SnuggleBot: a Cuddly Companion Robot for Lonely People to use at Home

by

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Abstract

We designed, prototyped, and deployed a novel companion robot for private in-home use that aims to promote engagement to support people living with loneliness. We identified and explored three key approaches to encourage engagement and provide comfort and prototyped a novel robot aiming to embody these principles: this resulted in SnuggleBot, a novel robot that is physically comforting, socially engaging, and requires care, to provide structure and increase engagement. We deployed our prototype unsupervised for a minimum of 7 weeks (with optional longer involvement up to 6 months) into the homes of seven people who live alone and self-identified as lonely. We reflect on our specific designs and how they promoted engagement and companionship. Our results indicate that robot designs incorporating physical comfort, social engagement, and requiring care have the potential to promote companionship, with many participants showing signs of bonding with the robot. Further, our design strategies were generally successful in that they promoted the behaviours and reactions that we intended. We found that most participants expressed that the robot is comfortable. The robot also promoted animism and engagement. Additionally, participants reported wellbeing benefits because of caring for the robot. This supports future research into robots developed with our design strategies, which can leverage our results to improve on our implementations of the design strategies.

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Publications

Some ideas and figures in this thesis have appeared previously in the following publications by the author.

Passler Bates, D., & Young, J. E. (2020). SnuggleBot: A Novel Cuddly Companion Robot Design. *Proceedings of the 8th International Conference on Human-Agent Interaction* (HAI’20), 260–262. https://doi.org/10.1145/3406499.3418772

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Additionally, some ideas and figures in this thesis are under submission to:

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1 INTRODUCTION

The ongoing global pandemic has highlighted loneliness as a public health concern (Fiorillo & Gorwood, 2020; Gardiner et al., 2018), as living with loneliness is associated with negative well-being outcomes including reduced quality of life (Arkar et al., 2004), lower cognitive function, depression, and cardiovascular disease (Courtin & Knapp, 2017). Social companion robots have the potential to mitigate loneliness, by using human or animal-like interaction techniques that can impact people's feelings, moods, and behaviours, in similar ways to another person or a pet (Rabbitt et al., 2015). For example, research has demonstrated that social robots can increase motivation to exercise (Fasola & Mataric, 2013; Hebesberger et al., 2016). Social robots can also increase children's engagement in education (Hong et al., 2016) and provide emotional support (Hung et al., 2019). In therapeutic uses, social robots can improve social engagement of people living with dementia (Hung et al., 2019) or children with autism (Kozima et al., 2005). They have also been found to generally improve quality of life (Moyle et al., 2013).

Figure 1: A person cuddles with SnuggleBot, the companion robot we designed and prototyped. We deployed SnuggleBot into homes of people who identify as lonely, to explore design strategies to support loneliness. (Picture by Passler Bates)

In this work, we designed and prototyped a novel social companion robot (Figure 1) that aims to encourage social engagement and provide comfort, with the potential to eventually support people living with loneliness. We deployed our original social companion robot into the homes of people who identify as lonely and analyzed how people responded to and interacted with our designs, how they engaged them, and whether they have the potential to provide comfort. In this work, we take the initial step to determine if our design (and the underlying design strategies) can encourage engagement; if so, this work is a precursor to future work which can study measurable impact on loneliness.

Despite potential benefits of using social robots in controlled and clinical settings, companion robots have not yet broadly translated into general home environments (e.g., as with the failed product JIBO, Ackerman, 2018; Hoffman, 2019). Research tends to target specific demographics (Rabbitt et al., 2015) such as children and older adults (e.g., Dautenhahn et al., 2009; Fasola & Mataric, 2013; Khosla et al., 2021; Kozima et al., 2005; Leite et al., 2014; Logan et al., 2019; Moyle et al., 2013; O'Brien et al., 2021; Wada et al., 2008) commonly with clinical conditions or special needs (e.g., Logan et al., 2019; Wada et al., 2008). Further, people tend to disengage with robots after initial interactions (M. de Graaf et al., 2017; M. M. A. De Graaf et al., 2014). We approach this problem by focusing specifically on engagement with a domestic robot, to encourage successful long-term in-home use for otherwise healthy adults with non-clinical wellness challenges such as loneliness.

Designing solutions to support loneliness is challenging, given that loneliness is highly individual and based on a disparity between one's desired social connections and one's reality: solutions will vary wildly between people (Dan Russell et al., 1980). As such, we aim to explore broadly for a range of potential approaches, including supporting physical and mental health, which are associated with lower levels of loneliness (Bruce et al., 2019). As part of this thesis, we conducted a cursory literature review on potential methods of supporting loneliness, and as a result identified promising avenues for designing a companion robot to encourage engagement and support overall wellness: physical comfort, social engagement, and requiring care.

We designed and prototyped a robot using these approaches and deployed it into homes of people who self-identify as lonely. From our study, we aim to learn about the effectiveness of our specific companion robot design strategies for encouraging engagement and companionship. Further, we aim to learn from participant feedback how our design strategies and implementation can be improved upon. Ultimately, we use this work to learn if our design strategies can promote engagement as a precursor to future work that can measure the impact of our robot on loneliness.

1.1 Methodology

Our research aim is to design and develop a robot that promotes engagement and will ultimately help with loneliness. Our overall methodology is to select and develop design strategies that will promote engagement, companionship, and wellness, design a robot using those design strategies, conduct a study using this robot to learn how effective our design strategies are, and analyze the data to result in recommendations for future work to refine our design strategies.

To identify design strategies, our approach is to search wellness literature for initial avenues to support user needs. We then explore designs using our design strategies. After creating our robot design, we build a stand-alone working high fidelity prototype.

We can use this prototype to learn how successful our design strategies are at encouraging engagement, how people experience and engage with our design strategies, and how people report that a robot with our design strategies impact their wellness. To answer these questions, and to observe how participants' experience of the design strategies might change over time, we conduct a longitudinal study. For the study protocol (detailed in Chapter 4), we draw from existing research on longitudinal domestic robots (Ananto et al., 2020; M. M. A. de Graaf et al., 2018). We deploy 5 robots into the homes of 7 participants who self-identify as lonely, where participants keep the robots for a minimum of 7 weeks. Participants are given the option to extend the study up to 6 months, which allows us to collect additional data and serves as an indicator of attachment to the robot if participants choose to keep the robot for more time.

We conduct interviews to collect nuanced data from our participants. Participants additionally complete diary entries to help them remember their interactions with the robot between interviews. To collect preliminary data on wellness and loneliness measures, we give participants questionnaires to complete.

The interviews and diary entries provide us with rich data which we analyze qualitatively to gain insight into our design approach. With our quantitative data, we create graphs to understand the general trends, but do not complete a statistical analysis because of our low sample size.

From our work, we gain insights from having our robot deployed into homes. The results from our study help us to understand if our design strategies are useful or not for promoting engagement. Further, we identify avenues to improve upon our design strategies for future work.

1.2 Research Questions

RQ1: How can we build a standalone, deployable robot prototype that embodies and or encourages specific behaviors that we identify from wellness literature as having the potential to support people who are lonely?

We want to build a robot grounded in wellness literature to support people who are lonely. To do this, we need to identify features for the robot to embody or specific behaviours that we want to encourage with the robot. We then need to design these into a robot and develop a prototype. When creating our prototype, we need to find ways to make the robot robust and feasible so that we can deploy the robot into people's homes to study how they interact with it.

RQ2: How successful are our design goals (drawing from our literature search) in encouraging their targeted behaviours (engagement and wellness related activities)?

We select our design strategies because we expect that they will be helpful in encouraging engagement and comfort based on prior work, which may ultimately help with loneliness. Learning if our design strategies encourage their targeted behaviours will help us to understand if they encourage engagement and comfort. Further, this will help future designers to decide if they want to incorporate these design strategies into their robots.

RQ3: What do participants think of the specific engagement and wellness-oriented design strategies that we employed?

Participants' experience and opinions of the design strategies will be important in determining if the design strategy is useful or not for a particular robot design. For example, people may care for the robot, but not enjoy doing so. We therefore need to understand how participants feel about physical comfort, social engagement, and requiring care in addition to learning about how participants behave towards the robot to evaluate the design strategies.

RQ4: What are the patterns of interaction that lonely people have with our cuddly robot?

Understanding the patterns of interaction that people have with the robot can help future robot designers to refine the design strategies. For example, if participants exhibit emergent interactions with the robot, designers can explicitly incorporate those interactions into future designs.

RQ5: How does a lonely person report the potential indicators of our cuddly robot's impacts on their loneliness and wellbeing?

Although our research is not designed to scientifically measure impact on loneliness, learning how people perceive the robot's impact on their wellbeing and loneliness can help establish if our design approach has the potential to help with loneliness. If successful, this work serves as a precursor to work that can measure the impact of our robot on loneliness. Additionally, learning what aspects of our robot design people report are helpful or not helpful can help to refine our design approach to inform the design of future robots to help with loneliness.

The next steps will include a detailed analysis of participants' adoption patterns as they go through the process of adopting a cuddly robot. This work is important because it can help future robot designers to design robots in a way that shapes robot adoption. However, because of the time required to conduct the analysis, it falls out of the scope of this thesis.

1.3 Resulting Prototype: SnuggleBot

To address our first research question, we conduct a search of wellness literature to look for avenues to promote engagement and support people's needs that we can build into a robot. As a result, we developed three design strategies. Our design strategies are physical comfort, social engagement, and requiring care. We chose physical comfort as a design strategy because physical comfort can have a calming effect. We select social engagement as a method to encourage continued interaction with the robot. Finally, we use requiring care to mimic the positive wellness impacts of caring for a pet.

Figure 2: Our robotic prototype that is socially engaging, physically comforting, and requires care. (Picture by Passler Bates)

We realize our three design strategies in our robotic prototype which we call SnuggleBot (Figure 2). SnuggleBot is physically comforting by having the form of a cuddly stuffed animal. We further promote comfort by adding a warming pad and weight to the robot. To promote social engagement, SnuggleBot makes movements to attract attention and encourage continued interaction and has a glowing horn which changes colours depending on its needs. To care for the robot, people need to keep the robot warm, give it attention, and keep it charged. We provide full details of our design and prototype in chapter 3.

1.4 Study and Results

In response to our second research question, we conducted a longitudinal study, and we see from our results that participants generally did engage in the targeted behaviours that we hoped to encourage with our design strategies. We hoped to encourage cuddling, hugging, and holding the robot with our physical comfort design strategy. We find that all participants did engage in some of these behaviours. We wanted to encourage repeated interaction with the robot with our social engagement design strategy. While some participants reported that the robot's attempts to attract attention did encourage them to interact with it more, the frequency of interaction with the robot varied wildly, from many times a day to no interaction over the course of a week.

Finally, we find that all participants did take care of the robot as we had intended with the design strategy of requiring care.

For our third research question of how participants respond to our design strategies, we found generally positive results. In response to our design strategy of physical comfort, we find that all participants found the robot to be generally comfortable. Participants reported enjoying features of the robot that we designed to be socially engaging, particularly the robot moving in response to attention that it receives. Our design strategy of requiring care was also generally successful, with participants showing signs of bonding with the robot and wellness benefits because of caring for the robot. However, some participants reported that caring for the robot could feel like a chore at times.

To answer our fourth research question, we observe interaction patterns that participants exhibit with the robot. We find that most participants integrated the robot into their daily lives, for example by keeping the robot near them, or interacting with the robot during their remote workday. Additionally, the robot served as a social catalyst for some participants, with participants discussing the robot with others or showing the robot to others. Finally, we found emergent interactions that participants had with the robot, such as petting the robot, and talking to the robot while caring for it.

In answer to our fifth research question of how participants report that the robot impacts their loneliness and wellbeing, we found that participants did report wellness benefits from the robot. We additionally graph the quantitative data that we collected from the questionnaires that we gave to participants and find that the UCLA loneliness scale shows a slight decrease over time. While we do not conduct statistics because of our small sample size, these initial results support future research with a larger sample size to find if there is a real decrease in the loneliness scores over time for participants who keep our robot in their home.

Overall, our results indicate that our design strategies have the potential to encourage engagement and comfort and provide promising avenues for future work such as refining the design strategies and conducting statistics on the UCLA loneliness measures with a larger sample size.

1.5 Contributions

In this section we enumerate the contributions of this thesis with respect to our research questions outlined earlier.

1. We identify three potential design strategies for social robots for promoting engagement and comfort and present concrete interaction designs and implementations for realizing them in a real robot. (RQ1)
2. We design and develop a novel companion robot that is robust, simple, and technically feasible for long-term deployment for lonely people. (RQ1)
3. We collect and present some of the first nuanced, qualitative data of a longitudinal deployment of a social robot into people's homes. (RQ2, RQ3, RQ4, RQ5)
4. We present results from an analysis of our longitudinal study indicating the potential of our design strategies for supporting wellness and promoting engagement and comfort. (RQ2, RQ3, RQ4, RQ5)
5. We present the following design tools and concrete recommendations to improve the design strategies (RQ2, RQ3, RQ4):
    - Avenues for attracting attention that are more noticeable should be explored.
    - More avenues for engagement should be incorporated, including avenues with more complex interaction.
    - Robots incorporating requiring care should explore increasing the stakes of caring for the robot.
    - Incorporating keeping the robot in good condition is an additional method of caring for the robot which requires little to no technical requirements.

- Methods of encouraging companionship should be explored. Our results indicate that robot forms that are less cute and interaction methods that encourage being co-located with the robot are promising avenues for increasing companionship.

1.6 Thesis Overview

In this chapter, we motivated our design exploration into a novel companion robot that promotes engagement and comfort. In chapter 2, we discuss related work in technologies and robots to support mental health, companion social robots, and domestic robot adoption, to highlight how our work fits within existing knowledge. In chapter 3 we overview our design and prototyping approach taken to arrive at our final prototype. Chapter 4 discusses our study design we use to evaluate our robotic prototype, and our analysis plan. In chapter 5, we present the results from our study. Finally, chapter 6 concludes the thesis by discussing the implications of our results, and recommendations to improve the design strategies and areas for future work.

2 RELATED WORK AND BACKGROUND

Human-Computer Interaction is a field of study that focuses on the interaction between people and computers (Hewett et al., 1992). Research in Human-Computer Interaction involves the design, evaluation, and implementation of technology (Hewett et al., 1992) to better serve people's needs. Areas of research within Human-Computer interaction include technology learnability, communication between people and computers, and design trade-offs (Hewett et al., 1992).

Similarly, Human-Robot Interaction is a field that studies the design and evaluation of robots (Goodrich & Schultz, 2007), and the interaction between people and robots. This includes a full range of topics including collaborative robots working with people in manufacturing (Grau et al., 2021), robots remotely controlled by people used for search and rescue (Goodrich & Schultz, 2007), and robots designed to interact with people socially for companionship. Within the Human-Robot Interaction field, the area of social robotics concerns the design of robots with human or animal-like features (e.g., faces, arms, legs) to communicate with people using life-like techniques (e.g., speech, synthetic emotions, facial expressions). For example, the social robot PARO (Figure 3), has the appearance of a baby seal, and can blink its eyes, move its neck and flippers,

Figure 3: The PARO robotic seal. (Peter Häll/Tekniska Museet, https://digitaltmuseum.se/021027754238/robotsal, CC BY-SA 4.0)

and make noises as part of its ability to communicate with people (Wada et al., 2008). Robots such as Paro are designed with these social techniques which contribute to familiarity and ease of interaction with the robot.

Social robots can also impact a person's feelings, mood, and behaviors, just like other living things can, with research demonstrating that social robots can improve quality of life (Moyle et al., 2013), increase motivation to exercise (Fasola & Mataric, 2013; Hebesberger et al., 2016), or increase children's engagement in education (Hong et al., 2016). In our work, we draw on prior techniques used in social robotics to develop a novel social robot to support lonely people.

2.1 Mental Health in Human-Computer Interaction

Prior work in Human Computer Interaction has found numerous areas where technology can improve people's mental health including supporting people who have clinical conditions, such as anxiety (Sanches et al., 2019; Topham et al., 2015), depression (Barry et al., 2017; Doherty et al., 2012; Qu et al., 2019; Sanches et al., 2019), and bipolar disorder (Abdullah et al., 2016; Sanches et al., 2019). Methods to help with mental health include automating the diagnosis of mental health conditions (Sanches et al., 2019), applications for people to self-track symptoms (Qu et al., 2019; Sanches et al., 2019), and applications which offer educational material (e.g., Topham et al., 2015) or exercises (e.g., Doherty et al., 2012). In our work, we leverage the ability of technology to help with mental health by developing a robot to support lonely people.

