DESIGNERLY
HRI
KNOWLEDGE

Functional Aesthetic Design of Therapy robots:Towards Strong Concepts for HRI.

Eduardo B. Sandoval[1], Dagoberto Cruz-Sandoval[2], Jesús Favela[3]

[1] University of New South Wales, Faculty of Arts and Design, Sydney, Australia, e.sandoval@unsw.edu.au

[2,3] Centro de Investigación Científica y de Educación Superior de Ensenada-Consejo Nacional de Ciencia y Tecnología, Ensenada, México, dagoberto@cicese.edu.mx, favela@cicese.mx

Abstract — This paper discusses the functional aesthetic, induced expectations and mindset recommendations generated during the design of a Social Robot prototype for Dementia Therapy. We aim to generate strong concepts applicable to Human-Robot Interaction (HRI). Our attempted contributions respond to the need of designing a robust, repeatable, prototype with a distinctive design in terms of aesthetics as affordances, semiotic values, consistency in materials and shapes which are not often reported in (HRI) literature. Previous work with a heavy focus in the human-machine interactive factors involved in the experimental sessions was done before this prototype. Similarly, we aim to report the design process involving discussions, design decisions and agreements pursuing a better user experience with a multidisciplinary perspective. We try to propose future strong concepts as *Robot embodiment follows function* and *Robot Affordances set user's expectations* usable in the specific context of HRI. Future work involves the distribution of the CAD for future implementations by other social robotics research teams, validation comparing with previous developments and variations of this prototype, and further discussion of our proposed strong concepts.

Keywords — Design of Social Robots, Design Heuristics for Social Robotics, Multidisciplinary research, Intermediate-Level Knowledge.

1.INTRODUCTION

This paper aims to contribute with a case study in the emerging field of Design of Social Robots. Design of Social robots is a critical topic that has been discussed in a limited way on HRI. The conceptualisation of Social Robots as products is vital and the design process should be documented if we aim to use these social robots extensively. The participation of product and industrial designers, among other less technical oriented professionals is critical for the success of robots out of the experimental laboratories. Furthermore, the current approach used to design social robots relies mainly on the experts in artificial intelligence, computer science, robotics, and other technical fields. There is a minimal participation of professionals in arts, design and humanities in the design of robots. Additionally, the involvement of these creative professionals happens later in the design process.

We contribute reporting the design process of our prototype and proposing two strong concepts from the work in the functional aesthetic expectations and recommendations done in the design of a social robot prototype used for Dementia Therapy. These are the product of interpretative research aiming to produce intermediate-level knowledge. As far as we know, the reporting of the design process as ours is very uncommon on HRI and we consider that these strong concepts (*Robot embodiment follows function*, and *Robot Affordances set user's expectations*) have potential for future better social robot designs and should be further discussed.

2. PREVIOUS WORK

This paper reports a partial development focused in the external design of a social robot used as a prototype for Dementia Therapy. Different aspects of this project have been reported previously in [1]-[7]. Validations and experiments with an earlier prototype have been done and interactive features were already established in [6]. In [6] is described the previous prototype called Eva and presents the requirements of the semi-autonomous conversational robot. An evaluation conducted with eight caregivers of people with dementia suggests that the robot has potential as an engaging autonomous agent used to converse with patients.

We expect that this redesign engages similarly or better with patients in the future. The current paper reports one of the latest stages of the project and further explores the design variables involved in future experiments. See Figure 1 to check over previous prototypes.

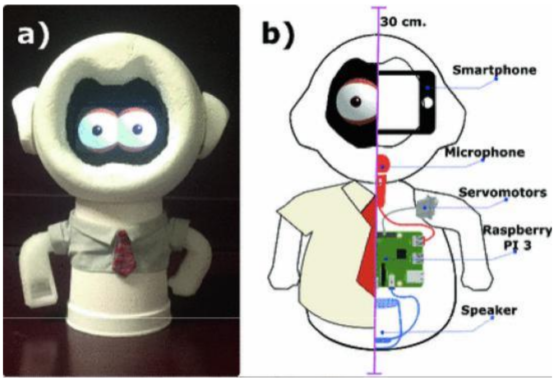

Fig.1: Early prototype of this project and main components present on it.

