Designerly Scaffoldings for Co-designing Social Robots and Human-Robot Interaction

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Abstract — Autism impacts around 5 million people in the EU (Autism-Europe). Research has shown that social robots, due to their deterministic nature, simplified appearance and technological capabilities, can enable therapy or become assistive technology for empowering autistic individuals with household activities. Consequently, toolkits have emerged for prototyping social robots. Regarding such toolkits, there is a methodological, inclusion gap: there is no comprehensive, scaffolded co-design process to include cognitively disadvantaged users in decision-making regarding robots' fundamental design choices. To overcome this gap and empower autistic adults to truly design their own (non-preprogrammed) robots, this research explores a social robot toolkit driven by designerly scaffoldings for driving participatory design activities.

Keywords — Participatory Design, Scaffoldings, Autism, Social Robots, Co-design.

1. INTRODUCTION AND RELEVANCE

1.1. Introducing this paper's research: The Co³ Project

The research project that this paper addresses is termed the Co³ Project and encapsulates: *Co*-designing a *Co*llaborative So-bot *Co*-creation Toolkit. And this is what the project is about. A so-bot, or a social robot, is a robot whose purpose is to work collaboratively with humans to assist them with various tasks. It comes with a "social interface", which is essentially all the characteristics related to its form, function and context due to which one would attach social qualities to it [7]. And so-bot co-creation entails inclusion of relevant stakeholders (especially the disadvantaged or vulnerable ones) in the social robot design process.

1.2. Increasing importance and ubiquity of so-bots (social robots)

Social robots (or so-bots), in one form or another, are becoming increasingly ingrained into society. The American think tank, Pew Research Center, predicts that by as early as 2025, "AI and robotics will be integrated into nearly every aspect of most people's daily lives". It claims that such agents with social intelligence will become increasingly competent at handling the tasks of our daily lives and will become ubiquitous in household and have an impact beyond general public and households: "Advances in AI and robotics will be a boon for the elderly, disabled [physical or mental impairments], and sick". The recent research within robotics and Human-Robot Interaction (HRI) literature also points out that robots are only going to become increasingly embedded within society, across functions and domains [11].

1.3. Social robots for autism

This ubiquity and importance of so-bots is especially true for their use within the autism domain. According to the triad of impairments theory [6], Autism Spectrum Disorder is composed of three symptom classes: Impairments in social communication (related to linguistics, facial expressions or body language), impairments in social interactions (related to emotions recognition and expression or social relationship development) and impairments in imagination (related to abstract thinking or generalizing insights). So-bots have the potential to aid autistic individuals due to: their predictable nature (making them easier to trust), their simple appearance (preventing overstimulation) and their greater approachability (due to absence of negative past experiences with them) [1].

Fong et al. [3] emphasize the need for effective design of the interaction between social robots and humans. Their study magnifies that so-bot development should not just be about adding technical capabilities to perform limited tasks, but also about designing human-robot interaction (HRI) in such an inclusive, human-centered way that social robots can "participate in the full richness of human society". Within the autism domain, the biggest state of the art gap that prevents such "full richness" participation is that so-bots are typically designed, developed, manufactured, and only then applied to the autism target group; rather than being co-designed with and for them.

This gap holds true for almost the entire state of the art: so-bots like Opsoro, Zeno, Kaspar, Darwin-OP2, Probo, Nao etc., were all designed and thereafter put to use for HRI research within autism. Research projects that do adopt participatory design to design products for the autistic population tend to achieve more engaging and effective results. Participatory design enables researchers to effectively learn about vulnerable groups and to design technology specifically for them particularly if the groups' lives are distant from their own [4]. Merter and Hasırcı [10] also show how participatory design for "special user groups" increases their life quality and illuminates their unique capabilities. Hence, this study incorporates participatory design, to broaden the usefulness and impact of HRI research.

1.4. Designerly scaffoldings

It is due to the above-mentioned triad of autism impairments that there is indeed a strong need to practice participatory design in order to ensure inclusiveness and empathy when designing for this target group. Whilst practicing participatory design itself can already enable such inclusive design, special tooling can be useful when designing for and with individuals that are autistic.

The reason for this is that participatory design alone is just a methodology for including relevant stakeholders in parts of the design process; it does not by itself e.g. induce imaginative or social abilities into autistic individuals that lack them. Therefore, some extra cognitive scaffolding is needed that can be embedded in artifacts that can facilitate participatory design activities. It is this scaffolding for alleviating the triad of impairments in autism that this paper calls for adoption of. For overcoming the triad is key to empowering autistic individuals to truly take part in participatory design activities for social robots.