2.1.1 Robots for Mental Health

Social robots have been leveraged to support wellness, with much of this work targeting people in institutional settings such as in care homes and pediatric hospitals. For example, in one study hospitalized children showed more positive affect interacting with the teddy bear robot Huggable (Figure 4) than a stuffed animal (Logan et al., 2019). The impact of

Figure 4: The Huggable Robot. (Image taken from (Jeong et al., 2015)

Huggable on loneliness has not yet been studied, and this robot has not been studied with otherwise healthy adults, or in people's homes. We expand on the success of the Huggable robot by deploying our robot into the homes of otherwise healthy people who feel that they are lonely. We additionally extend Huggable by incorporating the additional design strategy of requiring care.

In care homes, interactions with companion robots have been successful in increasing measurements of pleasure (Libin & Cohen-Mansfield, 2004) and positive moods (Hung et al., 2019), as well as lowering levels of depression and loneliness (Banks et al., 2008; Chen et al., 2020) among residents. Social robots have also increased engagement among care home residents with other people (Hung et al., 2019; Nakashima et al., 2010). This includes work with robots such as the social robot PARO developed for therapy for dementia patients (Wada et al., 2008), the Sony AIBO robotic dog (Figure 7), and the robotic cat NeCoRo (Figure 5). We draw on the successes of these works that demonstrate the ability of robots to support wellness. We explore if we can get similar results with our novel companion robot designed to provide comfort and engagement to members of the general public who identify as lonely.

2.2 Companion Social Robots

Robots used for wellness interventions commonly fall within the general category of companion social robots. Companion social robots have been developed for various purposes. Some of them are designed to incorporate animal-like or animistic features in the design, such as having an animal-like appearance. For example, the robot NeCoRo is designed to have the appearance of a cat (Libin & Cohen-Mansfield, 2004). Robots designed with life-like features may provide cues which promote engaging with the robot socially (Young et al., 2009). Further, companion robots engage people with the use of

Figure 5: The robotic cat NeCoRo. (Image taken from Libin & Cohen-Mansfield, 2004)

movements. For example, PARO can move its neck, flippers, and eyes (Wada et al., 2008). Given the engagement found with robots such as PARO (Marti et al., 2006; Mervin et al., 2018) which incorporate animal-like features and gestures, we build on prior work and incorporate engaging and animistic features in our approach.

Another approach taken in the design of some companion social robots is the incorporation of physically comfort, such as the PARO robotic seal and the robotic cat NeCoRo which both have soft fur (Libin & Cohen-Mansfield, 2004; Wada et al., 2008). Physically comforting robots such as PARO and NeCoRo can be engaging (Libin & Cohen-Mansfield, 2004; Marti et al., 2006; Mervin et al., 2018). They can further support people living in care homes including dementia patients with various wellness measures such as increased positive moods and levels of pleasure (Hung et al., 2019; Libin & Cohen-Mansfield, 2004), improved quality of life (Chen et al., 2020), and lower levels of depression and loneliness (Chen et al., 2020).

Further, the soft pillow-like TACO robot (Figure 6) was developed to support the mental health of hospitalized children, who hold the robot while it heats up. TACO moves to simulate breathing for successful therapeutic effects when holding it and illuminates LED lights to stimulate children visually (O'Brien et al., 2021). Children in a study held the robot, found it engaging and fun to

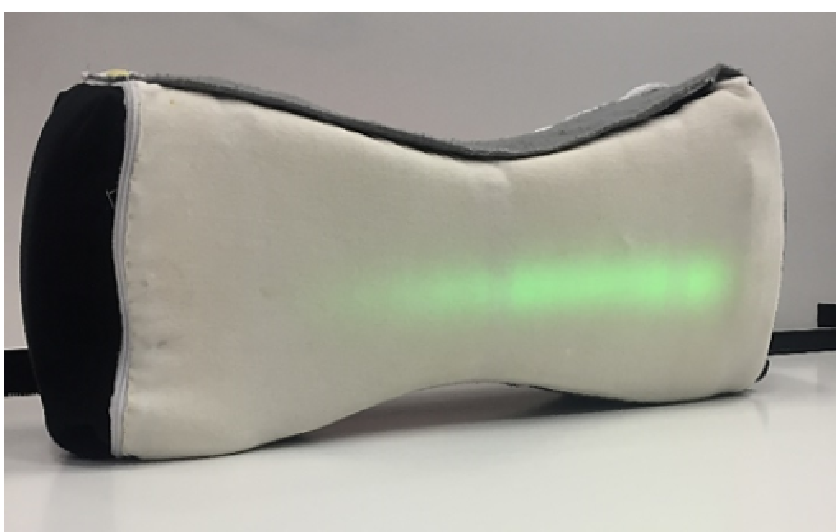

Figure 6: The TACO robot. (Image taken from O'Brien et al., 2021)

interact with, demonstrated affection towards it, and reported that they liked the heated effect and the LED lights (O'Brien et al., 2021). Early successes of robots like PARO, NeCoRo, and TACO in controlled settings highlights the potential for a physically comforting companion robot like our design to provide comfort and engagement for the broader population in less controlled home environments.

2.3 Domestic Robot Adoption

Work in domestic robot adoption has explored how people interact with robots in their homes. The Sony AIBO robotic dog has had some success integrating into homes (Kertész & Turunen, 2019). Similarly, some work reported (Sung et al., 2007) companion-like interactions with the iRobot Roomba vacuum cleaner (Figure 8). However, these examples are limited in that we do not yet see social robots being broadly adopted into homes despite these robots being available for commercial purchase.

Overall, the reasons for lack of in-home companion robot adoption are not entirely clear. Perhaps it is because many support robots are research prototypes in care homes and hospitals that require support structures and staff to facilitate the therapy (Hung et al., 2019) or teleoperate the robot (e.g., Logan et al., 2019). Robots such as PARO are further quite expensive (Hung et al., 2019) and difficult to repair (Hung et al., 2019). There are also concerns that robots may simply

Figure 7: The Sony AIBO robotic dog. (Heniz Nixdorf Museums Forum, https://nat.museum-digital.de/object/232911, CC BY-NC-SA)

Figure 8: the iRobot Roomba. (Jazzyartphotos, https://pixabay.com/photos/robot-vacuum-cleaner-irobot-cleaning-5311418/, CC0)

not meet high expectations that people may have, resulting in disappointment (Hoffman, 2019). For example, some early users of the JIBO robot (Figure 9) reported being disappointed with the robot in comparison with their expectations based on marketing (Ackerman, 2018). Prior work on domestic robot adoption has identified factors that may lead to adoption such as hedonic gains (M. de Graaf et al., 2017; M. M. A. De Graaf et al., 2015; Young et al., 2009), sociability of the robot (M. M. A. De Graaf et al., 2015, 2016), and privacy. We engage this problem of companion robot adoption through our attempt to create a novel companion robot for lonely people: by focusing on simple, deployable technologies in our design, and incorporating prior adoption work into the design by making a robot that is enjoyable to use, sociable and maintains user privacy by remaining offline, and deploying early prototypes for feedback, we aim to avoid many of the above issues.

Figure 9: The JIBO robot. (Image taken from Ackerman, 2017)

2.4 A Novel Investigation of Companion Robot Design

In this work, we draw on prior work demonstrating the ability of technology to support wellness in our design of a novel companion robot to support lonely people. We expand on the success of other social robots in supporting wellness and engagement by incorporating their techniques used into our design, such as physical comfort, and engaging and animistic features. We additionally add the design strategy of requiring care to our robot. Further, we build on the success that other robots have had in supporting engagement and wellness in controlled settings by deploying our robot into the less controlled home environments of otherwise healthy people who are lonely. Finally, we engage with the problem of robots not being broadly adopted by focusing on simple, deployable technologies in our prototype that we can use to collect early feedback. We also incorporate prior work on factors of adoption into our design by making our robot enjoyable to use, sociable, and maintain user privacy by remaining offline.

The next chapter outlines our design approach, and how we implemented our robotic prototype.

3 PROTOTYPE DESIGN

This chapter discusses our approach to exploring and selecting our design strategies, and how we applied them in our specific implementation. The chapter further discusses implementation details of our prototype, including technical details and challenges that we encountered throughout the process of building the robots. Once we solved the technical and design challenges outlined in this chapter, we built 5 copies of our robotic prototype for deployment into homes.

As we elaborate on in the rest of this chapter, to develop our design, we first explored wellness literature for potential ways to support people. We then sketched and paper prototyped potential companion robot designs that leverage these techniques, and iterated our design based on the literature and an informal feasibility analysis. The driving principles behind our exploration were to support loneliness by promoting engagement and comfort (based on our literature search). We further aimed to maximize technical feasibility and robustness to enable in-home long term unsupervised deployment. For this latter point we aimed for as-simple-as-possible solutions that do not require remote monitoring and processing (e.g., cloud infrastructure), and are robust due to their lack of technical complexity. This offline approach further increases user privacy. After narrowing our approach, we created an initial robot to test feasibility (e.g., sensing, actuation) to inform our final prototype.

3.1 Wellness Support Techniques

To design our robot, we turned to psychology research. We informally explored psychological resources by searching for wellness literature using Google, Mendeley, and University of Manitoba online library resources to find ways to support people, paying attention to supports that could be feasibly incorporated into a robot design. The goal was not to do a formal or complete survey, but rather, simply to identify promising avenues to explore in our design. Three overarching design goals emerged from our literature survey: the robot should be physically comforting, socially engaging, and require care from people.

Physical comfort – Wellness literature has established that providing physical comfort can improve wellness. A classic study demonstrated how infant monkeys prefer to spend time and seek comfort with a physically-comforting mother proxy (cloth-made, warm, Figure 10) than a non-comforting proxy that provided food (cold, wire construction, Harlow, 1958), highlighting the importance of physical comfort compared to sustenance.

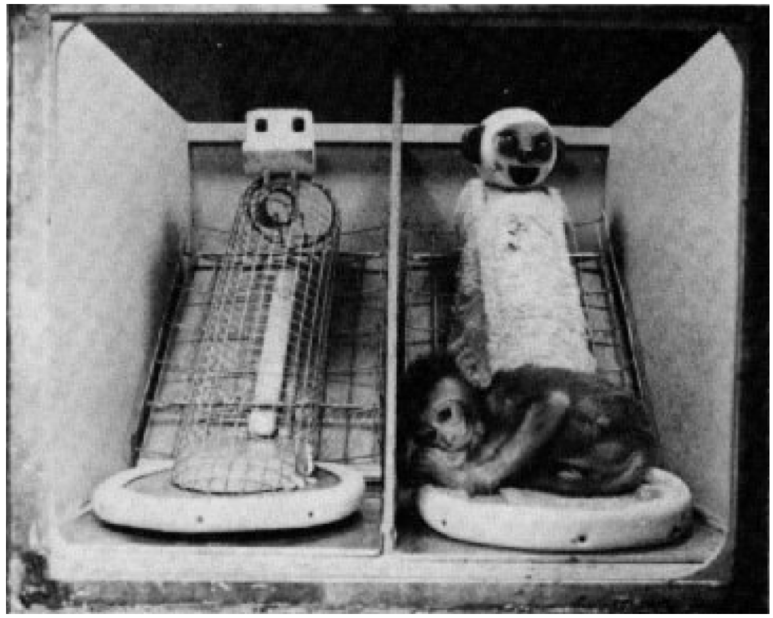

Figure 10: A baby monkey from Harlow's work with the wire mother (left) and cloth mother (right, Image taken from Harlow, 1958).

Similarly, for people weighted blankets can reduce anxiety (Eron et al., 2020), and physical warmth can promote wellness and serve as a proxy for social warmth (Bargh & Shalev, 2012). Research suggests that lonely people tend to take more warm baths and showers, and that holding a warm pack can provide comfort while recalling a negative social experience (Bargh & Shalev, 2012). In therapy, people holding and hugging something can improve wellbeing and serve attachment needs (e.g., doll therapy for dementia Mitchell et al., 2016). For robots, people may prefer to hug soft, warm robots rather than cold, hard robots (Block & Kuchenbecker, 2019), and physical comfort has been prominent in companion robot designs that support loneliness (Chen et al., 2020) and provide comfort (O'Brien et al., 2021) as with PARO, TACO, and Huggable. As such, we selected physical comfort as a target strategy in our design exploration.

Requiring care – Pet ownership is a common strategy for supporting wellbeing, providing a source of social support (McConnell et al., 2011) and companionship (Chandler et al., 2015), and daily life structure and purpose; pet owners tend to be less lonely (McConnell et al., 2011). Caring for "virtual pets" such as the Tamagotchi product (Figure 11) can also promote emotional engagement, with children developing attachments to the toy. For example, some children asked their parents to care for their Tamagotchi while the children were in school (Turkle, 2007). To emulate similar effects of pet ownership such as empathic engagement we target the robot requiring care as a design strategy, by having simple needs that it communicates to people.

Figure 11: The Tamagotchi. (Yellow Tamagotchi, Museum Rotterdam, https://museumrotterdam.nl/collectie/item/78041, CC BY-SA 3.0 EN)

Social engagement – Social engagement can invoke empathy and attachment (Seo et al., 2015). Perhaps because of this, social robots commonly use anthropomorphism and zoomorphism (generally, animism) to encourage social interaction (Young et al., 2009). This includes the design itself (e.g., Wada et al., 2008), as well as how the robot behaves, for example people may pay more attention to a robot that uses gestures (Sidner et al., 2005). Resulting social robot interaction is quite engaging (e.g., Hong et al., 2016), even compared to other technologies or simulated robots (e.g., Seo et al., 2015), and in one study perceived robot sociability was a major factor in continued use (M. M. A. De Graaf et al., 2016). Further, lonely people appear to have a particular tendency towards animism of nonhuman agents (Epley et al., 2008) and robots (Eyssel & Reich, 2013). Thus, to support animism and attachment we target social engagement as a key strategy of our robot design. As such, we design the robot to have attention-grabbing and animistic features such as simple gesture movements.

Following this literature we design for physical comfort, social engagement, and requiring care. Overall, we anticipate that the combined effects of designing our robot to be physically comforting, to require people to take care of it, and to be explicitly socially engaging, will result in an engaging robot that people interact with, perhaps bond with, and serves as a source of social interaction and support that can promote wellness.

3.2 Prototyping based on our Design Strategies

While aiming for simplicity, we brainstormed solutions to our design goals by sketching out ideas (Figure 12) and iterated on our best ideas by sketching out more variations of them. We also informally shared our ideas with our research group to further develop the ideas. Our goal while brainstorming was to find simple, implementable solutions to our strategies. With our design, we are not aiming to find an optimal solution to support loneliness, but are instead trying to create a proof of concept for our design strategies, while still being technically simple, to enable us to evaluate the extent to which our design goals encourage their targeted behaviours (cuddling and holding the robot, repeatedly interacting with it, and caring for it) and participants' thoughts of our design goals.

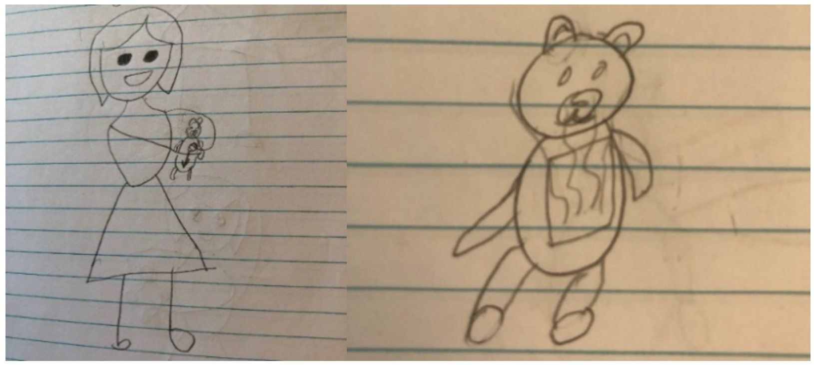

Figure 12: Excerpts from our early sketching process: hugging the robot (left) and a heated robot (right, Picture by Passler Bates).

3.2.1 High Fidelity Prototype

We decided to construct the body of the robot from a stuffed animal to make it physically comforting as per our design goal. To choose which stuffed animal we would use, we bought a range of stuffed animals (Figure 13) and informally tested them for their comfort and their cuteness.