3. DESIGN GOALS

For the design of this prototype, we discussed and agreed to focus on specific design goals:

1) *Repeatable embodiment*: We aim to share this prototype with a broader community of robot enthusiastic, developers, and social robotics researchers. Hence, we chose 3D printing as an additive manufacturing method broadly available for a significant number of users interested in social robotics. Construction time was also a variable to consider; we design eight main pieces which can be printed in a matter of days and maintain the specifications steady. Similarly, customization is possible if future users required it. The STL files will be available in an online repository soon.

2) *Robustness*: Previous versions of the prototype were made using fragile materials as expanded polystyrene and plastic parts. This prototyping is a common practice in HRI when commercial robots are not available. These kinds of prototypes are under the permanent risk of being damaged.

3) *Identity*: A posteriori, during the design process, we determinate that we should propose a unique identity for this robot and its purpose. After the first iterations, we notice that materials used in the 3D printers should match with the possible shapes that can be print. Similarly, we should consider the constraints imposed by the 3D printers used and conciliate with the design possibilities and interactive features. After intense discussion and prototyping; polygonal sections were used to accomplish this design goal. This polygonal design provides some historical context about when and how the robot was designed.

4) *Semiotics and Affordances*: Simplicity, users' context and functionality should be presented as the core values of a social robot designated to be used as a conversational agent. The microphone has a dominant value being the core device supporting interactivity. We moved from a skeuomorphic eye's design towards a more minimalist eye's design. This minimalist style was adopted to be aligned with the new embodiment. The role of the eyes in conversational robots is to support verbal interaction and should not be dominant in the communication with the user.

4. DESIGN PROCESS

For this prototype, we adopt a democratic decision making considering the magnitude of the project and the work developed in previous prototypes. Design decisions were agreed and implemented by the core design team. However, a democratic process involves continuous discussion; which is a not conflict-free process. The similar level of experience of the core design team allowed this process and results are acceptable for the original purpose of the project. However, we cannot recommend this approach to the future development of social robots for larger teams and more complex platforms. As is discussed in [8] and [9], similar social agents have not fully succeeded, a possible cause of this is the compromise design decisions aiming to democratize the decision making matching different approaches and disciplinary goals.

On the other hand, design principles for social robotics described in previous work [12] were used as guidelines for the development of the robot. Examples of these principles are Multidisciplinary teams design robots, Robot users before robot designers, and Robot embodiment is aesthetic, understandable and useful. None design philosophy was implemented explicitly; (i.e., UX, Human-Centered Design, Emotional Durable Design, and participatory design). However, the multidisciplinary background of the team and our previous experience in robot design allow us to proceed as we were performing Product Design.

The design process followed a no strict agile project management. Usually, short daily sessions from 15 to 30 minutes to discuss progress and agree future characteristics of the robot embodiment were done during five days per week. The full process, since the conception to the construction of the final prototypes, took three months. Four iterations of design and printing were made to test the CAD designs and quickly move to the redesign process. See Figure 2.

4.2 Multidisciplinary Team

A duo of researchers in HRI conformed the core design team for designing and building this prototype. One of them has a background in computer science and software development. Similarly, this researcher has experience in the design of experiments on HRI with a focus on dementia therapy as part of his PhD. Before the current prototype, this researcher developed several early prototypes with expanded styrene and plastic materials to be used in experiments in Dementia therapy. The other researcher has experience leading the design and construction of robot prototypes for research and industry. For instance, Inmoov robot, JPL Open source rover, and Hoiho robot as a social interface [13], and a robot lifter for hospital use. Previous experience in experimental HRI is also present, particularly in the design of interactive social experiments between humans and robots [10]-[12]. He was co-author of some papers related to the current research in Dementia. His training has been in bionic engineering, industrial design, and HRI. The third author is a senior researcher; he was continuously consulted along the design process of this latest prototype.

4.2 Tools and Components

The robot was designed using Blender and printed in Makerbot Replicator printers using standard PLA filament. A standard Bluetooth speaker was used to provide a voice to the robot, and a 6.5 inches android phone was used to display the robot expressions. The microphone was upgraded, and a Matrix Voice Microphone was used for this prototype.