The concept of scaffoldings was coined by Vygotsky [12], according to whom externalized structures (to which he included language) are capable of influencing and informing a person's inherent cognitive information processing and understanding processes. Clark [2] takes this scaffolding concept further by arguing for these externalized structures, artifacts or processes to be considered as "backdrop of intrinsic bodily dynamics", through which an individual is able to leverage reliable environmental properties to solve cognition-centered problems. This definition by Clark [2] of cognitive scaffolding is what this paper bases its position on, where individuals are able to exploit external, environmental structures (including other humans, artifacts, tools and "material agents") that form a backdrop relative to which the individual's cognitive problems can be solved.

1.5. Research question

The Co^3 Project, then, aimed to bridge the gap regarding inclusion of autistic adults in so-bot development by using designerly scaffoldings. The project was built upon the opportunity for advancing the research on the use of social robots for autistic individuals, and on the participatory design methodology for co-designing such social robots. The purpose of this research project was, therefore, to explore the co-design of a so-bot toolkit for and with adults on the autistic spectrum at an autism care institute in Oldenzaal, The Netherlands. This was to be done with a focus on incorporating scaffoldings, that truly enable the inclusion of a vulnerable target group, to drive the participatory design activities. The following research question guided this purpose:

How might we co-design a scaffolded toolkit for co-designing social robots for and with autistic adults? What implications can such a scaffolded approach lead to?

2. RESEARCH TOOL AND METHODOLOGY

2.1. Why was participatory design (PD) through designerly scaffoldings chosen as the research methodology?

The authority for decision-making about robot applications and design has mostly been restricted to the robot designers or researchers working on the human-robot interactions. But as Lee et al. [8] point out, the depth and broadness of the societal impact such robots can have demands a more inclusive design process that is driven by participatory design methodologies. The success Lee et al. [8] have regarding participatory design of social robot concepts with a group of extreme users suggests that users/participants can be much more than informants and this form of a bottom-up, participatory approach is the philosophy behind this paper's research methodology.

2.2. Designerly scaffoldings to co-create social robots: So-bot Co-creation Toolkit (So-bot Co-creation Toolkit)

The overall purpose of the study was to co-design a so-bot co-creation toolkit by including the target group right from the start through the use of scaffoldings. Thus, after some initial research and ideation of preliminary so-bot toolkit ideas, an interview session was conducted with the target group at an autism care institute. The session involved: Understanding experiences of autistic adults and introducing them to social robots. The session revealed the need for a process-centricity rather than primarily a technological one. A technology-centric approach where so-bot building blocks are presented to the target group and they are expected to develop useful so-bot concepts was not possible. Having solely a technological toolkit cannot automatically bring technical familiarity, imagination-related skills and collaborative skills to an autistic target group (that is deficient in these). Thus, the project was led to be more process-centric: Where a process or a narrative would be established as extra scaffolding around technological building blocks.

Continuing with this process-centricity, the process designed for the Co^3 Project's research can now be discussed. It is called the So-bot Co-creation Process and figure 1 shows it at a high level. The first step involves the participant making choices or decisions about various aspects (robot type, robot tasks, robot functions etc.) of a so-bot concept through a narrative-driven approach (facilitated by a facilitator). The choices made by the participant about these aspects then form a recipe or a blueprint for the participant's so-bot concept. Once such a blueprint is drafted, a prototype of the entire or parts of the so-bot concept can be built, which can then be tested. These four steps are conducted in a flexible, iterative way with participants encouraged to move back and forth between them. Moving along the rocess, the specificity increases, the practical constraints increase and the real-world "prototypability" at the final step is fed back to the previous steps. As such, the process promotes reframing of the initial problem and divergence of the possible so-bot solution(s).

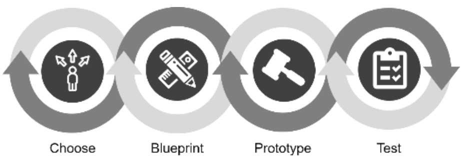

Fig. 1. The four step So-bot Co-creation Process

The process still had to be made "usable", and for that it had to be embedded into the So-bot Co-creation Toolkit which forms the tangible scaffoldings for the process. The So-bot Co-creation Toolkit (summarized in figure 2 that depicts *actual* portions of the toolkit) comprises materials corresponding to the steps of the process: The toolkit's So-bot Co-creation Cards facilitate (1) choice-based "Choose" and "Blueprint" steps and the toolkit's So-bot Co-creation Building Blocks facilitate (2) robot building "Prototype" and "Test" steps.