Figure 13: The stuffed animals we purchased and tested as part of our initial design process. (Picture by Passler Bates)

We chose the narwhal stuffed animal because it felt like a comfortable size to hug and hold, and had a cute smile that drew us in. Selecting the body of the robot allowed us to narrow our ideas for what the robot would do even further. We then refined our initial sketch ideas into solutions that could be used with the stuffed narwhal robot body, ensuring that the features of our robot cover all three of our design strategies.

Physical Comfort

Figure 14: The original stuffed animal we selected for the robot body. (Picture by Passler Bates)

We built our robot into a stuffed animal body to provide a comfortable experience for holding. We purchased (and informally tested) a range of existing stuffed animals, avoiding branded designs (e.g., Disney characters) to reduce people applying existing impressions to the robot. We settled on a design (Figure 14) that is "cute," zoomorphic, and large enough to support cuddling and embedding electronics.

We created a foam assembly to insert into the robot that holds and covers the rigid electronics. Through experimentation we settled on dense memory foam as it feels comfortable to hold and hug like a typical stuffed animal, adds weight, and is rigid to both mask electronics and wires from being felt during hugging, and to provide leverage for actuators to push against when moving limbs. We added weighted beads to further mimic the heavy feel of a weighted blanket. Finally, we placed a heated compress in the robot (explained below) to provide warmth to the user. Thus, we achieved our comfort strategy completely through design, without any mechanical or processing requirements.

Socially Engaging

We selected a zoomorphic narwhal design and created animal-inspired movements to leverage tendencies toward animism and to encourage pet-like interaction. To try and catch a user's attention and encourage social engagement SnuggleBot communicates when it wants attention by flipping its pectoral fins (arms) and using its glowing horn (Figure 15, changes colour depending on needs). Further, SnuggleBot reacts to receiving hugs by flipping its caudal fin (tail), to display happiness and encourage hugs. SnuggleBot is only active from 9am-9pm. While it is "sleeping" to avoid bothering users, the horn is off, and it will not move.

Requires Care

Our robot requires three forms of care to maintain its "happy" state: people need to keep SnuggleBot warm, give it regular hugs, and charge its battery. Users must keep SnuggleBot's heat pack warm (Figure 16) by microwaving it (the heat pack) and returning it to the robot's tummy pouch (Figure 15); the horn turns blue when SnuggleBot is cold. Further, users must provide the robot with regular hugs, or SnuggleBot gets lonely, and the horn turns purple, and it intermittently flips its arms. When both lonely and cold the horn alternates between the colors (once/s). The robot has an internal battery which the user must maintain, charged via a port on its belly (resembles a navel); the horn stays red when the battery is low. To support horn color interpretation, we embroider a legend on the heat pad (Figure 16).

These designs aim to provide benefits of caring for the robot while supporting our comfort strategies of hugging the warm, heavy robot, and encouraging users to socially engage with it.

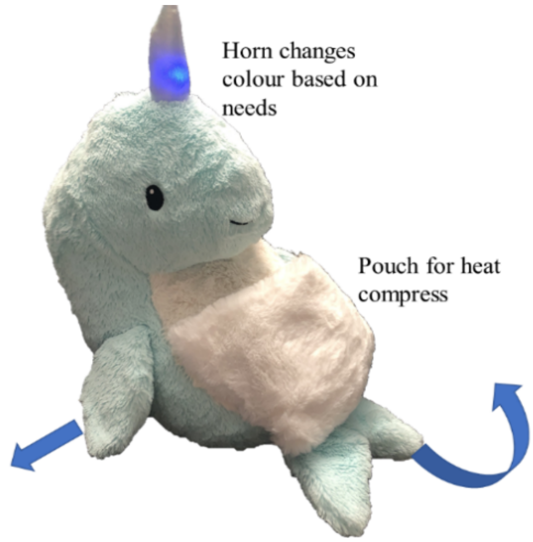

Figure 15: The robot has a glowing horn and a pouch for a heat compress, and the flippers and tail are actuated. (Picture by Passler Bates)

Figure 16: The embroidered heat pack reminds people of what the horn colours mean, while making the robot feel comfortable to hold. (Picture by Passler Bates)

Implementation

We instrumented the stuffed animal using microcontrollers and custom circuitry (Figures 17 and 18).

Sensors Used – We built a hug sensor by using two pieces of conductive fabric, separated by pieces of velostat[1], where electrical resistance changes with applied pressure; we measured using a voltage divider. We further used a thermometer sensor (embedded in a Wishiot DS3231 time module).

Robot Components – We actuated the arms and tail using HiTec HS-422 servos, by attaching wooden dowels to extend into the stuffed animal appendages. We embedded three RGB LED lights (connected in parallel) in the horn; the horn stuffing acts as a diffuser for the directional lights, making it viewable from all angles. All sensors and actuators were connected to a Pro Micro form factor Arduino clone (KeeYees) with a 4GB SD card module for logging. This device is sufficient for all computational needs (basic sensing, state machine, and clock) and has low power demands. We added an off-the-shelf 6000maH, 12vDC battery pack (Talentcell), with a custom power harness (with regulator) to provide

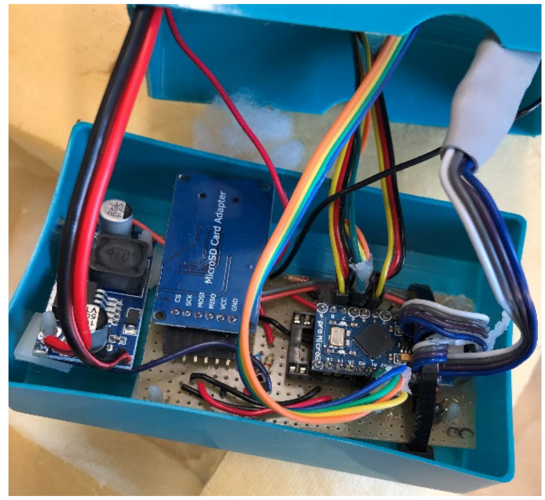

Figure 17: Our custom circuit. (Picture by Passler Bates)

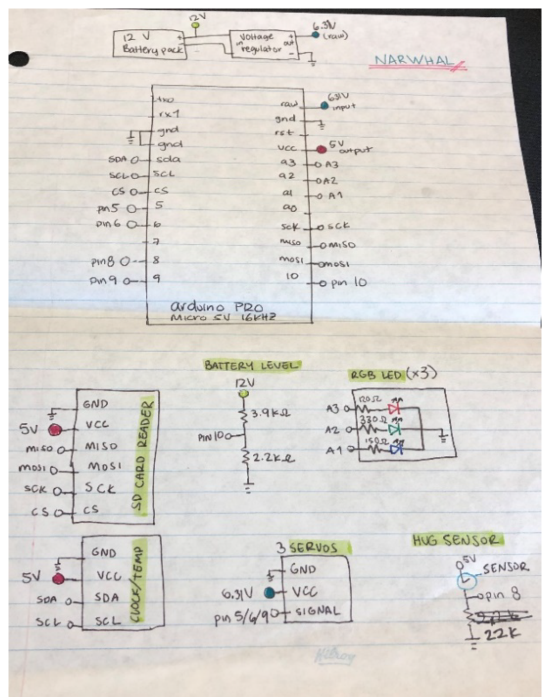

Figure 18: Circuit diagram of our custom circuit. (Drawn by Adriana Lorena González)

[1] Our sensor was inspired by https://www.instructables.com/Flexible-Fabric-Pressure-Sensor/

the required power to the lights, motors, and Arduino. The robot maintains its charge for approximately two days.

Mounting Robot Components – We placed the Arduino, modules, and voltage regulator in a project box to keep warm components away from the foam and stuffing. We mounted everything carefully within the robot to maintain the softness for hugging, using spray epoxy, hot glue, and hook and loop fasteners to affix the servos to the foam core (Figure 19). We placed the temperature sensor at the front of the robot, where the heat pack would be. We placed the battery in a cut-out at the back and the weighted beads at the bottom to balance weight distribution and keep a low center of gravity for easy holding.

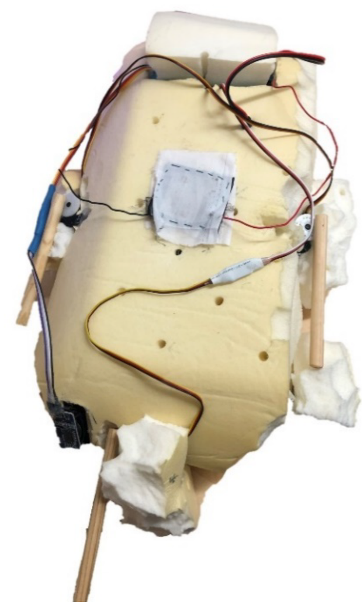

Figure 19: The memory foam skeleton which houses the motors and circuitry of the robot. (Picture by Passler Bates)

Implementation of Robot Behaviour – We created a simple state machine on the Arduino that monitored sensors and time to change the actuators and lights as needed. The robot enters a low power state based on a low voltage threshold (measured via a voltage divider to the Arduino) and will not leave this state until the battery was fully charged. The robot monitors the ambient temperature and assumes any rapid temperature gain means it was heated, and becomes cold when the temperature becomes near it was when it was last heated; it will not require heating more than once per 1.5 hrs. The robot will enter the lonely state if it has not recognized a hug in the past 1.5 hours, exiting this state as soon as a hug is received. We logged all state transitions and outputs. Note that this robot operates completely offline, which helps maintain the privacy of the user and lowers power demands.

Prototyping Exploration and Development

While the original early prototype was completed as part of my undergraduate senior project, most of the work was conducted as part of my MSc program. The first prototype could not yet be deployed as it was made from high-power, complex, expensive devices that required a wired connection to a PC making the robot not portable (Phidgets[2]). It further did not have circuitry for detecting the battery level and details of the behaviour program such as the timing of behaviours needed to be finalized. Additionally, early hug sensors, the connections of our circuit, and the mounting of the robot were not robust enough for deployment.

In this thesis, we addressed the above problems. We re-engineered the robots to be made from an embedded system with custom wiring and circuitry. This allowed for the robot to be portable as our prior system needed to be tethered to a computer, and further allowed for a longer battery life of the robot, as our custom circuit requires less power than the Phidgets system. We further added circuitry to detect when the robot had a low battery. We additionally implemented changing the horn colour accordingly when the battery of the robot is low to the behaviour program and finalized the remaining details of the behaviour program. Finally, we improved the overall robustness of the robot. We had technical support in solving some of these problems from a previous graduate student, Adriana Lorena González, who built the circuits and assisted with the building of the robots and problem solving the robustness of the robot. In the remainder of this section, we detail the processes we took to overcome the challenges we faced in developing our prototype.

Details of Behaviour Program – During this thesis, we finalized details of the behaviour program such as what to do if the robot has more than one need at a time. We chose to make the horn colour switch back and forth between two colours in this situation. We also needed to decide on the timing of when the robot would become cold. When the robot indicated that it was cold based on the actual temperature of the robot, we felt that people would have had to microwave the heat pack too often. Thus, we added a delay between when the actual temperature of the robot cooled down and when the horn of the robot would indicate that it was cold. We experimented with different amounts of time for this delay and settled on 1.5 hours.

[2] https://www.phidgets.com/

The robot also needed to be able to detect that it was cold in different temperature homes. Because of this, we could not simply set an absolute temperature that the robot would become cold at. To solve this problem, we implemented an algorithm to monitor the ambient temperature of the room and change the horn colour accordingly.

Our robot also needs to be able to operate without a charge for a reasonable amount of time so that users do not feel the need to keep the robot plugged in all the time. To improve the power efficiency of the robot, we use a state machine to monitor the sensors of the robot, and alter the state and horn colour of the robot as the inputs change.

Robot Robustness – We found more robust ways to construct our robot. One problem we encountered was that the early off-the-shelf hug sensor that we used became less sensitive over time. As such, we constructed a robust custom hug sensor for the robot as explained in the above implementation section. Another problem we faced with robustness was ensuring that the motors did not become disconnected from the body of the robot. After experimenting with various methods to attach the motors to the foam core of the robot such as using zip ties, we discovered that attaching the motors to the body with hook and loop fasteners and further strengthening the connection with spray epoxy and hot glue kept the motors attached. Another problem we faced was the time module would get disconnected from the microcontroller. This would occur because the time module, which also measures the temperature, is placed at the bottom of the robot near the heat pouch. When the robot received a hug, the wire connecting the time module to the microcontroller would then get tugged on. To solve this, we wrapped a zip tie around the circuit board and wrapped the wire around the zip tie before connecting it to the circuit, which displaced the tugging force such that it pulled horizontally at the zip-tie rather than vertically at the connection to the circuit.

Collaboration with Sewing Company

We worked with a local custom sewing company to create modified versions of the initial stuffed animal that we found for our first prototype. The creation of our final stuffed animal required several iterations as we experimented with various design aspects in each iteration, and because there were challenges in communication with the company as we struggled to get our desired outcome.

To begin the process, we asked the sewing company to make a blueprint of the original animal with our required modifications. Our modified version includes the pouch on the belly to hold the heat pouch and has the fins attached to the body of the narwhal with an open rather than closed seam, so that the wooden dowels could be inserted into the fins for actuation.

Following completion of the blueprint, the sewing company completed the first iteration of the modified stuffed animal. This was completed during my undergraduate degree (Figure 20). However, more iterations were required with the sewing company during this thesis. We iterated on the fabrics used for the stuffed animal to ensure that the robot's colours were soothing, and that the LED lights could shine through the fabric used for the horn. We also iterated on details such as the face of the narwhal.

Figure 20: The first iteration of our modified stuffed animal (left) and the original stuffed animal (right, Picture by Passler Bates)

Communication of Horn Colours – As the horn colours were a somewhat arbitrary mapping, we needed the design to communicate to users what the horn colours meant. For our prototype, we experimented with different methods of communicating the meanings of the colours. In one iteration, a flap was inserted into the pouch which could be folded out to see a sticker of the legend (Figure 21). However, we decided to instead embroider the legend onto the heat pouch because the sticker did not stick to the fabric well, and because the flap made it more difficult to insert and remove the heat pouch.

Figure 21: An iteration of the stuffed animal which included a flap for the legend. (Picture by Passler Bates)

Cuteness of the Narwhal's Face – We also went through several iterations of the face of the narwhal and took great care to ensure that the face of the robot looked cute, to elicit the animistic reactions and attachment that we were aiming for with our design. The second stuffed animal we received from the sewing company had a white, thin mouth (Figure 22), and a third iteration had a mouth that was straight across. We decided to create our own mouth by attaching a thick piece of curtain trimming, with a wide smile to add to the cuteness of the narwhal (Figure 23).

Finally, we iterated on the eyes used on the narwhal's face (Figure 24). We informally elicited opinions of the narwhal's face from lab members, friends, and family, and determined that larger, less realistic looking eyes were the cutest.

Figure 22: An iteration of the smile of the narwhal. (Picture by Passler Bates)

Figure 23: Our final version of the robot face. (Picture by Passler Bates)

Figure 24: Comparison of the eye we decided to use with a previous iteration of the robot eye. (Picture by Passler Bates)

3.3 Summary

This chapter outlines our design approach for developing a robot prototype for lonely people. We explored three design strategies in our approach to promote engagement and wellness: physical comfort, social engagement, and requiring care. This chapter further details how we implemented these three design strategies in our robotic prototype, and which aspects of the prototyping work was completed prior to the beginning of my M.Sc.

The next chapter explains how we evaluate our design approach in a longitudinal study. It includes the study tasks, measures, study protocol, participant selection, and an overview of the analysis methods used.

4 DESIGN GOAL EVALUATION

This chapter discusses how we evaluate our design strategies, and how we choose our evaluation methods. We discuss the tasks that we gave participants to do with the robot and our study procedure, along with the data we collect. We also discuss which participant demographics we include in our study and our participant recruitment. Finally, we outline the strategies we used for analyzing the data.

The primary goal of our evaluation is to reflect on the three design strategies we identified as potential avenues for domestic support robots. We deploy our robot into homes and learn about participants' interactions with, reactions to, and thoughts regarding our design strategies. We further evaluate the extent to which our design strategies encourage their targeted behaviours (cuddling and holding the robot, repeatedly interacting with it, and caring for it) within a real-world context. From these results, we aim to learn more about how to employ these strategies in robot design, and more fundamentally, how practical they may be for encouraging engagement and comfort, which we expect would ultimately support people with loneliness. Concretely evaluating actual impact on loneliness in a generalizable fashion is beyond the scope of this proof-of-concept project; the results from this will position us to more broadly study how such a companion robot may impact loneliness in future work.

