "That's excellent" (P2) or "Yeah, [P1], good job!" (P1). P1 explained, "The scenario of [...] trying to play the games and stuff and getting frustrated. That kinda helped me display my feeling of what I wanted to say. So CARMEN knew, she knew what's up."

Other participants wanted CARMEN to show encouragement or positive behaviors to affect the frustrated feelings they were experiencing. "Yeah, uh, like a celebration, you know? Confetti [...] to me [...] is like a celebration. It could be [a] celebration of life, you know?" To clarify that we understood the design, we asked if P5 wanted this response from CARMEN when he was experiencing frustration, and he responded, "Oh yeah, yeah. What do you want me to do when I [am] frustrated? Cry?" P6 similarly suggested encouragement, "Well, [the robot] could say, if at first you don't succeed, try try again, because uh that's what you need to do. You have to remind yourself that you have to keep at it."

More natural behaviors. Participants wanted to make changes to the robot's voice and movements to make its behavior seem more natural. Participants wanted the robot's voice to match the tone and intonations, so be happier and more enthusiastic when saying something positive. P2 commented, "CARMEN should sound a little more excited about that [performing well]." P1 felt that the voice made CARMEN sound condescending when it said "Good job."

Participants also wanted CARMEN to more more naturally. P5 commented, "That movement, it's moving, but it's robotic."' When we asked P5 to describe how he wanted the robot to move instead, he explained that what he had in mind could not be conveyed on the robot. He explained, "There are a lot of things I could think of, but there isn't that much you can do with the robot, you know." He used hand motions to convey how he wanted the robot to "sway."

E. Personalization

Adding personal interest. Participants incorporated personal interests when programming the robot. P2 was a fan of the Top Gun movie, and incorporated elements from it into his programs. This included having the tablet display a jet taking off and fireworks, and having CARMEN play music from the movie (see Fig. 4). Participants also wanted CARMEN to display images from national parks, ocean and forest scenery, pictures of pets, and old family photos to help them relax. P7 loved playing card games, and suggested that CARMEN could play those games with her. "CARMEN can support you or can, you know, play that games with you in order, you know, to stimulate your memory, your cognition."

Personal conversations. Participants expressed wanting personal conversations with CARMEN. P5 and P6 imagined CARMEN would discuss a difficult day with them. P6 said, "If I could convey that to her, she could say, why don't you sit down for a minute and let's talk about it or let's discuss it or let's unwind, you know, uh just you know sit down, get a glass of water, get a drink or whatever you're gonna do, and let's talk about what happened and let's discuss."

VI. Discussion

A. Including PwMCI in programming robots

Overall, participants were overwhelmingly positive about participating in our study, and appreciated the opportunity to be involved in research. All participants expressed feeling comfortable using PODER to program the robot, even though they had no prior experience. We provide recommendations for enhancing inclusion of PwMCI in programming robots.

Using scaffolding techniques provides greater flexibility in how PwMCI can use and learn about robots and programming. For instance, we initially leveraged *show and tell* to demonstrate how to use PODER, then engaged in *pair programming*. Many participants used *kinesthetic demonstration* and *think aloud* techniques to express their ideas until they started using the tangible and/or digital programming interfaces. These techniques have also shown success for facilitating inclusion of other marginalized populations in programming (e.g., tangible programming for children with visual disabilities [73], pair programming for women computer science students [74]).

PwMCI may learn about robots by programming real robots. Most participants expressed a sense of ownership and accomplishment when seeing the robot perform their programs in real time, noting how this experience helped them better understand how robots work and what they can do. This shows the significance of including PwMCI in programming robots, which counters stereotypes about their lack of interest, ability (physical or cognitive), or digital literacy [10,75].

Additionally, **creating and concretizing robot behavior may improve PwMCI's confidence in learning robot programming.** Our results suggest that programming a robot can fundamentally alter how participants view their role in technology development. In our work, PwMCI shifted their perspective from being an end-user of a finalized technology product to a person who can program a robot according to their interests, desires, and needs. Some of the positive responses from participants suggest that allowing them to control what the robot says and does can be hugely empowering. This aligns with prior work [67,76], which argues that we can start to flip the script on how the end user is positioned relative to the roboticists' beliefs about the robots' role; here, the user (in their case, older adults) can be the one to "teach" the robot and share their wisdom, to facilitate more inclusive robot design.

Promoting integration of the "whole-self". Disability Justice emphasizes "recognizing wholeness", where each person has internal experiences composing their own thoughts, sensations, emotions, perceptions, etc. [77,78]. In other words, disabled users have personal preferences and interests beyond their identity as a disabled person, which technologists cannot assume [13]. PODER enabled participants to personalize robots to their broader interests, or support their whole self. For example, P2 used references from his favorite movie to program more enjoyable and engaging interactions, P4 programmed the robot to conduct the breathing exercises he uses to relax, and P7 proposed the robot could play her favorite card game. HRI researchers can use programming to understand how disabled people can integrate their experiences, interests, and desires into the design and development of assistive robots.