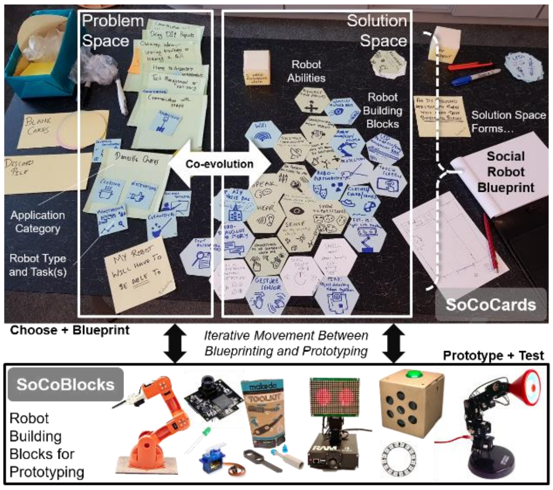

Fig. 2. The constituents of the So-bot Co-creation Toolkit

For (1), the toolkit features So-bot Co-creation Cards which divide the workspace into a problem space and a solution space (figure 2). The problem space consists of a so-bot concept's aspects related to the participant's need(s) or problem(s). It consists of cards regarding the application category of focus (e.g. domestic chores, offering infotainment, task management, well-being) and regarding robot type and task(s) (e.g. cooking robot that reads recipes and fetches food or companion robot that serves as a play partner etc.). And this problem or need space is where a PD participant starts with the process of blueprinting a so-bot concept. Once decisions are taken regarding these aspects, the participant is iteratively moved to the adjacent solution space. This space consists of cards related to aspects of the so-bot concept solution being developed: robot abilities (robot should be able to speak, hear, move, grasp etc.) and robot building blocks (robot should have speech recognition, mic, camera, wheels, arms, LEDs etc.). The facilitator also creates a narrative-type scaffolding around the cards, to facilitate co-design. Having a side by side problem and solution space encourages continuous, rapid iterations between the two, promoting co-evolution of problem and solution (figure 2).

For (2), the So-bot Co-creation Toolkit contains So-bot Co-creation Building Blocks (like a robotic arm, LED ring, robotic lamp etc.) for rapidly prototyping, integrating and testing (parts of) so-bot concepts (figure 2). So-bot Co-creation Building Blocks help with grounding into the real-world of and testing of the so-bot blueprint(s) generated through the first two steps of the So-bot Co-creation Process.

The toolkit was developed through both empathizing with the target group and through ideas contained within PD and so-bot literature. The idea of dividing the content up into category cards aligns with the nature of Frauenberger et al.'s [4] card-based co-design planner and with the proven effective "Inspiration Card Workshop" concept from Halskov and Dalsgård [5] where they also had a generic, card-based co-design tool. Makhaeva et al. [9], validate how a process with physical (e.g. So-bot Co-creation Building Blocks), methodological (e.g. So-bot Co-creation Cards) and social (e.g. facilitator) structure-freedom interplay elements enhances a PD participant's personal creativity path's discovery.

2.3. Conducting research through and on the So-bot Co-creation Toolkit

Once the So-bot Co-creation Toolkit was developed, it had to be tested as a research tool/probe for gathering insights (conducting research through it) and its own effectiveness had to be reflexively evaluated (conducting research on it). To achieve that, two further co-design sessions were conducted: a blueprinting session and a prototyping session. These sessions were conducted by an external so-bot co-creation facilitator who was chosen for his similar "technical/DIY" facilitation role at the autism care institute where this study was conducted with three autistic adults (two male and one female).

The blueprinting session involved, firstly, getting a participant acquainted with the whole process and with the So-bot Co-creation Cards by creating a narrative full of question prompts around it. Secondly, generating several (generic) social robot concept ideas through iterations between the problem and the solution space of the So-bot Co-creation Cards. Thirdly, nudging a participant towards personalizing, combining, recombining and reinterpreting the existing So-bot Co-creation Cards.

The prototyping session involved, firstly, the grounding of concepts generated in the blueprinting session into a participant's actual household environment by asking the participant to describe or draw their rough floor plan and household, after which the facilitator could discuss how the concepts could be embedded into household spaces. Secondly, prototyping and testing of already generated concept(s) from the blueprinting session by using So-bot Co-creation Building Blocks in a way that a concept can be prototyped as far as possible (even if the prototype involves role-play). Thirdly, feeding back the results from prototype testing to modify the blueprint(s) and to retest the changes made.

3. IMPLICATIONS

The blueprinting and the prototyping sessions outlined in the previous two paragraphs were conducted and became the primary source of insights and inferences derived from the Co^3 Project's research. Here is an overview of the main implications (Liz, Martin and Tom are pseudonyms used for participants' names to protect their privacy):

Designerly scaffoldings can help advance the social robot state of the art. The state of the art went beyond typical anthropomorphic designs and beyond the typical autistic children target group and beyond what can be created by a designer themselves. In words of the facilitator himself, *"Concepts that came out were personal. Right there on the edge. Beyond the logical, simple first solutions. Flic buttons combined to a screen with a simple light. Having speech but no hearing. I could not have come up with this on my own."*. Hence, the So-bot Co-creation Toolkit and the scaffoldings therein (So-bot Co-creation Cards and So-bot Co-creation Building Blocks) did empower autistic individuals to develop truly novel and personalized concepts that could not have been thought up solely by a designer. The figures 3 and 4 show Tom's and Liz's results from both their blueprinting and their prototyping sessions.