Instead of eliciting participant input as the first step in our design process, we instead deploy a real robot for use by people within their homes, in a longitudinal study, to gain data grounded in real-use environments and contexts. Further, this enables us to gain reflections on current robot capability and mitigate issues relating to people's inflated expectations of robots that can lead to disappointment (M. de Graaf et al., 2017; Horstmann & Krämer, 2019) given the reality of current technical limitations (Hoffman, 2019).

We built five SnuggleBots (Figure 25), deployed them for 7 weeks (optionally longer, explained below) each into homes of people who self-identified as being lonely, and conducted a series of interviews and questionnaires to reflect on our design strategies.

Figure 25: The 5 robots we built. (Picture by Passler Bates)

4.1 Tasks and Robot Interaction

The core task of the study was for people to interact with the robot as if it were their own, so that we could gain grounded data as to how our robot is used in a real-world context. As such, we put careful attention to highlight to participants that they should feel free to interact with the robot as much or as little, and in whatever context or fashion, they would like. We did this to minimize the risk of participants interacting with the robot more often than they would like to out of a sense of obligation to the study. We introduced the robot to participants as a cuddly companion that they can interact with in their daily lives but provided little guidance beyond explaining the core robot purpose and designed interaction patterns. We explained that the robot will on occasion wiggle its fins, the meaning of the different horn colours, and how to care for the robot. We highlighted the instructions on the heat pack, and asked participants to try plugging in the charger and giving the robot a hug. However, we did not explain to participants exactly when the flippers or the tail would move, to explore freely how participants responded to these movements. If participants asked about specific behaviour details such as precisely why or when the robot would move, we told them that the robot behaves depending on a range of factors including how and how often they interacted with it, and that it might move if it wants attention.

4.2 Measures

We conducted and recorded scheduled interviews where we inquired about designed-for behaviours such as generally engaging with the robot, cuddling it, hugging it, and caring for it, and about opinions of the design. We further asked participants for diary entries once a week via an online form (paper upon request). We conducted our interviews via Zoom video and used online forms due to the COVID-19 pandemic.

We measured self-report levels of participant loneliness, state anxiety, and mood at regular intervals to assess trends in level of wellbeing, via the UCLA Loneliness scale (D Russell, 1996), State-Trait Anxiety Inventory (Wenzel, 2017), and participants' mood with the PANAS questionnaire (Brdar, 2014). We present an initial overview of these results to provide insight into potential impact on loneliness, although given our study size we cannot make generalizable conclusions from this data.

4.3 Procedure

We leveraged an existing structure with a phased approach (Figure 26) for our procedure from longitudinal domestic robot studies (Ananto et al., 2020; M. M. A. de Graaf et al., 2018). Our study protocol uses the following phases:

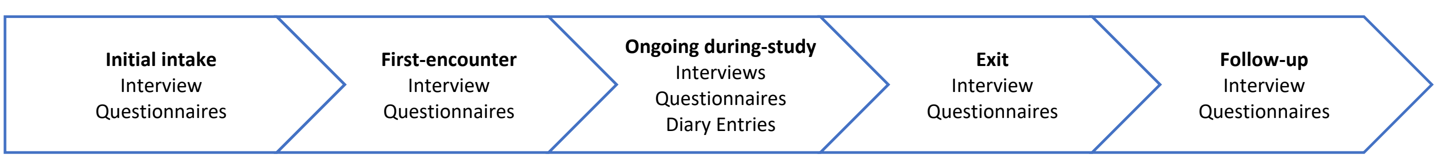

Figure 26: Flow diagram of the study phases and data collected at each phase.

Initial intake: Before deploying the robot, we conducted an interview and conducted wellness-related questionnaires to learn about participants' expectations of the robot.

First-encounter: We delivered the robot to participants homes and conducted a virtual (via Zoom) robot orientation and study session where participants try interacting with the robot. Participants filled out the wellness questionnaires, and we conducted an interview to inquire about participants' first impressions.

Ongoing during-study: We asked participants to complete the wellness-related questionnaires and diary entries weekly. We conducted virtual (Zoom) interviews every two weeks to monitor ongoing interaction and attitudes toward the robot. This phase lasted a minimum of 7 weeks, but participants were given the opportunity to stay in the study for longer, up to a total study length of 6 months.

Exit: We retrieved the robot from participants upon completion, followed by a virtual exit interview. We were more direct than in previous phases (e.g., "What did you think when you saw the robot flap its tail?") where we wanted to limit the impact of our questions on participant perceptions. Participants completed the wellness questionnaires.

Follow-up: One week after the robot was returned, participants completed the questionnaires, and we interviewed them about how they felt with the robot gone.

Participants were compensated $20 CAD every week for the first 10 weeks of the study. If participants chose to extend the study, they were not compensated beyond the initial study length, because we wanted to learn if participants wanted to keep the robot in their home, and for how long, without the potential variable of a financial incentive.

4.4 Participant Recruitment

We recruited participants 18 years of age and above who self-identified as being lonely and who lived alone. We used word of mouth, social media posts and bulletin boards posted in general local online groups and public spaces to attract as diverse a participant pool as possible. Participants were asked to provide pseudonyms to use in dissemination for their privacy. To reduce the chances of adverse participant reactions (e.g., when taking a robot back) as required by our ethics board we noted on recruitment materials that we cannot include participants with a history, current diagnosis, or suspected mental health conditions. As a study finished, we re-furbished the given robot and deployed to a new participant.

4.5 Analysis Plan

We transcribe the interviews with support from an Undergraduate student in the lab, Skyla Dudek. We conduct a thematic qualitative analysis on our interview and diary entry data to investigate our core research questions relating to participant engagement with our robot design.

A thematic analysis consists of a systematic approach to identifying themes in the data (Hawkins, 2017). This consists of finding themes in the data, coding the data according to those themes, and analyzing the coded data to find patterns and relationships within the data (Lapadat, 2010).

We find themes and code the data using a mix of inductive (finding themes directly from the data, Hawkins, 2017) and deductive (themes originating from prior theory or research outcomes, Hawkins, 2017) coding. We start with an initial set of focal points and related data codes based on our design strategies. We add new codes as salient novel points arose in the data. Our final focal points and code book are provided in Appendices J and K.

Following, we group the coded data by grouping quotes within each code and labeling the groups of quotes. From our groups of quotes, we uncover dominant themes in the participants' behaviours and opinions. Finally, we pay attention to themes that emerge amongst multiple codes to discover cross-cutting inquiry points.

We graph the quantitative data to look for trends in changes in participants' wellness measures over time. However, we do not conduct statistics on the data because of the low sample size.

4.6 Summary

This chapter outlines our study design for our longitudinal study we use to evaluate our design approach. Participants kept our robot in their home for a minimum of 7 weeks during the study and were instructed to interact with it as often and in whatever way that they would like. We gave participants the option to extend the study up to 6 months. In this chapter we further present the data we collect, including semi-structured interviews, diary entries, and questionnaires. We also explain how we recruit for our study. Finally, we detail our data analysis plan.

The next chapter presents the study results. We examine participants' thoughts on each of our three design goals, and how successful our design goals were at encouraging their targeted behaviours. We also explore the interaction patterns that participants have with the robot and provide an overview of participants' adoption trajectories.

Thesis Advisor	Author
James E. Young	**Danika Lorraine Passler Bates**

5 RESULTS AND DISCUSSION

We deploy our robot into the homes of 7 participants who self-identify as lonely. We explore how successful the design goals were at encouraging their targeted behaviours to evaluate the impact of the design goals on engagement and comfort.

Before presenting the main results from our study, we give background information on each participant, to better understand their lifestyle as well as why they feel lonely. We include how long each participant chose to keep the robot in their home, which provides one data point regarding how attached participants felt to the robot.

We detail how participants engage with each of our three design strategies. We further examine the overall interaction patterns that participants have with the robot to better understand the impact of all of the design strategies together. Finally, while an in-depth adoption analysis is outside of the scope of this thesis, we provide an overview of participant expectations and adoption trajectories to understand at a high level how our robot was received and adopted by people.

Finally, we discuss the results of our study at a high level, reflecting on our design strategies as well as the overall success of the robot.

5.1 Participants and Data

We recruited 7 participants from a range of backgrounds, as summarized in Table 1.

Table 1: Summary of Participants

Name	Age	Occupation	Pronouns	Description	Deployment Duration
Pester	70-79	Commissionaire	he/him	Last partner was 23 years ago, reports that “there’s a couple things that didn’t go quite right in the love department”. Pester misses the companionship of his deceased dog.	12 weeks
Vanessa	18-29	Nurse	she/her	Reports difficulty spending time with friends since school ended. Has a	25 weeks

Name	Age	Occupation	Pronouns	Description	Deployment Duration
				partner (not co-habitating) Moved out on her own at beginning of study and moved back with her mother and brothers during study.	
David	40-49	Survey Interviewer, Tennis Instructor	he/him	Spends time with his family and non-cohabitating girlfriend often but works remotely and lacks companionship during the workday.	7 weeks
Art	30-39	Customer Service Representative	they/she	Had just gone through a break-up and was in between jobs. Living alone with a pet cat for one month before the study; previously lived with their partner.	7 weeks
Dancer	30-39	Statistician/Methodologist, Tutor	he/him	Recently moved to Canada and does not yet have close friendships despite meeting people. Works from home and wants to see more people during the workday.	16 weeks
Sheila	40-49	Primary occupation unknown[3], secondary job cleaning apartment block	she/her	Living alone with two cats for the past 3 years, single for the past 12 years. Likes having her own space but misses having someone to go out to do things with.	7 weeks
Leslie	18-29	Aerospace industry	she/her	Recently moved out of parents' place, does not see friends or family often. Moving while working long hours (12-hour shifts plus overtime) has been stressful.	11 weeks

The total data we collected from all 7 participants includes 37.7 hours of interviews (transcribed) and a total of 107 questionnaire entries and 70 diary entries.

[3] The audio where she says her job title was inaudible in the interview.

5.2 Target Design Strategies

5.2.1 Design Strategy: Physical Comfort

Attitudes Towards Physical Comfort – Incoming attitudes toward the physical comfort element were mixed. When asked at the beginning of the study if they thought that cuddling the robot could help with loneliness, two participants were open to the idea of the robot helping with loneliness (Pester, Art), while three expected that cuddling the robot would help reduce loneliness (Vanessa, David, Dancer). One participant (Leslie) initially expressed hesitancy about cuddling.

> *"I would have to be more comfortable with it for me to do that … like maybe in a few more days." - Leslie, First-encounter*

By later in the study, concerns over embarrassment and social norms emerged regarding cuddling a robot (Pester, Dancer).

> *"I'm not going to take it to couch with me and wrap my arms around it, sorry.…Because if I were to die and they found me like that I'd be embarrassed." - Pester, Ongoing during week 11*

Comfort of The Robot – However, all participants but one (Pester) reported that the robot was comfortable. Three reported liking the overall softness of the robot (Vanessa, David, Dancer), although one participant (Pester) found the fake fur unrealistic in comparison to a pet.

Four participants reported liking the weight of the robot (Vanessa, Dancer, Sheila, Leslie), while one (Art) found the robot awkward to handle and expressed concerns over others being able to hold it. Three participants reported liking the robot size (Vanessa, David, Dancer), although one found it too large, taking up too much space in their apartment[4]. Most participants (Pester, David, Art, Sheila, Leslie) did not comment on robot warmth. While 1 participant (Vanessa) found the heat pouch warmth comforting, another (Dancer) talked more generally.

> *"I feel more secure, I feel warmer and safer at least a little bit, especially when I'm hugging it." - Dancer, Ongoing during week 7*

[4] It is possible that this participant was complaining about the robot *and its carrying case*, a plastic tote.

While this participant noted that cuddling could get too warm, they noted the limited impact of the heat pack.

> *"You couldn't really feel it that much unless you were specifically touching its pouch. Like if you were holding it normally, maybe you'd feel it a little bit?" - Dancer, exit*

Physically Comforting Behaviours – All participants reported engaging in our targeted physically comforting behaviours: cuddling, hugging, and holding the robot, with reported frequencies varying widely: some reported interacting almost daily (Pester, David, Art, Dancer, Leslie) while others did not (Vanessa, Sheila), with the overall average being 2-5 interactions on days that participants engaged. When participants did interact, some reported giving the robot brief hugs (Pester, Dancer), while others reported cuddling or holding from a couple minutes to "quite a few hours" (Leslie). Four participants reported taking the robot to their bed at night (Vanessa, Art, Dancer, Leslie), 1-5 times per week, or cuddling the robot during a nap (Vanessa, Sheila). While some cuddled the robot while sleeping (Vanessa, Dancer, Sheila) others reported keeping it in their bed but did not report cuddling (Art, Leslie).

Three participants reported positive wellness effects of the hugging or cuddling (Vanessa, Dancer, Leslie) including helping with loneliness (Vanessa, Dancer) e.g.,

> *"it has a soothing presence just because it is cute and cuddly and designed to be hugged, so... I'd say a marginal positive benefit in decreasing loneliness and anxiety and stress." - Dancer, exit*

Finally, some participants noted that the hugging and cuddling frequency decreased by the end of the study (Vanessa, Leslie). One participant (Pester) noted that he only hugged the robot to serve its needs and had stopped by the end of the study.

5.2.2 Design Strategy: Social Engagement

Animism Towards Robot – The narwhal zoomorphic design was successful in encouraging animism from all participants, shaping how they perceived and interacted with the robot, e.g.,

> *"It feels like there's someone else present with you in your home or your apartment. And yeah, I feel like I'm very drawn to go like interact with the robot and pick it up and*

> *hold it and I feel like it's very therapeutic. It feels like a pet or like a baby or something." - Vanessa, Ongoing during week 3*

And participants used anthropomorphic and zoomorphic language to talk about the robot, e.g.,

> *"he wagged his tail so it was almost like he was answering me you know what I mean?" - Pester, Ongoing during 5*

Although one participant continued to use mechanical language to talk about the robot until the end of the study.

> *"I guess there's a timer on it that sets it to retrigger itself later on." - Art, exit*

And some participants reported exploring the robot's functionality in ways one would not expect of a living pet, for example, some (Vanessa, David) discovered that if they forcefully manipulated the pectoral fins of the robot, the tail would move. Another participant (Pester) tested whether the robot's cold sensor was working by putting the robot in the fridge to see if the horn would change colour.

Success of Robot at Attracting Attention – In terms of robot outputs, all participants reported noticing the horn communication and tail movements, highlighting their salience. In contrast, most participants (Pester, Vanessa, Art, Dancer, Leslie) often failed to notice the robot using its arms to get attention.

> *"I was definitely expecting like the arm flippers to move a little more, but it seems to just be like the bottom one that's the main one. But I think I caught it doing it once, I'm not a hundred percent sure." - Art, Ongoing during week 1*

Two participants (Pester, Vanessa) thought the robot was possibly broken because they failed to notice arm movements. However, robot log data indicated that the arms were moving as expected; it was simply not noticed by the users. One participant augmented the robot to increase the saliency.

> *"So, I left the plastic bag on it … it makes a little bit of noise what I was thinking of doing was adding a couple of bells to his tail so I could cheat from my bed and hear him ding ding ding" - Pester, Ongoing during week 7*

Note that this participant was not sure whether the arm or tail moved to get attention, up until the end of the study.

> *"I thought it was more random sort of an extra thank you." - Pester, exit*

In terms of engagement, participants reported varying urgency to respond to the robot requiring attention, with some (Pester, Dancer, Sheila, Leslie) trying to respond quickly, reporting that it was hard to ignore the robot, and others reporting that it was easy to ignore the robot (Vanessa, David, Art).

Attention Difference Based on Modality – There appeared to be differences between the response to different robot modalities. While some (Pester, Dancer, Sheila, Leslie) found the horn color successful in prompting them to attend to the robot, some noted they felt particularly compelled to respond to the arm movements (Pester, David, Leslie).

> *"it's hard to ignore, especially this morning at 9. It started like flapping its arms so quickly attend to it" - Leslie, Ongoing during week 9*

Two (Pester, David) noted that they felt more pressure from arm movements than the horn, e.g.,

> *"There's probably more of a sense to nurture it when it's actually making the noises or flapping its arms a little bit more. Then you kind of feel okay I should tend to the robot." - David, Ongoing during week 3*

Another noted the impact of the time of day.