B. Sustaining Inclusion

PODER enabled participants to overcome their initial hesitance to be involved in technology development, with many expressing interest in remaining included with the PODER and CARMEN development processes. Intentionally bringing PwMCI in to shape future technology and research agendas is essential to subverting technoableism and marginalization of disabled people [13]. PODER helps poise PwMCI to be agents in their own lives and care, rather than passive recipients of researchers' agendas, by facilitating a more active role and better understanding of these technologies.

Our participants cited pair programming as an essential step to gaining confidence with PODER, as they could ask researchers to demonstrate and explain different components of the tool when they needed assistance. This highlights the importance of taking the time to help guide participants through the development process to constructively and thoughtfully include PwMCI and other disabled populations in HRI. Scaffolding strategies such as those which PODER employs are crucial to facilitating such inclusion.

However, long-term involvement of roboticists may not be feasible, especially in research contexts [17]. Thus, sustainable strategies are essential to promoting sustained and long-term involvement of PwMCI in HRI research and development. One possibility is to train community health workers to use tools such as PODER, and deploy these technologies to community centers. For example, our team works closely with a local Alzheimer's support center that may be able to use PODER to pair program these systems or use them for cognitive stimulation with their participants. This research direction would draw upon the emerging body of HCI and HRI research on sustaining community use of sociotechnical resources such as makerspaces and social support systems [40,79,80].

Training stakeholders could also engage care partners in the development process, or even lay the groundwork for PwMCI to organize workshops and support pair programming with other PwMCI. Our participants naturally considered how their programs might be adapted to other users (e.g., P2 wanted firework sound effects, but noted that they might not be appropriate for someone with PTSD). This connects to the disability justice principles of interdependence and collective access by shifting power to PwMCI to sustain and disseminate knowledge effectively for their communities [78].

C. Ethical Considerations

Participants wanted the robot to have more human-like features (e.g., expressive voice, conversational ability) and responded positively to personalizing CARMEN. However, these raise ethical concerns regarding emotional well-being and autonomy. Robot anthropomorphism and personalization can help promote engagement and usability, but if used carelessly, can be deceptive and lead to incorrect assumptions about a robot's abilities [81–83].

In providing PwMCI the means to easily personalize social robots, they may more adeptly create their own "perfect companion" which behaves exactly how they want [81,84]. This could lead to increased emotional dependency and withdrawal from social activities [85]. Participants expressed that programming the robot with PODER helped them better understand how the robot works and its limitations, thus preventing over-anthropomorphizing the robot. For instance, P6 commented on how programming the robot gave him a better understanding of how robots work, and that CARMEN was only going to do what he programmed it to do.

In addition, design tensions arise when stakeholders such as PwMCI, researchers, clinicians, and carepartners have different views on designing robots for and with PwMCI [86,87]. When designing for PwMCI, we need to be aware of these tensions between stakeholders [81] and the potential for ableist paternalism, which many disabled people are subject to [88]. PwMCI should be seen as experts when designing and programming tools for PwMCI and have their perspectives highlighted, as many disability justice advocates have pointed out that many technology studies have excluded disabled people and instead only consult proxies [77,89].

Our work raised interesting points regarding balancing the potential for robot (and researcher) paternalism with the desires of participants [88]. In our study, participants expressed wanting CARMEN to hold conversation, provide advice on problems in their life, and give encouragement. These features may lead to robot mediated paternalism [88] and open the door to robot capabilities that the robot ethics literature warn against, such as reducing a user's autonomy by influencing decisions, deceiving users, or privacy loss [81,83,84,90]. At the same time, since these are features suggested by PwMCI, refusing to support these features in PODER or similar tools may also be paternalistic of us as researchers and developers. More research is needed to determine how to best meet the desires of users and support their autonomy while minimizing the potential risk of personalized systems.

D. Limitations and Future Work

One limitation of our study was the small sample size. A larger sample would help us dig deeper into participants' experiences with PODER and how to improve it. On the other hand, when working with smaller populations, we want to ensure we do not burden participants with frequent repeated sampling [91]. Another limitation is possible self-selection bias. During recruitment, prospective participants were told they would be using a robot, and those who expressed interest may have already had positive views of technology. Finally, participants expressed wanting more time and practice using PODER. Thus, in the future we plan to recruit: 1) a larger sample, 2) participants with a broader range of technology interests, 3) conduct longitudinal studies.

PODER is readily extensible to other robots by modifying its programming interface. This involves importing a robot model, modifying the blocks for the robot's capabilities, and updating the program synthesizer for the robot's architecture to create robot-specific code. Thus, we plan to demonstrate PODER's extensibility with other robot platforms so users can design and program personalized interactions for other robots.

VII. Conclusion

We presented PODER, a collaborative robot programming framework that facilitates inclusion of people with cognitive impairments in social robot programming. We hope this work will lay the foundations for increased inclusion of people with cognitive impairments in HRI research and ultimately generate more technologies made with and by these populations.

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