Designerly scaffoldings can empower autistic adults to solve their own problems (without unnecessary robot involvement). Perhaps Martin's session is the best example of an unexpected form of participant empowerment. When coming up with a blueprint for his so-bot concept and when describing his preferences for the so-bot, he said, *"It shouldn't do the work for me…it should only tell me when something needs to be done"*. Hence, participant empowerment through our co-design approach is not necessarily technology-centric and about creating so-bot solutions that can sense and do everything. It could, in fact, mean the reduction of offloading of tasks to the so-bot, such that the so-bot becomes merely a passive assistant.

Designerly scaffoldings can create active engagement and inclusion of autistic adults in a process for co-designing social robots. According to the facilitator, active engagement in the process was manifested and achieved by for example: *"Asking them [participants] to draw their rooms for grounding"; "Not having too open imagination"; "A problem explicitly asked from them was a source of active engagement."*. The facilitator further remarked about participant engagement: *"Each [participant] came up with a pretty original concept really tailored to specific and very personal issues…"; "The level of depth in which concepts arose were not just sketching exercises…[they were situations] where a robot had to solve a real problem"*.

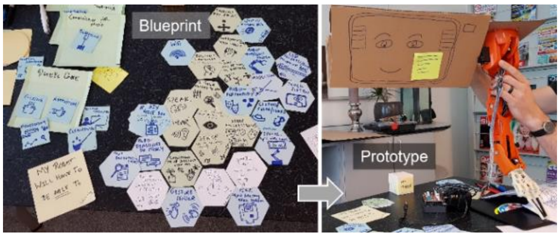

Fig. 3. Tom's cooking assistant so-bot with a digital face, an interactive touchscreen and an arm for cooking tasks

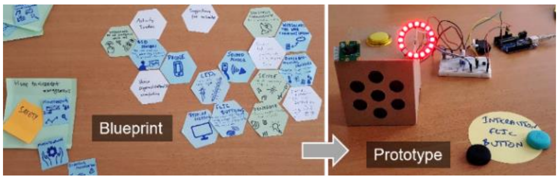

Fig. 4. Liz's security, maintenance and well-being so-bot that provides non-intrusive, task-oriented feedback through an LED ring or through localized button-activated speech

The project showed flexibility and appropriateness of the So-bot Co-creation process to various situations, preferences and participants; and led to the emergence of diverse concepts. It was shown that the process's flexibility was an asset. In the facilitator's own evaluation of the so-bot co-creation sessions: *"If you see how the process facilitated three different people, with three different needs, in achieving the outcome. And coming up with radically different concepts. Security system with remote buttons [figure 4], clutter detector, cooking arm [figure 3]…the process went completely different with the three of them. And accommodated their different ways of working and mindsets. It was open-ended in terms of outcome. So yes, flexibility criteria were met."*.

Designerly scaffoldings for co-designing social robots align with the situatedness of autism and dependence of creativity on the right context. Contrary to popular belief, it is not that autism is not "typical". It is just that people who have it are not provided with a context that is appropriated, situated and suited to their specific quirks, qualities and mindsets. Viewing autism as such and providing the right scaffoldings for such situatedness to happen makes autism pragmatically "neurotypical". For instance, the facilitator said, *"But it [the co-creation process] was a meaningful thing...he [Tom] liked it and felt that he achieved something useful. Also, for [Liz] same holds and for [Martin]."* The facilitator reasoned about this usefulness of process and concepts by saying, *"Because…for them [participants] it was really about problems that were important to them"*. And this is what situatedness can achieve. It involves providing the right context appropriated to a particular participant, their personality and their problems. And when that happened, *"Concepts that came out were…beyond the logical, simple first solutions… I could not have come up with this on my own."*, as the facilitator noted. Is that not as competent as what one would imagine a neurotypical individual to be in a creative task? That is how powerful the right cognitive scaffolding and the right co-design context can be.

4. CONCLUSION

The Co^3 Project has produced a toolkit of linkable social robot building blocks centered around which are holistic, designerly scaffoldings for conducting social robot participatory design with cognitively impaired individuals. That process has artefacts meticulously designed with the participants in mind–giving the artefacts sufficient scaffolding to make co-design navigable by bridging the impairments in imagination and social interaction of the involved participants. By doing so, the project aims to show how actively incorporating designerly scaffoldings can make the co-design of human-robot interaction more inclusive. The project aims to inspire a movement of open-source, scalable and democratized social robot co-design, which is driven by scaffoldings and which can empower egalitarian inclusiveness in design of all users–to evoke questions on which human-robot interactions to design in the first place and why.

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