> *"It was definitely the flipper was the most notable, cause I have like a little bit of a divider in my apartment. But like, in the evening it's definitely the horn that's a little bit more prominent cause I usually have my lights fairly low." - Art, Ongoing during week 1*

Impact of Tail Movement – Most (Pester, Vanessa, David, Dancer, Sheila, Leslie) noticed that the robot moved its tail when it received attention, and most noted that this was affirming (Pester, Vanessa, Leslie) and made them feel good (Pester, Vanessa, David, Dancer, Leslie).

> *"I sort of look forward to the tail wag because then it sort of tells me that I've done everything right you know? I've hugged it the right way." - Pester, Ongoing during week 5*

Some noted that this encouraged them to interact with the robot more (Vanessa, Dancer, Sheila), for example:

> *"It made me kind of giddy sometimes and it made me want to hug it more. Like just seeing that it was happy or trying to get my attention." - Dancer, exit*

Desire for More Engagement – Overall, some participants (Pester, David) noted that the robot was too predictable.

> *"I had a couple of dogs, you can kind of predict almost their every move sometimes, but they still might do some things out of the ordinary, they might feel more happy or more sad a certain day, they might surprise you from time to time, react spontaneously whereas the robot is probably too predictable." - David, exit*

And overall, some participants (Pester, David, Dancer, Sheila, Leslie) expressed a desire for more engagement such as increasing the time the robot was awake, or more complex interaction, as it was easy to forget about when it did not ask for attention.

> *"by forcing you to take care of it more, you would develop that bond quicker and it would have more of a presence in your life, as opposed to I guess it's easy to just like let it sit around sometimes. It would make it harder to forget about if it needed more attention" - Dancer, exit*

5.2.3 Design Strategy: Requiring Care

Caring for the Robot – All participants reported engaging in care including hugging the robot, warming it up, or charging it throughout the study. Some (Vanessa, Sheila) remarked that the needs encouraged more interaction with the robot than a stuffed animal. Further, while all but one (David) expressed enjoying or being interested in the care at some point, frequency and consistency of care varied amongst participants.

All participants responded to the robot when it was lonely (insufficient hugs) at various points in the study, up to 8 times per day. While all reported hugging specifically, participants reported various behaviours to placate the robot. Some were functional, such as pushing on the robot's chest (Pester) or manipulating its flippers (Vanessa, David), which would trigger the hug sensor. Others were more pro-social such as holding it until it responded (Vanessa, David, Sheila), cuddling it (Vanessa, Dancer, Sheila), carrying it around (Vanessa, Leslie), or petting and touching it (David, Art, Leslie). By the end some (Pester, David) reported not hugging the robot anymore, and exclusively used alternatives.

All participants reported warming up the robot up when it needed, up to 5 times per day, although some noted they missed days. Some participants used alternative methods instead of heating the pouch, including holding the robot and using their body heat (Vanessa, Art).

Participants typically charged the robot when needed, with some (Pester, Vanessa, Sheila, Leslie) using animism to discuss the activity and noting guilt when they missed charging the robot (Pester, Sheila, Leslie).

> *“he needs me to charge him and he’s probably cold, I feel bad, his light’s probably flashing and he’s wondering where I am.” - Sheila, Ongoing during week 3*

Some participants reported sometimes leaving the robot without a charge for days at a time (Pester, Vanessa, Leslie); the longest reported period was one week (Leslie, week 10). Participants reported forgetting to charge the robot (Vanessa), being busy (Leslie), or in one case not having a power source (Pester).

> *“the last 2 days it was ’offline‘ i.e. low battery + I could Not recharge enough in the truck, driving back to city from the lake, where it ran ‘low’.” - Pester, diary week 6*

Some reported taking care of the robot less often as the study progressed, perhaps due to becoming more accustomed to the robot.

> *“like at the start I was trying to like interact with the robot a lot to learn about the robot and yeah take care of the robot a lot but now I feel like I kind of know the robot and <laughs> I feel like it’s more chill now than trying to always like get the heat pack” - Vanessa, Ongoing during week 11*

Or a dwindling sense of responsibility, even after three days.

> *“the initial start of feeling the responsibility to tend to it was fairly strong. But has dwindled over time.” - Art, diary 1*

Drawbacks and Benefits of Requiring Care – For others, by the end of the study care had begun to feel like a chore (Pester, Art, Sheila) as the robot demanded too much attention (Pester, Art, Sheila). Some disliked being interrupted during tasks (Pester, Art) or having to care for the robot when tired or sick (Pester, Art, Sheila).

> *"Because I've been so sluggish, it's been like flapping for attention and it's like 'I'm right here, I'm just not moving'" - Sheila, exit*

Some reported that caring for the robot contributed to a sense of companionship (Vanessa, Dancer, Leslie), increased lifelikeness (Pester, Art, Sheila) and intelligence (Vanessa, Leslie), and most participants compared the robot to a pet (Vanessa, Dancer, Sheila, Leslie). This appeared to contribute to animism, with some (Vanessa, Art, Dancer) discussing the robot's feelings in relation to care or neglect.

> *"I do get like a vague sense that I'm like disappointing it." - Art, Ongoing during week 3*

Some participants reported that caring for the robot helped to establish a routine (Art, Dancer), provide a sense of purpose (Pester, Vanessa, Dancer, Leslie), or made them feel needed (Vanessa, Dancer, Sheila).

> *"Makes you feel like needed or appreciated when you take care of the robot, it makes you feel like you did something good for the robot." - Vanessa, Ongoing during week 19*

Participants (Pester, Vanessa, Dancer) expressed that this could be helpful for loneliness.

> *"having that companionship always there, having something designed to be hugged, always available to you. Having something to take care of, it's giving you that sense of companionship and responsibility, helps reduce loneliness." - Dancer, Ongoing during week 5*

Or support wellness in general, with the care relieving stress or anxiety (Vanessa, Dancer), distracting from negative thoughts (Art, Dancer, Leslie), or providing an opportunity for self reflection (Vanessa).

> *"how's the robot feeling? It's feeling lonely or cold. And I'm like do I have energy to take care of the robot, do I have like how am I feeling? Like maybe if I'm feeling stressed maybe I should take some time to cuddle with the robot because it will be good for me too" - Vanessa, Ongoing during week 23*

Impact of Robot Not Being Alive – Some discussed limitations of the potential for bonding given that the robot was not alive (in comparison to, e.g., a pet; Pester, David, Sheila).

> *"I mean it's not life or death like a plant or a pet, like the light turns red you know ... it's fine. Warm up his pouch or plug him in and he'll bounce right back so it's not like high stakes." - Sheila, Ongoing during week 5*

Although one noted that they cared for the robot despite knowing that it is artificial.

> *"it has programmed stimuluses … but you know, that doesn't change the fact that I want to take care of it." - Dancer, Ongoing during week 1*

Participation in Study as Reason for Care – Finally, some noted their sense of duty to the research study as a reason for their behaviour.

> *"I would still do it just for the sake of the study, maybe I would feel something later on in the study, so just want to keep doing it anyway just for that aspect." - David, exit*

Whereas others (Art, Sheila) reported they would act the same regardless of the study.

> *"There is still that sense of responsibility right so, like regardless, even if it was the study or not" - Art, Ongoing during week 1*

5.3 Interaction Patterns

In addition to reflecting on the specific design goals, participants reported how they generally interacted with the robot and integrated it into their lives.

5.3.1 Integration into Homes and Lives

Participants reported interacting with the robot as rarely as no interaction in a week, and as often as "one thing per hour" (Dancer). We note a decrease in frequency of interactions with the robot for some participants over the course of the study.

Some noted keeping the robot next to them, for example, on the couch or on a chair while relaxing (Pester, Vanessa, Art, Dancer, Sheila, Leslie) or on a desk or TV nearby (Pester, David, Dancer). The reported reasons included enjoying being near the robot (Art, Dancer, Sheila, Leslie):

> *"I actually put it on my desk next to my computer, so it was just kind of there hanging out with me while I was in training" - Dancer. Ongoing during 9*

and having it readily available (David):

> *"I just sort of am seeing it on my desk for hours at a time. So, I think given that situation it's been useful. Just makes the work day a little more pleasant, to kind of have it there just pick it up once in a while, have it on my lap" - David, Ongoing during 3*

or to enable participants to easily monitor and respond to the robot's needs (Pester).

Some participants moved the robot between rooms throughout their day to keep it near (Vanessa, Leslie) or from the bed to the couch in the morning (Dancer). Others (Pester, David, Art, Sheila) reported almost always keeping the robot in the same location.

Some reported cuddling or holding the robot while relaxing, such as watching TV (Vanessa, David, Dancer, Sheila) or reading (Leslie), or taking the robot with them to sleep (Vanessa, Art, Dancer, Leslie) or during a nap (Vanessa, Sheila) to cuddle with (Vanessa ,Dancer, Sheila) or just be near; Art and Leslie reported keeping it in their bed but did not report cuddling.

Some participants reported caring for the robot while taking care of themselves (Vanessa), or pets (Art, Sheila), or when they were passing by the robot (Pester, Dancer).

Participants who worked from home reported interacting with the robot during their workday, for example, caring for the robot, giving it hugs, or holding it on their lap as a break from work (Vanessa, David, Dancer). David reported interacting with the robot less on non work days.

While some participants went on trips most did not take the robot with them (Vanessa, David, Dancer, Sheila); only Pester took the robot with him to his vacation property.

5.3.2 Robot as a Social Catalyst

Some reported that the robot served as a social catalyst, for example, having people ask them about it (Pester, Leslie) or using it as a conversation topic (David, Dancer, Sheila).

> *"It was definitely a conversation topic, … it's been cool to bring up but normally it's been in the flow of conversation. I think if there was a lull in conversation I could definitely bring it up for something to talk about" - Dancer, Ongoing During week 3*

Some shared pictures of the robot (David, Leslie), posted on social media (Vanessa), or showed the robot in person (Pester, Leslie, Vanessa, David). One participant invited people specifically to see the robot (Pester). However, this same participant noted the potential stigma around having this robot.

> *"I don't tell anybody about it other than neighbour across the back lane, or second cousin. I don't really want to tell somebody I meet on the chinwag on the front street*

> *that I hug a little robot. You what? You're how old? So I don't." - Pester, Ongoing during week 5*

5.3.3 Emergent Interactions

In addition to our designed-for behaviours that we explained to participants, participants reported additional actions they took with the robot. For example, all but one (Dancer) petted the robot. Further, some (Pester, Vanessa, Dancer, Sheila, Leslie) reported talking to the robot while caring for it.

> *"Typically when... it's cold or lonely. I'll baby talk it more like a dog, like it's a puppy that needs to be taken care of." - Dancer, Ongoing during week 13*

Further, some participants (Pester, Sheila, Leslie) reported taking care of the robot more generally (in addition to the needs it communicated), for example, trying to keep it clean.

> *"just in general wipe it down really and I try not to put it on the floor anymore I don't like it getting dusty so" - Leslie, Ongoing during week 7*

Finally, one participant made modifications to the robot (Pester), for example, covering the robot in plastic so that he could notice the robot's movements better. Further, some participants reported that they covered the robot's horn due to its brightness (Vanessa, Sheila, Leslie).

> *"So, I was reading, and I was holding it close <laughs> the light was a little too bright for me, so I had to like cover it a little but it kind of grabs attention pretty much consistently." - Leslie, Ongoing during week 1*

5.3.4 Bonding and Wellness

Drawing from the combination of our design strategies, participants reported that the robot promoted wellness. For example, that the robot was comforting or calming (Vanessa, Art, Dancer, Leslie), or caused a reduction in stress (Vanessa, Dancer, Leslie) or anxiety (Dancer). Perhaps one reason for this is that having the robot created structure and companionship.

> *"Living alone, my days can be a little unstructured beyond work, so having the robot to take care of has helped provide some routine and companionship in my day-to-day life." - Dancer, diary week 4*

One even reported wanting to protect the robot.

"it's like hugging a little baby or holding a baby its like very soft yeah just its size is very cute and I just want to like protect it." - Vanessa, Ongoing during week 7

For some they developed a sense of responsibility, such as one person considering returning early from a social gathering to take care of the robot.

"wasn't paying any attention to him [the robot] you know? Felt a little bit, just for a couple of seconds but I remember that ooh should I leave [the social gathering] now? Oh, …it's inanimate it won't you know, no problem." - Pester, Ongoing during week 1

The same person also delayed leaving to run errands.

"I wouldn't leave the house because I knew that a hug was coming a hug request, so I didn't leave until I got it" - Pester, Ongoing during week 7

Some (Pester, Art, Sheila) noted conflict regarding feeling guilt given that the robot was not alive:

"Honestly, it would feel bad, and then it was kind of like annoying because I'm just like 'it's a robot, like it's fine.'" - Sheila, exit

With one noting that they would miss the robot, despite lack of use.

"That was actually kind of sad… it's been a constant companion for a few months so it's kind of tough seeing it go so. But I wasn't taking care of it anymore" - Leslie, exit

When asked if they felt that the robot was a companion, some (Vanessa, Dancer, Leslie) responded positively. However, others reported that initial sense of companionship faded over time (Pester, Art), or that they had difficulty bonding with the robot (David, Sheila).

"I was curious to see if it would develop into more of a bond. So, I mean it hasn't yet. It could maybe but um... since it hasn't happened yet, it probably won't happen but... at the same time I try to keep an open mind with it so. That's why I try to have it on my lap as much as I can" - David, Ongoing during week 3

We summarize the results from wellness-related questionnaires in Figure 27. Note that variation is high on the STAI and PANAS results, with patterns varying between participants. The UCLA Loneliness scale appears to show a slight decrease over time for many participants, and overall, given the sample size we did not conduct statistics.

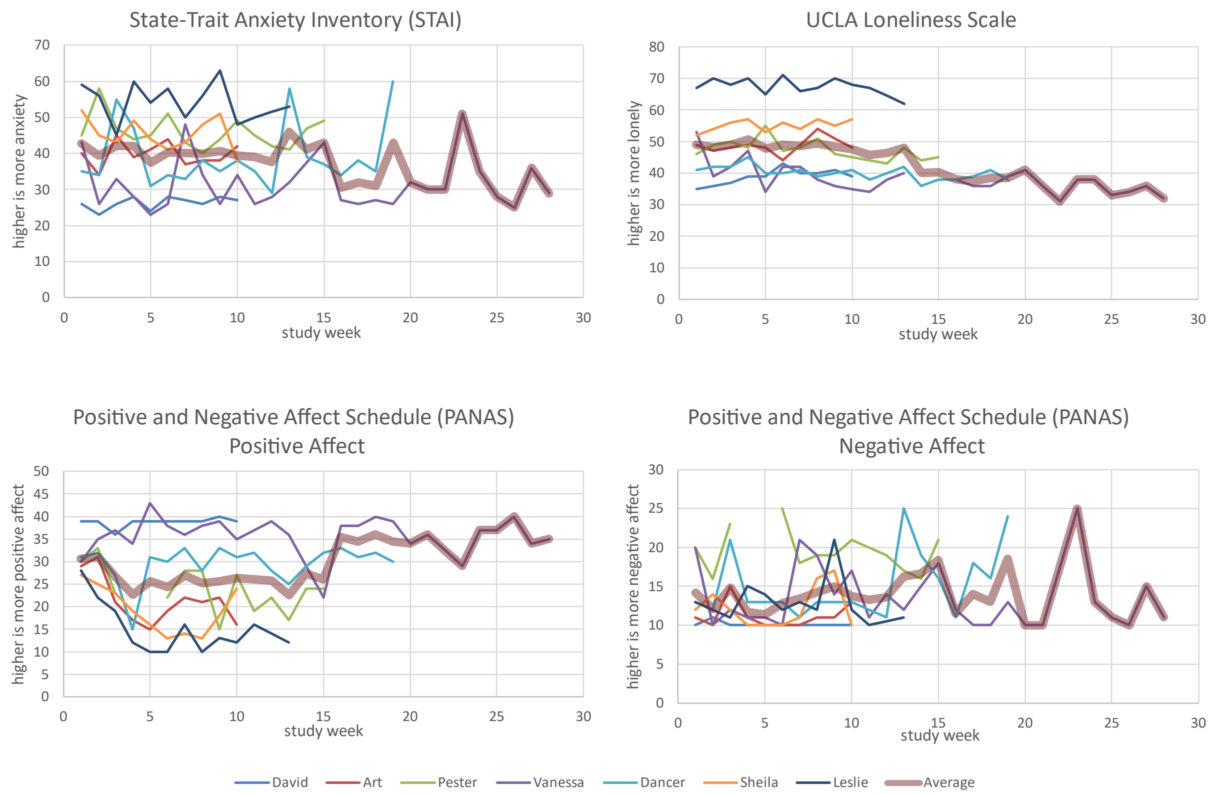

Figure 27: Summary of wellness questionnaires results, by participant. Average line based on number of participants at that time in the study, reduces (to 1) as participants drop out.