5. RESULTS

Daily discussions to take design decisions produced four main iterations in the design of the prototype along the three months. See Figure 2. This agile methodology allows us to reduce delays and test and reject ideas quickly. We moved from the original design in the early prototype towards a more robust, minimalist prototyping aiming to be repeatable by other research teams. The prototype presents a distinguishable embodiment aligned with the plastic material used in 3D printing. The early prototypes revealed that the final texture would match with the polygonal sections present in the robot embodiment. Other processes (primer and paint) to polish the appearance of the robot could be not necessary if a higher resolution in the 3D printers is used. Hence, a future prototype can be assembled after 3D printing and adjustment can be easily done.

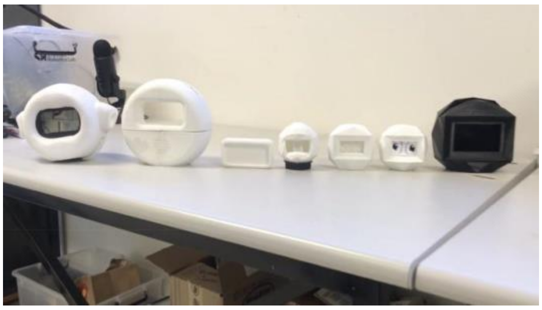

Fig. 2: Four iterations were made in the re design of the robot.

Figure 3 shows the CAD of the final prototype in an explosion view to assembly eight parts. Dimensions were established according to the internal components and constrained by the limitations of the 3D Printer. In the same way, we tried to maintain specific proportions to suggest a humanoid robot. Stability and space for future components also determinate the volume in the robot's base and head. Two prototypes were built, one in white and one in black to be used in different locations. We aim to validate the color of the robot as a factor impacting the interaction with the user soon.

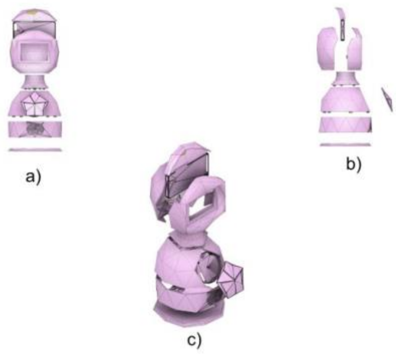

Fig. 3: CAD explode view of the final prototype. As can be observed there are eight main pieces in PLA, cover for the microphones is in clear plastic.

The eyes displayed in the screen were redesigned to show an expressive but minimal design matching the voice and the new embodiment of the robot. However, this characteristic of the robot should be discussed further in a different report.

Further validation of this change is required due to disagreement between the designers.

Figure 4 shows the final prototypes printed and ready for future evaluations. Non-utilitarian anthropomorphic features (arms) and prompts (tie in the neck, and fabric shirt) were removed because not a strong argument to have them was presented, and they would complicate the construction of the robot. Furthermore, we consider these features affect the expectations of the users when interacting with robots; in our experience, we agreed that very often people perceive humanoid robots as more capable of interacting. However, social robots have still minimal skills for multimodal and physical interaction.

5.1 Aesthetic suggestions applied to this prototype

The design process of this robot prototype made us reflect and acknowledge the importance of a distinctive embodiment that can be replicated: One of our recommendations related to functional aesthetics and induced expectations matches with the proposed in [15] as *'Aesthetic and minimalist design'*. Minimal humanization sets user's expectations rightly. In other words, if no arms and prompts are present, people can understand better that the robot is a highly skilled conversational agent but would not expect some physical interaction. Other recommendation as a mindset for design teams that we propose are: 'Trust your experience, do not over trust it'. 'Think fast using your experience.' and 'Intense discussion, action, prototype, redo.' These recommendations were applied during the design process and allow us to finish the prototype with acceptable results.