5.4 Expectations and Adoption Trajectories

While an in-depth analysis of eventual participant robot adoption is beyond the scope of this thesis, as we focus on the design strategies for encouraging engagement and comfort, in this section we summarize the prominent themes relating to user expectation and ultimate adoption of the robot. First, we present the overall general results, then detail each participant’s trajectory from expectations until they finished the study.

Overall, all participants reported a positive outlook at the beginning of the study. Various reasons for joining were given, such as curiosity, a desire to help with research, and belief that the robot would be helpful to them.

When leaving the study, David, Art, and Sheila decided to stop at the pre-set study design 7 week end point, and Vanessa stayed until the end. Pester, Dancer, and Leslie dropped out in the middle, returning the robot after 12, 16, and 11 weeks, respectively. Again, reported reasons varied, with some reporting that they did not feel companionship with the robot, others feeling that they did not have anything more to say in interviews, and others citing inconvenience or a lack of time for the study. After the study was over, most participants expected that they would miss the robot when they gave it back. However, although some did report thinking about or missing the robot at the follow up interview, other participants reported that they did not miss or think about the robot much.

In the remainder of this section, we provide targeted trajectories for each participant.

Pester was interested in the study because he wanted to learn about the robot. Upon first interacting with the robot, Pester was disappointed that the robot could not speak, and described the robot's appearance as "kinda sucky for a narwhal." Pester was unsure if he would continue to interact with the robot throughout the study and expressed that he may ignore it eventually. Pester kept the robot in his home for 12 weeks. At the beginning of the study, Pester gave the robot hugs, but by the end of the study he reported pushing on the robot's chest instead of hugging it. Pester reported leaving the study because he felt that caring for the robot became boring over time and that the robot no longer felt like a companion. However, when leaving the study, he asked if he would be allowed to change his mind later and complained during the exit interview about not having have that option. Pester reports that he would probably not get a robot in the future, but that he is not against it.

Vanessa was interested in participating in the study because she thought that a social robot could help with loneliness and was curious about the robot. Vanessa's initial reaction towards the robot was that it was “really cute and really soft” and expressed that she enjoyed holding it. She expected that during the study she would cuddle with the robot on the couch and might keep the robot nearby while studying. Vanessa stayed in the study the maximum amount of time. Vanessa reported that the robot felt like a companion. She expressed sadness about giving the robot back, and that she missed it after it was gone. She reported that she would have a robot again.

David hoped that the robot might be able to help break up his workday and provide him with opportunities to socialize during the day and was curious about the impact that the robot may have on him. David discovered alternate methods to taking care of the robot’s loneliness need rather than hugging it such as moving its arms around, and by the end of the study reported that he did not give the robot hugs. David chose not to extend the length of the study and kept the robot in his home for 7 weeks. David reported he left because he did not feel a bond to the robot and that he was saying the same things about the robot. He reports that he probably would not buy a companion robot. As reported in the follow-up post study interview, David reported that he did not think about the robot much after giving it back.

Art recently bought a robot vacuum when they moved to their new place and had experience with robot vacuums as their previous partner had owned one. Art hoped that the robot could be a distraction for them as they went through life changes and hoped that the robot could help regulate their schedule and could potentially be a comfort item. Art reported feeling an initial sense of companionship towards the robot, but that this faded over time. They also reported that caring for the robot could feel like a chore at times. Art chose not to extend the length of the study and kept the robot in their home for 7 weeks. Art reported that they felt relieved over no longer having the robot because it freed up space in their apartment. After giving the robot back, they reported that it was “out of sight out of mind.” They expressed that they probably would not get a companion or comforting robot in the future.

Dancer was interested in participating in the study because he wanted to help with research and because the study seemed fun. Dancer kept the robot in his home for 16 weeks. Dancer’s robot broke down several times during the study such that the horn stopped glowing and it no longer made movements. He reported that when the robot was broken, it was no longer lifelike, and he became less engaged with it. He also expressed that with the breakdowns the study was becoming inconvenient, and he felt he did not have anything more to add in interviews. When giving the robot back he reported expecting he would miss it, and that the robot felt like a companion. At the follow-up, he reported thinking about it sometimes, but not missing it "a ton." Dancer reported that he would be open to having a robot in the future, and that he would be interested in buying this robot if it cost $60 or less.

Sheila had prior experience with robots, as she owns a Roomba. Sheila joined the study because she was curious about the robot and thought that the robot could be helpful to have something to talk to, and that participating in the study could help encourage mindfulness. By the end of the study, Sheila reported that caring for the robot felt like a burden. Sheila chose not to extend the length of the study and kept the robot in her home for 7 weeks. Sheila reported leaving the study because she was too busy. When returning the robot, she reported that she did not feel that the robot was a companion because of its limited interaction capabilities. However, she expressed that it was "kind of sad" giving the robot back and that she expected she would miss the robot. During the follow-up interview, Sheila reported that she was not sad about no longer having the robot, and that she got used to it no longer being around after a couple days. She reported that she would be open to having a robot in her home in the future.

Leslie was interested in the study because she thought it would be exciting to have a robot. She thought that the robot could be useful to have someone to interact with, because she finds when she does not that her thoughts can "downward spiral." Leslie reported that the robot was like a companion. Leslie kept the robot in her home for 11 weeks. Leslie reported wanting to end the study because she was too busy with work, and she was not taking care of the robot anymore. She expressed that she was sad to see the robot go, and that she expected she would miss the robot. Leslie did not complete the follow-up interview, so we can not report on her feelings once she no longer had the robot.

5.5 Discussion

5.5.1 Design Strategies

Participants found our prototype comfortable, with the softness, weight, and size being noted as important. However, most participants did not comment on the robot warmth. Those who did mentioned the limited impact of our heat pack, suggesting that its size, heating power, or position may not have been particularly useful.

Our prototype was also successful in encouraging social engagement, with the overall zoomorphic design garnering animism. Of particular note is how the robot responded to interaction, with participants responding positively to the robot's tail motion. However, the robot had mixed success getting people's attention, with several people missing the arm movements and one augmenting the robot to amplify the arms' saliency; some also noticed that the arm motor sounds were easier to notice than the movement itself. However, when noticed, the arms were more effective at engaging people and created urgency to care for the robot, particularly in comparison to the light, which some people covered to reduce its visibility. Perhaps this is related to the light being somewhat abstract and not fitting the animistic or zoomorphic design, in contrast to the arms. Thus, future work should continue to explore methods for lightweight attention-grabbing and communication, to support the animistic design while being salient yet not bothersome.

Our strategy of requiring care had generally positive results. All participants cared for the robot, although frequency varied and decreased throughout the study. Some reported engaging in care not designed for, such as cleaning the robot, which is a promising avenue for future care-related design without technical requirements. Participants exhibited signs of bonding because of the need for care such as feeling guilt at neglecting the robot. We also note the strong positive response to the robot moving its tail in response to a hug, with some expressing that this encouraged more interaction.

Others reported that the robot demanded too much attention, and could feel like a chore, with some finding ways to care for the robot without demonstrating empathy (e.g., pushing on the robot instead of hugging it). We also note a link between participants who characterized the care as a chore and reporting a lack of companionship by the end of the study. Thus, perhaps future work could investigate how to increase the stakes or importance of caring for the robot, to create a perception of sufficient benefits (vs. being a chore), as this may help develop companionship. Despite these caveats most participants reported wellbeing benefits because of caring for the robot, even if they noted that it had less impact than caring for a pet. Thus, if we can continue to design for improved care it can be an avenue for companion robots to support wellness.

5.5.2 Overall Success

Overall, the care, comfort, and animistic design resulted in many people treating the robot as a pet or living thing and demonstrating signs of bonding and self-reported wellness benefits, including feeling an increased sense of purpose, improved structure, less anxiety, and leveraging the robot as a social catalyst. Further, while much of the numerical questionnaire data was noisy, suggesting individual patterns rather than general results, the UCLA loneliness scale suggests a potential reduction over time, which should be formally investigated with a larger sample size. Despite this, we had limited adoption success and a falloff of interaction through the study. Our results highlight potential avenues for increased engagement and bonding with a companion robot, and thus potentially stronger uptake.

Most participants expressed a desire for more robot engagement, perhaps via more complex interaction; some expressed that the robot was too predictable. Thus, research should continue to explore more methods to increase interaction complexity or randomness, and provide more avenues for engagement, with an eye to reduced predictability.

Our data highlighted that people who did not report engaging empathically with the robot (e.g., few or no hugs) also did not see the robot as a companion. This correlation provides an avenue for improving companion robot design as we should investigate how to encourage empathic behaviour which may improve the sense of companionship. Perhaps one reason for this is that some participants were embarrassed about having a cute, cuddly robot; exploring alternative form factors to avoid this concern may improve engagement.

Our results support existing research suggesting that establishing a common locus may support social engagement and attachment (Mollen et al., 2023), as participants who moved the robot around their home with them further reported feeling that the robot was a companion at the end of the study. Thus, developing interaction methods to encourage keeping a robot in one's space may further increase bonding.

Participants incoming attitudes and expectations towards the robot appears to have had an impact on how participants interacted with the robot. For example, of the four participants (Pester, Vanessa, David, Sheila) who listed curiosity about the robot as a reason why they were joining the study, most (Vanessa, David, Pester) engaged in exploratory behaviour with the robot.

Participants' expectations were not always met by the robot. Of the four participants who expected that the robot would be helpful for loneliness (Vanessa) or provide opportunities for social interaction (David, Sheila, Leslie), only two (Vanessa, Leslie) reported feeling that the robot was a companion.

5.6 Summary

We investigate participants' thoughts on the design strategies, as well as how successful the design strategies are in encouraging their targeted behaviours. Our results indicate that our design strategies were generally well received, with people engaging in the targeted behaviours of the design strategies. Our results further suggest that our design strategies may provide wellness benefits and help with loneliness by promoting companionship. We additionally explore participants' interaction patterns with the robot and discover that participants vary in the extent that they integrate the robot into their lives. Further, we report on the adoption trajectories of our participants. Overall, although most participants chose to extend the study beyond 7 weeks, our robot had limited long-term uptake.

The next chapter discusses the contributions of this thesis and the limitations of our work. We further provide suggestions for future work.

6 CONCLUSIONS

In this chapter, we outline the contributions of this thesis and provide recommendations for robots designed using our design strategies. We also describe opportunities for future work that can build on this thesis to further explore social robots that promote engagement and companionship.

6.1 Contributions

In this section we present the contributions of this thesis, as they relate to our research questions.

RQ1*: How can we build a standalone, deployable robot prototype that embodies and or encourages specific behaviors that we identify from wellness literature as having the potential to support people who are lonely?*

We explored a range of designs for a robot to encourage engagement and comfort through physical comfort, social engagement, and requiring care. We developed a concrete implementation of these design strategies into a novel companion robot for lonely people, which we call SnuggleBot. In our design and implementation, we focused on simplicity to create a robot that is robust and technically feasible. As a result of our simplicity approach, we were able to deploy our robots into homes unsupervised for up to 6 months. This supports future robots being designed with our simplicity approach, which may lead to more long term robot adoption by minimizing the expense and support structures required to maintain technically complicated robots.

RQ2*: How successful are our design goals (drawing from our literature search) in encouraging their targeted behaviours (engagement and wellness related activities)?*

With our design strategies of physical comfort, social engagement, and requiring care, we wanted to encourage cuddling and hugging the robot, repeatedly interacting with it, and caring for the robot. We designed and conducted a longitudinal study, with our analysis indicating that our design goals were generally successful in encouraging their targeted behaviours. We found that all participants engaged in cuddling or hugging the robot. However, some participants did not hug the robot when it was lonely as we had intended, once they discovered alternate methods to care for the robot's loneliness need such as by pushing down on the robot's chest. Results with regards to repeated interaction were mixed, with the frequency of interaction varying amongst participants. To encourage repeated interaction with the robot, we designed the robot to move its arms when it was lonely. We found that most participants reported missing or not noticing the arm movements. However, some participants did report that when they did notice the arm movements, they felt encouraged to interact with it. Finally, we note that all participants did take care of the robot. Overall, participants generally responded with the behaviours that we designed our robot to encourage.

RQ3*: What do participants think of the specific engagement and wellness-oriented design strategies that we employed?*

We find that participants generally reported enjoying our implementations of our design strategies. With regards to our physical comfort design strategy, all participants reported that they thought that the robot was comfortable overall. However, some participants reported embarrassment about interacting with our cuddly robot. For our social engagement goal, participants also enjoyed aspects of the robot design related to our strategy of social engagement such as the robot moving in response to attention that it receives. Participants additionally expressed a desire for more engagement from the robot, such as by having more complex interaction. Finally, some participants expressed that they felt that the robot's requests for attention were too predictable. With our goal of requiring care, participants reported that caring for the robot provided them with wellness benefits. However, some reported that caring for the robot could feel like a chore at times. Overall, our results suggest that participants thought our design strategies can be helpful for people, and our results further indicate areas of improvement for our design strategies and implementations of those strategies.

RQ4: *What are the patterns of interaction that lonely people have with our cuddly robot?*

We identified patterns of interaction that participants had with the robot which help us to gain further insight into the impact of our design strategies. We found that participants integrated the robot into their daily lives by for example keeping the robot next to them, moving the robot with them from room to room with, or interacting with the robot throughout their remote work day. The success our robot had at integrating into participants lives indicates that our design strategies promote attachment with the robot. However, we also note that the frequency of interaction with the robot decreased over time for some participants. We also found that the robot served as a social catalyst for some participants, with participants showing the robot to others or discussing the robot with people. Participants also demonstrated behaviours that indicates signs of bonding, such as delaying leaving their home to tend to the robot. Finally, we identified emergent interactions that participants had with the robot, such as petting the robot, talking to it while caring for it, keeping it in good condition, and covering the horn to reduce the brightness. Overall, the patterns of interaction that we identified indicate that our design strategies were successful in promoting attachment, and provided benefits to people, for example, by serving as a social catalyst. From the emergent interactions of our participants, we further identify recommendations to refine our design strategies which we outline in section 6.2.

RQ5*: How does a lonely person report the potential indicators of our cuddly robot's impacts on their loneliness and wellbeing?*

Although we do not seek to scientifically measure impacts of our robot on loneliness and wellbeing, there were strong indicators in our results that our design strategies could support the well-being of lonely people. For example, people did cuddle with the robot, repeatedly interact with the robot, and care for the robot. Some participants also reported that they felt a sense of companionship with the robot. Based on our background literature, we expect that these behaviours and the sense of attachment to the robot our participants reported may lead to wellness improvements. Further, some participants reported that interacting with the robot led to actual wellness benefits. Additionally, our graph of the UCLA loneliness scale shows a slight decrease over time. This supports future research with a larger sample size to investigate if there is a real decrease over time in the UCLA loneliness score for participants who keep our robot in their home. Overall, our results provide preliminary support that our design strategies are helpful in supporting wellness.

6.2 Recommendations

In this section, we present recommendations to improve robot designs implementing our design strategies.

We generated recommendations that would improve the effectiveness in encouraging the targeted behaviours of the design strategies. In our study, participants reported that they did not always notice the movement of the arms. As such, the arms were not effective in encouraging interaction in these cases as we had intended. However, when participants did notice the movements of the arms, the animistic arm movement was effective in encouraging engagement as intended. As such, we recommend that future work should explore additional methods to engage people which are more effective at catching people's attention, while still incorporating animism. Another way that participants did not behave as we had intended was that some participants chose to use methods other than hugging the robot to care for its loneliness need. As we note that those who did not engage empathically with the robot by hugging it also did not report a sense of companionship with the robot, we recommend that future robot designs explore methods of encouraging empathic engagement as this may lead to companionship. One avenue for increasing engagement may be using a different form factor, as participants reported embarrassment interacting with our cute and cuddly robot.

Participants also gave us feedback which we use to create recommendations to improve our design strategies. Firstly, most participants expressed a desire for more engagement from the robot, such as wanting more complex interaction with the robot. Participants also reported that the robot was too predictable. To satisfy these desires from participants, we recommend that robot designs should provide more opportunities for engagement, with more complex interactions. Further, these engagement methods should aim to increase randomness from the robot so that it does not feel as predictable. Secondly, participants expressed that caring for the robot could feel like a chore at times. We recommend that future robot designs should increase the stakes of caring for the robot, as a benefit to caring for the robot. We expect that this may offset the feeling that caring for the robot is a chore. As we note a link between the participants who felt that caring for the robot was a chore and those who did not feel a sense of companionship with the robot, we also expect that increasing the benefits of caring for the robot will contribute to companionship with the robot.

From the emergent interactions of our participants, we identified further recommendations to refine our design strategies. Participants cared for the robot in ways not designed for, such as cleaning the robot to keep the robot in good condition. We recommend exploring incorporating cleaning the robot into the design of a robot, as this is a promising avenue for requiring care in a robot without increasing technical requirements. Additionally, as we note that participants who moved the robot around their home with them from room to room expressed that the robot felt like a companion, we recommend exploring methods to encourage establishing a common locus with the robot, as this may encourage companionship with the robot.

From the ways that participants did not behave in the ways we hoped to encourage with our design strategies, the direct feedback of our participants, and the participants' emergent interactions, we identified recommendations to refine our design strategies. We expect that robots that implement our design strategies with these recommendations will be engaging and support companionship.

6.3 Limitations

A primary limitation with our prototype was limited long term uptake. Our results suggest that future designs will need to provide more perceived benefits to offset care feeling like a chore. Further, our findings indicate that exploring more avenues for engagement, such as more complex interactions are needed. From these results, this now highlights additional questions and design avenues that if addressed in future work, may lead to longer term engagement.

To obtain more nuanced data for our exploratory study, we conducted interviews with the participants. However, as participants frequently report on their interactions to a researcher, they may interact with the robot differently than they would outside of a study out of a sense of obligation to the study. Participants sometimes made comments that suggested that they were interacting with the robot for the sake of the study.

Given the early exploratory nature of the project we limited initial deployment to five robots. While this was important to learn insights such as the embarrassment that some participants felt about our robot before investing too much time into our early design, the narrow sample size limits generalizability. Moving forward, future iterations should consider studies with more robots to deploy.

With our goal of getting early feedback on our design strategies, another limitation of our work is that we do not consult extensively with mental health professionals. Consulting with experts in the design of technologies for mental health is important because of the vulnerable nature of the intended users of these technologies (Topham et al., 2015). In our work, we limit the risk of causing harm to vulnerable populations by asking that potential participants who have been diagnosed with a mental health condition self-exclude themselves from our study. However, future work using our design strategies to design robots to help with loneliness and wellness should consult with mental health professionals to ensure that the robot is designed in an ethical way.

6.4 Future Work

As outlined in section 6.2, in this thesis we provide recommendations for future work to explore to improve and build upon our design strategies.

We discovered improvements that could be made to our design strategy of social engagement. Our results indicate that when noticed, the animistic avenues that we use to attract attention were generally successful at engaging people. However, they were not always successful at being noticed. To improve upon this, future work should explore more methods to attract attention that is more noticeable, while also incorporating animism to engage people to care for the robot. Further, participants expressed a desire for more engagement from the robot. Future designs should consider incorporating more avenues for engaging people, and methods of engagement that would allow for more complex interaction. Additionally, as participants found the robot to be predictable, randomness should be incorporated into the robot's requests for attention.

Improvements and iteration can also be done with our design strategy of requiring care. We discovered that some participants took care to keep the robot in good condition, by engaging in behaviours such as cleaning the robot. Incorporating this into the design of future robots could be an additional care interaction that would require little technical requirements. Additionally, as some participants noted that caring for the robot felt like a chore at times, exploring avenues to increase the stakes of caring for the robot is a promising area for future work, to create more benefits of caring for the robot.

We found avenues for future work to explore to further promote companionship. We found that some participants did not engage with the robot empathically as we had hoped. We also found that some participants were embarrassed by the cute, cuddly robot. As such, future work should explore methods of encouraging empathic engagement, perhaps by changing the form factor of the robot to be less cute. Designers of future robots should also consider adding interaction methods to encourage being in the same location as the robot, as our results provide support for a common locus promoting companionship.

The graphs of our UCLA Loneliness scale indicate a slight decrease over time. This supports future work with more participants with our robot to conduct a statistical analysis to discover if there is a real decrease in the loneliness of participants who keep our robot in their home.

We plan to explore the adoption patterns of the participants in depth in future work. This work is important to understand why and how social robots can be adopted, to inform the design of future robots that can be more readily adopted. To accomplish this, we plan to first do a thorough survey of the existing adoption literature. Following the survey, we will create codes based on adoption patterns and stages found in prior work. We will then code our data and see if our participants followed the same adoption stages and patterns found in existing work. We will also code for any emergent patterns that we discover that have not been found in previous work.

6.5 Conclusion

In this thesis, we designed, prototyped, developed, and deployed a novel companion robot to promote engagement and comfort, analyzing the data to reflect on the impact of our design strategies, how people interact with the robot, and potential indicators of the impact of the robot on loneliness and wellbeing. To do this, we first identified three design strategies grounded in wellness literature to promote engagement with social robots, with the ultimate goal of providing support for loneliness: physical comfort, social engagement, and requiring care. We then designed and developed a novel social robot implementing these design strategies. Next, we deployed our prototype in a longitudinal study into the homes of 7 people who live alone and self-identified as feeling lonely to evaluate our design strategies. We analyzed our study data and found that our robot was generally found to be comfortable. Further, our robot was successful in encouraging engagement and animism. We also find that participants reported wellbeing benefits of caring for the robot. Our results indicate that our three design strategies of physical comfort, social engagement, and requiring care have potential to create robots that promote engagement, wellness, and companionship, with many participants demonstrating signs of bonding with the robot. We further found a decrease in our graphs of our participants' UCLA loneliness scores. Although we did not conduct statistics in this thesis because of our sample size, this trend together with our positive results in engagement, wellness and companionship for our design strategies supports future research into the impact of our design strategies on loneliness. We also note that our approach of designing a robot around simplicity resulted in a robust prototype that we were able to deploy into homes unsupervised for up to 6 months. As loneliness continues to increase (Gardiner et al., 2018), future work should continue to investigate deployable robots that can support people in their homes with loneliness.

Overall, our work contributes to the growing field of technological interventions for wellness, and more specifically, for supporting people who are lonely. As social robots and companion technologies continue to advance, our findings provide novel approaches, an example feasible robot, and original nuanced feedback from participants who lived with our robot for 7 weeks to 6 months. We envision that our research will be useful to others to develop ongoing work in the area.

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Appendices

Appendix A- Questions for Interviews

First-Encounter

Goal: Expectations

- When you got to know that you would receive a robot, what was your expectation towards it?
- What was your first impression of the robot?
- Now that you've seen the robot, what do you think about it?
    - What do you think of how the robot looks?

Goal: Robots and Pets

- Can you tell me about your interaction experience with the robot?
- Is there anything in particular about the robot that you like that you'd like to highlight?
- Do you find any similarity between the robot and a pet or an animal? Can you explain?
    - What about differences?
- What do you expect from a pet?
- Do you think you would eventually treat your robot as if it was a real pet?
- Will you be able to consider the robot as a pet if it meets the expectation?
- Do you think the robot will be able to understand you?
- Do you think it will judge you?
- What do you think the robot is capable of doing?
- Do you think you will be comfortable interacting with a robot?
- Do you see the robot as life-like?

Goal: Thoughts about the robot

- Do you think robots will be helpful in reducing loneliness?
- What do you think about the idea that this robot may be programmed to like you?
- What do you feel about having a robot in your home?
- Do you have any plans for what you will do with the robot in the next few weeks? What are you planning to do with the robot?
- Do you think you'll keep interacting with the robot?
    - How do you want to interact with the robot in the coming weeks?
- Would you rather interact with the robot or a regular stuffed animal?
- Do you think you will like cuddling with the robot? / Do you think cuddling with the robot will help with loneliness?

Ongoing-During

Goal: Patterns of Interaction

- Can you tell me about what the past week/month with the robot in your home was like?
- Can you walk me through how you interacted with the robot yesterday?
- Is this a typical day for you and the robot?
    - What was happening right before you interacted with it?
- Did you notice anything new while interacting with the robot?
- Did anything exciting happen?
- Did you learn something new about the robot? can you explain?
- Do you feel like you use the robot differently?
- Did you cuddle or hold the robot?
- Did you do anything to take care of the robot?
    - How?
    - How often do you do this?
- Do you ever notice the robot needing something?
    - How does this make you feel?
- Does the robot ever try to get your attention?
    - How? Did it work? Was it easy to ignore?

Goal: Relationship with the Robot

- How do you feel about interacting with the robot? Do you think the robot is intelligent?
- Do you feel like the robot is useful?
- Do you think using the robot is easy or hard?
    - What is easy?
    - What is hard?
- Can you describe the relationship you have with the robot?
- Do you feel the need to interact with the robot?
- While you are gone,
    - do you feel the robot misses you?
    - Do you miss the robot?
- Do you think the robot has grown to have some feelings for you?
- Do you think you will have a strong bond with the robot in the long run?
- Do you feel like you and the robot are creating a connection?
-

Goal: Sociability and Acceptance

- Do you see the robot as life-like?
- Do you think it has any type of social skills?
- Has the robot disappointed you in any way?
- What would you change in the robot?
- Do you feel safe when interacting with the robot?
    - What makes you feel safe?

    - What makes you feel unsafe?

Goal: Robot as a pet

- Do you view the robot as a pet?

Goal: Interaction Changes

- How often do you interact with the robot? Is there a particular time you interact with it?
    - How long do you interact with it each time?
    - How often have you used it since we last spoke?
- Do you ever speak to the robot?
    - How much do you speak with the robot?
- Does the robot ever act in a way that you don't expect?
- Do you interact with the robot after a certain circumstance? – after a long day of work, working out for some time, or in a lonely evening?
- What are your current thoughts on keeping the robot for longer in your home, given that you will have the option to at the end of the study?
    - If no,
        - why?
        - Would you change something?
        - Do you just don't feel comfortable with it around?
    - If yes
        - why?
        - Has the robot helped?
        - Would you want to change something about it?

- If last ongoing-during interview: According to the original study schedule, I will pick the robot up from you in two weeks, and we will have our final follow up session a week after that. You do have the option to continue in the study for longer if you would like, up to a total study length of 6 months. Unfortunately, the study protocol doesn't have the support to continue paying an honorarium beyond the initial 10 weeks. Staying in the study for longer is completely optional. I will explain more details about how staying in the study longer would work, but do you have any questions so far?

  If you do choose to stay in the study longer, you will continue to do the weekly questionnaires, and we will continue to meet every two weeks. I will take the robot back one week before you have been in the study for 6 months total, and then we will have our follow up interview 6 months after you started the study. If you choose to stay in the study beyond 10 weeks, you are not obligated to stay for the entire 6 months and can choose to end it at any time, but the study protocol is for you to do an exit interview on the day I take the robot back and a follow up interview session one week after I take the robot back. Do you have any questions about this? Would you like to stay in the study for longer, or would you like to stick to the original study schedule

Goal: Social Involvement

- Did you tell anyone about the robot?
- Did you have any guests over since we last spoke?
- Did the robot help you in any way to start a conversation with someone?
- Does anyone from your work know that you have a robot in your home?
    - Did they show any interest to know more about it?
    - What did you feel about their interest?

Goal: Impact on loneliness

- How are you feeling since you got the robot?
- Does the robot make you feel happy?
- Has the robot impacted your mood?
- Has there been any changes in your life or anything you'd like to talk about, since getting the robot?
- Do you feel that this has been a positive thing for you, a negative thing, or no real change?
- Now that you have some experience with the robot, do you think the robot can be helpful in reducing loneliness? Can you explain?

Appendix B – Consent Form

Project Title: Investigating Long-Term Use of Pet Robots in Homes for Wellness Support.
Researchers: Dr. James E. Young, Danika Passler Bates, James Berzuk
(young@cs.umanitoba.ca, passlerd@myumanitoba.ca, berzukj@myumanitoba.ca)
This consent form, a copy of which will be sent to you via email for your records and reference, is the only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like to have more details, feel free to ask the researcher. Please take the time to read this carefully and to understand any accompanying information.

Participation in this study is voluntary: you may choose to withdraw from this study at any point in time during both the interaction and interview part of this study. Risks of participating in this study are no greater than in everyday life.

Unfortunately, at this time we cannot accept participants who have been diagnosed, or suspect they may be living with serious conditions such as depression, or un-managed stress and/or anxiety, as we are not trained to appropriately help in these situations. If you cannot participate in the study due to this, please just inform the researcher that you are no longer interested after hearing about the details. If you feel that you could use help or would like to talk to someone, please visit the following website that lists local resources:

- https://umanitoba.ca/student-supports/counselling-resources-students
- https://sharedhealthmb.ca/covid19/providers/mental-health-resources

Given that this is a study about robotic pets, there is a possibility of participants becoming attached to the robots during the study. Because of this, some participants may experience negative feelings such as sadness at the end of the study.

Study Procedure:

You are invited to participate in a research study that lets you keep a stuffed narwhal robot in your own home and interact with it. The study is planned to be conducted for a period of 10 weeks, during which you will keep the robot in your home. This is a cutting-edge piece of technology, which means it may break or have problems (e.g., a flipper may stop working). As a participant, you have absolutely no liability or responsibility for any damage, harm, or problems that occur with the robot. It is designed to be treated like a pet, and you should feel free to treat it as you wish without any worry or concern for liability.

Throughout the study, we will have interviews (you can select your preferred platform– phone or online interview using your software of choice), and you will complete a range of questionnaires. The study consists of several phases. The goal today is to learn about your background, your attitude towards technology, and your interest towards this study. Following, after the robot is delivered, we will regularly talk with you and give some questionnaires about your perspective towards the robot and its effects, which will continue for 8 weeks. During this time, we will have interviews and questionnaires to talk about your daily interactions with the robot, and the robot's impact on your everyday life. Finally, we will get the robot back from you, and will follow up one week later to discuss about your daily life and how you feel about no longer having the robot. No expertise or experience is necessary for participation in the study.

We will conduct interviews every second week, which are expected to take between 30 and 45 minutes each, using an online video-chat platform of your choice (we can assist in setting something up) or telephone, as you prefer. With your permission, we will record these interview sessions for data analysis; your recordings will be kept secure and will only be used for this purpose. Further, we will ask you to complete questionnaires and diary entries about your daily life and interactions with the robot about every second day. These will be completed using an online system that we will direct you to, and we will provide clear instructions; these will take approximately 10 minutes to complete each time. We will provide weekly email reminders to complete the questionnaires, and we will provide your personalized study website where you can visit at any time to see the overview schedule.

This study uses Survey Monkey which is a United States of America company. Consequently, USA authorizes under provisions of the Patriot Act may access this survey data. If you prefer not to submit your data through Survey Monkey, please contact one of the researchers so you can participate in an alternative method (such as paper-based questionnaire). The alternate method may decrease anonymity, but confidentiality will be maintained.

Honorarium:

In appreciation for your time and participation in this study, you will be compensated with $20 dollars after signing the consent form. Further, you will subsequently be compensated $20 for every week that you continue to participate in the study for up to 10 weeks. This will result in a total potential compensation of $200 if you do not withdraw before study completion. We will give the honorarium using e-transfer, or if preferred, we will give the honorarium in cash by properly disinfecting and placing them in an envelope. If e-transfer is used, we will verbally agree on a password during today's interview, that we will then use to secure the transfer. You can freely withdraw from the study at any time without any consequences (you can keep your honorarium received until that date).

Consent:

All information you provide is considered completely confidential; your name will not be included, or in any other way associated, with the data collected in the study. Video or audio recording (depending on the interview medium) of the interview sessions are essential to the research analysis. Data collected during this study will be used for data analysis purposes only. We may use anonymized quotes from the recording for purposes of public presentation; however, we will not present video, screenshots, or audio. Each participant will be assigned a number that will be used to present anonymized quotes (e.g., P4 for participant 4).