6. STRONG CONCEPTS GENERATED IN THIS PROJECT AND HEURISTICS

Considering the development done in this prototype and the interpretation of our findings, we aimed to generate some generative intermediate-level knowledge in the form of strong concepts. Strong concepts are described by Höök and Löwgren as *"design elements abstracted beyond particular instances which have the potential to be appropriated by designers and researchers to extend their repertoires and enable new particulars instantiations."* These strong concepts are contestable, defensible, and substantive according to the previous definition. We consider that the interpretative research we performed with this prototype allowed us to generate at least two strong concepts.

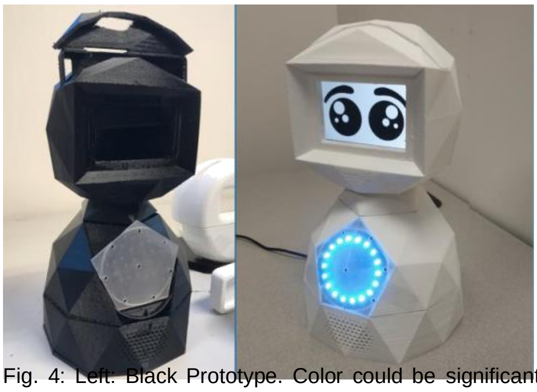

Fig. 4: Left: Black Prototype. Color could be significant affordance having an impact on users in future interactions. Right: Final functional prototype of Eva robot. Led lights with the microphone array and the minimal eye gestures are the affordances indicating a conversational agent.

The first strong concept is: *Robot embodiment follows function*; in other words, do not force the anthropomorphic characteristics in a social robot if it is not vital for its purpose. The second strong concept generated in this project is *Robot affordances set user's expectations*; in Figure 4 can be observed that an element is central in the robot: the microphone array with coordinated LED lights provides an evident cue of the robot as a conversational agent. This microphone is the main affordance present in a conversational robot. Similarly, eyes' expression provide support to the verbal interaction; being minimal, they do not become central in the interaction and distract the attention of the users. This feature is still under discussion because authors still differ in the approach to be taken over this robot feature (skeuomorphic and expressive vs. minimal). Future validations for these characteristics together are required.

We consider that our proposed strong concepts match the criteria proposed by Höök and Löwgren in terms that 1) all the interactive features of previous prototypes were implemented in this new one. 2) Also, the design has a focus in the robot embodiment as an interface between technology and people. 3) The strong concepts carry a core design idea with the potential to be applied to other HRI domains (physical HRI, collaborative HRI, etcetera) and 4) They are on an abstraction level above specific instances. Our strong concepts of *Robot embodiment follows function*, and *Robot Affordances set user's expectations* can be implemented in many different ways in the conceptualization of different interactive robots.

Our interpretative research followed the typical process of reflection/ discussion, articulation of the ideas, and abstraction that connects theoretical, empirical and analytic domains applied to Human-Robot Interaction to generate these concepts. However, we acknowledge that further discussion in a future paper is required to develop these strong concepts in a proper way.

We consider that our proposed strong concepts accomplish the conditions of being *'generative pieces of knowledge in the sense that they help generate new solutions for a particular design situation. [16]'* for other robot designers and future work is required to elaborate on this matter. However, we are not experts in the topic and the expertise of a Design theorist is required to refine these concepts and test their validity.

6.1 Future work

In the near future, we aim to report over topics as the conflict in the multidisciplinary design process, semiotic values in social robots and its future historical context. Similarly, we aim to share our designs in a digital repository with the HRI community as soon as possible. Overall, we aim to further discuss and develop the strong concepts developed in this paper.

References

[1] Cruz-Sandoval, Dagoberto, and Jesus´ Favela. "Semi-autonomous conversational robot to Deal with problematic behaviors from people with dementia." International conference on ubiquitous computing and ambient intelligence. Springer, Cham, 2017.

[2] Cruz-Sandoval, Dagoberto, and Jesus Favela. "Human-robot interaction to deal with problematic behaviors from people with dementia." Proceedings of the 10th EAI International Conference on Pervasive Computing Technologies for Healthcare. 2016.

[3] Cruz-Sandoval, D., Eyssel, F., Favela, J., and Sandoval, E. B. (2017, March). Towards a Conversational Corpus for Human-Robot Conversations. In Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction (pp. 99-100).

[4] Cruz-Sandoval, Dagoberto, Jesus Favela, and Eduardo B. Sandoval. "Strategies to Facilitate the Acceptance of a Social Robot by People with Dementia." Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction. 2018.

[5] Sandoval, Dagoberto Cruz, and Jesús Favela. "Co-designing ambient-assisted interventions using digital interlocutors for people with dementia." Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers. 2017.

[6] Cruz-Sandoval, Dagoberto, and Jesus´ Favela. "A Conversational Robot to Conduct Therapeutic Interventions for Dementia." IEEE Pervasive Computing 18.2 (2019): 10-19.

[7] Cruz-Sandoval, D., Morales-Tellez, A., Sandoval, E. B., and Favela, J. (2020, March). A Social Robot as Therapy Facilitator in Interventions to Deal with Dementia-related Behavioral Symptoms. In Proceedings of the 2020 ACM/IEEE International Conference on Human-Robot Interaction (pp. 161-169).

[8] C. Caudwell, C. Lacey, and E. B. Sandoval, "The (Ir)relevance of Robot Cuteness: An Exploratory Study of Emotionally Durable Robot Design," in Proceedings of the 31st Australian Conference on Human-Computer-Interaction, Fremantle, WA, Australia, Dec. 2019, pp. 64–72, doi: 10.1145/3369457.3369463.

[9] G. Hoffman, "Anki, Jibo, And Kuri: What We Can Learn from Social Robots That Didn't Make It", IEEE Spectrum - IEEE Spectrum," IEEE Spectrum: Technology, Engineering, and Science News, May 01, 2019.https://spectrum.ieee.org/automaton/robotics/home-robots/anki-jibo-and-kuri-what-we-can-learn-from-social-robotics-failures (accessed Sep. 19, 2019).

[10] E. B. Sandoval, J. Brandstatter, M. Obaid, and C. Bartneck, "Reciprocity in Human-Robot Interaction: A Quantitative Approach Through the Prisoner's Dilemma and the Ultimatum Game," International Journal of Social Robotics, vol. 8, no. 2, pp. 303–317, 2016, doi: 10.1007/s12369-015-0323-x.

[11] E. B. Sandoval, J. Brandstetter, and C. Bartneck, "Can a Robot Bribe a Human? The Measurement of the Negative Side of Reciprocity in Human Robot Interaction," in Proceedings of the Int. Conf. of Human Robot Interaction, Christchurch, New Zealand, 2016.

[12][E. B. Sandoval, S. Brown, and M. Velonaki, "How the Inclusion of Design Principles Contribute to the Development of Social Robots," in Proceedings of the 30th Australian Conference on Computer-Human Interaction, New York, NY, USA, 2018, pp. 535–538, doi:10.1145/3292147.3292239.

[13] E. B. Sandoval, J. Brandstetter, U. Yalcin, and C. Bartneck, "Robot Likeability and Reciprocity in Human Robot Interaction: Using Ultimatum Game to determinate Reciprocal Likeable Robot Strategies," Int J of Soc Robotics, Jun. 2020, doi: 10.1007/s12369-020-00658-5.

[14] E. B. Sandoval, H. Castillo, S. Tellez, "Service Robot with Social Interface" (Registered Industrial Design) MX/f/2017/002789, 2019/1, Mexico.

[15] C. Bartneck and J. Forlizzi, "A design-centred framework for social human-robot interaction," in RO-MAN 2004. 13th IEEE International Workshop on Robot and Human Interactive Communication (IEEE Catalogue No.04TH8759), Sep. 2004, pp. 591–594, doi: 10.1109/RO-MAN.2004.1374827.

[16] W. L. in R.-B. U. Experience, "10 Heuristics for User Inter-face Design: Article by Jakob Nielsen" Nielsen Norman Group. https://www.nngroup.com/articles/ten-usability-heuristics/ (accessed Jul.17, 2020).

[17] Höök, K, and Löwgren, J. (2012). Strong concepts: Intermediate-level knowledge in interaction design research. ACM Transactions on Computer-Human Interaction (TOCHI), 19(3), 1-18.