That is, your image or sound will not be used in papers, presentations, put on the internet, etc. Please initial your response below.

a. I CONSENT to be recorded via online conference software, and am aware my voice and camera will be captured. _______

b. I CONSENT to audio recording only via online conference software (i.e. I will have my camera turned off and only my voice will be captured). _______

c. I CONSENT to audio recording only via digital recorder over the phone. _____

All the physical data and the digital data (encrypted using military-grade AES-256 and put in a USB Memory stick) will be stored in a locked office (E2-582) in the EITC building, the University of Manitoba, to which only researchers associated with this study have access until April 2024. Once published (in journals, conferences or thesis of students), results of the study will be made available to the public for free at hci.cs.umanitoba.ca. Again, no personal information about your involvement will be included. Please note that the University of Manitoba may look at the research records to see that the research is being done in a safe and proper way.

You have the option to sign up to receive a summary of findings for this research. This summary will be in non-scientific language and will be sent to you upon completion of our analysis by March 30, 2023. Please initial your response below if you want to receive the information:

I DO want to receive a summary of the findings of this research ________

If you do, please provide an email address or postal address

____

Your signature on this form indicates that you have understood, to your satisfaction, the information regarding participation in the research project and have agreed to participate as a subject. By signing the form, you also

confirm that you are of the age of majority in Canada (18 years or more). In no way, this form waives your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and to refrain from answering any questions asked, without prejudice or consequence. After the study ends, you can withdraw from the study any time up until 1 month after you return the robot back to the researchers; past this time data analysis and writing will be conducted and it will be impossible to remove the data.

Thesis Advisor	Author
James E. Young	**Danika Lorraine Passler Bates**

This research has been approved by the Research Ethics Board at the University of Manitoba, Fort Garry campus. If you have any concerns or complaints, you may contact Dr. James Young at 204-474-6791 or young@cs.umanitoba.ca, or the Human Ethics Secretariat at 204-474-7122 or humanethics@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.

Having read the provided information and after all my questions were answered to my satisfaction, I understand what I am freely consenting to.

Participant________________________________

Appendix C – UCLA Loneliness Scale

Participant ID _______________ Session ____________ Study _________ Date____/____/____

(this is a standardized questionnaire, D. Russell, "Ucla Loneliness Scale Version 3 (description of Measure)," J. Pers. Soc. Psychol., vol. 39, pp. 3–4, 1996.)

Instructions: Indicate how often each of the statements below is descriptive of you.

As a reminder, you are free to withdraw from the study at any time or not answer any question.

Statement	Never	Rarely	Sometimes	Often
1. How often do you feel that you are "in tune" with the people around you?	1	2	3	4
2. How often do you feel that you lack companionship?	1	2	3	4
3. How often do you feel that there is no one you can turn to?	1	2	3	4
4 How often do you feel alone?	1	2	3	4
5. How often do you feel part of a group of friends?	1	2	3	4
6. How often do you feel that you have a lot in common with the people around you?	1	2	3	4
7. How often do you feel that you are no longer close to any-one?	1	2	3	4
8. How often do you feel that your interests and ideas are not shared by those around you?	1	2	3	4
9. How often do you feel outgoing and friendly?	1	2	3	4
10. How often do you feel close to people?	1	2	3	4
11. How often do you feel left out?	1	2	3	4
12. How often do you feel that your relationships with others are not meaningful?	1	2	3	4
13. How often do you feel that no one really knows you well?	1	2	3	4
14. How often do you feel isolated from others?	1	2	3	4
15. How often do you fee1 you can find companionship when you want it?	1	2	3	4
16. How often do you feel that there are people who really un-derstand you?	1	2	3	4
17. How often do you feel shy?	1	2	3	4
18. How often do you feel that people are around you but not with you?	1	2	3	4
19. How often do you feel that there are people you can talk to?	1	2	3	4
20. How often do you feel that there are people you can turn to?	1	2	3	4

Appendix D – STAI Scale

Participant ID _______________ Session ____________ Study _________ Date____/____/____

(this is a standardized questionnaire, A. Wenzel, "State-Trait Anxiety Inventory," SAGE Encycl. Abnorm. Clin.Psychol., pp. 3–4, 2017, doi: 10.4135/9781483365817.n1316.)

Instructions: Several statements which people have used to describe themselves are given below. Read each statement and then circle the response option to the right to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

As a reminder, you are free to withdraw from the study at any time or not answer any question.

Sl. No.		Not at all	Somewhat	Moderately so	Very much so
1	I feel calm	1	2	3	4
2	I feel secure	1	2	3	4
3	I am tense	1	2	3	4
4	I am regretful	1	2	3	4
5	I feel at ease	1	2	3	4
6	I feel upset	1	2	3	4
7	I am presently worrying about possible misfortunes	1	2	3	4
8	I feel rested	1	2	3	4
9	I feel anxious	1	2	3	4
10	I feel comfortable	1	2	3	4
11	I feel self-confident	1	2	3	4
12	I feel nervous	1	2	3	4
13	I am jittery	1	2	3	4
14	I feel "high strung"	1	2	3	4

15	I am relaxed	1	2	3	4
16	I feel content	1	2	3	4
17	I am worried	1	2	3	4
18	I feel over-excited and rattled	1	2	3	4
19	I feel joyful	1	2	3	4
20	I feel pleasant	1	2	3	4

Appendix E- PANAS Scale

Participant ID ________________ Session _____________ Study __________ Date____/____/____
(this is a standardized questionnaire, I. Brdar, “Positive and Negative Affect Schedule (PANAS),” Encycl. Qual. Life Well-Being Res., pp. 4918–4920, 2014, doi: 10.1007/978-94-007-0753-5_2212.)
Instruction: Please read the following and Indicate what you feel right now.

As a reminder, you are free to withdraw from the study at any time or not answer any question.

Positive and Negative Affect Schedule (PANAS)		**Very slightly or not at all**	**A little**	**Moderately**	**Quite a bit**	**Extremely**
1	Interested	1	2	3	4	5
2	Distressed	1	2	3	4	5
3	Excited	1	2	3	4	5
4	Upset	1	2	3	4	5
5	Strong	1	2	3	4	5
6	Guilty	1	2	3	4	5
7	Scared	1	2	3	4	5
8	Hostile	1	2	3	4	5
9	Enthusiastic	1	2	3	4	5
10	Proud	1	2	3	4	5
11	Irritable	1	2	3	4	5
12	Alert	1	2	3	4	5
13	Ashamed	1	2	3	4	5
14	Inspired	1	2	3	4	5
15	Nervous	1	2	3	4	5
16	Determined	1	2	3	4	5
17	Attentive	1	2	3	4	5
18	Jittery	1	2	3	4	5
19	Active	1	2	3	4	5

Thesis Advisor | Author

James E. Young | **Danika Lorraine Passler Bates**

20	Afraid	1	2	3	4	5

Thesis Advisor | Author

James E. Young | **Danika Lorraine Passler Bates**

Appendix F – Study Schedule and Protocols

Participant ID _______________

(Dates will be scheduled later)

Item	Date	Phase	Questionnaire	Interview
Week 1 -Initial session – 1 Week Before robot delivery		Initial-Interaction	Yes	Yes
Week 2 - Robot Delivery		First-Encounter	Yes	Yes
Week 3		Ongoing-during	Yes	Yes
Week 4		Ongoing-during	Yes	
Week 5		Ongoing-during	Yes	Yes
Week 6		Ongoing-during	Yes	
Week 7		Ongoing-during	Yes	Yes
Week 8		Ongoing-during	Yes	
Week 9 Last Day of Robot deployment		Exit	Yes	Yes
Week 10 Follow-up Session		Follow-up	Yes	Yes

Thesis Advisor	Author
James E. Young	**Danika Lorraine Passler Bates**

Study Protocols

List of Appendix:

Appendix A: Semi-structured Interview Questions

Appendix B: Consent Form and Exit Reflection Form

Appendix C: Questionnaire A

Appendix D: Questionnaire B

Appendix E: Questionnaire C

Appendix F: Schedule and Protocol

Appendix G: Demographic Questionnaire

Appendix H: Diary Entry Form with Questions

The following lists the specific steps for our study. The exact text that will be read to the participants is given in blue.

During initial intake phone / video chat interview:

Expected Outcome: This phase will provide important context for analyzing and understanding participants' attitude toward companion robots before use (rather than attitudes toward the robot from use) and provide insights on their initial expectations towards the robot.

Procedure: One researcher will meet a participant using phone/video chat platform on a pre-scheduled date.

Thank you for joining us. We will conduct this longitudinal study over a 10-week period. After the initial 10 weeks you will also have the option to continue the study up to 6 months. First, we will do this initial interview, today. Then, we will have the first encounter phase when you will first get the robot. After you have the robot, we will do biweekly interviews and weekly questionnaires, to be conducted online (you can select your preferred platform – phone or online interview using software of your choice). Finally, we'll talk again on the day that the study finishes, and we pick up the robot, and finally we will do a follow-up interview session a week after. You will receive a $20 honorarium after signing the consent form today and you will receive $20 for every week for up to 10 weeks during the study. We intend to give the honorarium to you using e-transfer, however, if you prefer, we will give you the honorarium in cash by properly disinfecting and placing them in an envelope. You will receive the URL of the online questionnaires in your email. I understand that this is a lot to take in. I'll be giving you a schedule, and you will only have to do things once or twice A week. Do you have any questions at this point?

Thesis Advisor	Author
James E. Young	**Danika Lorraine Passler Bates**

The University of Manitoba is committed to taking measures to protect the health and safety of their campuses and the wider community. Your safety is important to us. The university has suspended most research that cannot be conducted remotely or virtually. Our study has been approved to proceed by our Faculty, the Vice-President (Research and International)'s office and the Joint-Faculty Research Ethics Board. In order to gain approval, we created policies to ensure the safety of the research team and participants. These plans were reviewed and approved by the parties above, as well as a representative from the Office of Risk Management. These policies include:

- All study research teams will wear masks during delivering and picking up the robot from your doorstep.
- We require all of our research team members to screen themselves for symptoms daily.
- We are following meticulous infection control practices, including disinfection, wearing gloves, and hand washing.
- If you have any symptoms of COVID, you need to inform us before our visit to your residence.
- Research team members will be travelling to your residence in their own vehicles and the vehicles will be thoroughly disinfected before the trip.
- You are receiving a box where you will find a robot. The robot has been disinfected and placed in a plastic wrap inside the box. The box was also disinfected using standard disinfecting wipes.

We want to inform you that we need to record the online interview sessions for research analyses purposes. You will learn more about this in the informed consent form (Appendix B) that I am sending you now. You will receive a URL in your email that will redirect you to your personal study webpage which I will update throughout the study and is where all of links to all the forms you will need to complete throughout the study will be. Right now, the study website has a link to the informed consent form. You need to put your whole name in a text box in the online informed consent form and submit it. A copy of the informed consent form will be emailed to you for your reference after this interview. After submitting the form, we will set up the details for e-transferring you your honorarium. Please complete the consent form and let me know when you are done. I'll be here if you have any questions.

Thanks for completing the consent form! I am going to start the recording now, okay?

We will now set up the e-transfer. I made a password by randomly generating three words separated by a dash, the password is <password> is that okay? Is sending the e-transfer to your email okay?

After the researcher has sent the participant their honorarium -

If you return to your study website you should see the demographic questionnaire and the covid-19 consent form. The demographic questionnaire will ask you for a pseudonym that you can choose for yourself and that we will use if we need to refer to you in publications. After you have completed the Covid-19 consent form and the Demographic questionnaires, let me know, and I will then make the questionnaires available for you to fill out. Let me know if you have any questions.

Thesis Advisor | Author

James E. Young | **Danika Lorraine Passler Bates**

Please refresh the webpage and the questionnaires (Appendix C, D, E, G) for today's session will be available. Please complete the questionnaires, and then we will further continue today's session. Let me know if you have any questions.

After they sign the consent form and complete the questionnaires -

Great! Thanks for taking your time to complete the questionnaires. We will send you a similar email once a week that will redirect you to the same webpage we used today which contains the questionnaires (Appendix C, D, E). Once you get the robot, you will also get a reminder in the middle of the week to complete a diary entry form (Appendix H). The diary entries will help you remember the interactions you had with the robot throughout the week.

The core study is 8 weeks where you will keep the robot in your home. After the 8-week period, you have the option to keep the robot in your home for up to a 6-month period if you would like and we will continue to have our biweekly meetings. We give the honorarium for a total of 10 weeks. Unfortunately, the research protocol doesn't have support for additional honorarium beyond 10 weeks. I will remind you of this later and you don't need to decide right now if you want to continue with the study for longer or not.

While you have the robot, please feel free to interact with it as much or as little as you like. If for example, you end up not feeling like using it that is okay. I want to know about it whether you are using it a lot or a little so please treat it however you'd like and we can talk about it in our interviews.

(not read to participants) The online questionnaire platform will be programmed using Survey Monkey where the survey will be hosted on password protected servers in US, Ireland or Canada using encrypted data. Once downloaded, data will be stored on password-protected encrypted drives of the researchers (specifically, the Principal and Co-Investigators). Researcher will start the initial interaction interview session after the participants complete the questionnaires, and the interview session will consist of questions from the question sets explicitly designed for this session (Appendix A).

After the interview session is complete, the researcher will remind the participant about the next scheduled session and what they might be expecting in that session.

First-encounter Protocol

Expected Outcome: This phase will give us insights on participants' thoughts about the robot, their interaction plans, and their expectations from the robot, right after they interact with the robot for the first time.

Procedure: One researcher will take a box consisting of a robot and leave it outside the participant's residence. Once the researcher confirms that the participant received the box, they will go back to the lab and conduct the first-encounter interview session online.

Thesis Advisor | Author

James E. Young | **Danika Lorraine Passler Bates**

Thanks for joining us! I assume you already found a robot inside this box with the instructions on how to use it.

If they say they did not open it, the researcher will ask them to open the box and take out the robot.

This robot is designed to be a cuddly companion that you interact with in your daily life. It doesn't move around or walk, but it can wiggle its tail and flippers when it wants to. The narwhal has a pouch on the front, like a kangaroo – can you check inside it now? There is also a heat pouch, that you can warm up in the microwave to keep the narwhal warm. Heating it up for about 30 seconds should be warm enough. I also put the heat compress on a plate when I microwave it to make sure the heat pouch stays clean. The heat pouch has a graphic on it to explain how the robot feels. The robot has a horn, that can light up and communicate information to you, as explained on the graphic. Can you take a look at it now, and see if you have any questions?

So basically, the horn will glow white when the robot is happy, purple when it is lonely, blue when it is cold, red when the battery is low, and will turn off when the robot is sleeping or the battery is dead. If you forget what the horn colours mean, just check the graphic in the pouch. The robot sleeps from 9pm to 9am, so please don't be alarmed tonight when the horn turns off.

Another thing about the narwhal is that it likes to be hugged and you can do this without worrying about breaking it. When the narwhal hasn't been hugged for a while, it gets lonely and its horn glows purple. You can hug it to help it feel better. Can you try giving it a hug?

The narwhal needs to be charged sometimes, about every second day. You know the battery is low when the horn turns red. If the robot's battery becomes empty, the light turns off. To charge it, you need to plug it in. Look at the robot's belly, notice that there is a black belly button – this is the charger socket. Check to make sure you can find it now and try plugging it in. When the battery is full the horn will stop being red. The battery should last for a while once charged so please don't worry about it or feel that you need to keep it always plugged in.

There is also a zipper on the back of the robot. This is for construction and maintenance of the robot by the research team. There is no need to open it.

After they are done interacting, the researcher will ask them to fill-up the online questionnaires allocated for that day.

Now that you have interacted with the robot for the first time, I am sending you the URL for today's questionnaires. Please complete them and then we will have a short interview session.

Then, the researcher will conduct the first-encounter interview session, which will consist of questions from the question sets designed specifically for that session (Appendix A).

Afterward, the researcher will remind them about the next phases and what they might be expecting in the coming days.

Ongoing-During Protocol

Expected Outcome: The interview sessions from this phase will provide insights about participants' general wellness, interaction process with the robot, and their relationship with the robot.

Procedure: The ongoing-during phase will be the most prolonged period of the overall study. This phase will have weekly online questionnaire sessions and bi-weekly online interview sessions. Participants are also expected to fill-up the online diary entries once every week (they will receive a reminder via email/text, and they can opt out from getting reminders if they wish).

We will conduct the bi-weekly interview sessions at a pre-scheduled time. Each interview session will have questions from the questionnaire sets (Appendix A) and follow-up questions from previous interview sessions.

Exit Protocol

Expected Outcome: This phase will provide insights on participants' thoughts about the overall study, if they feel any changes in their general wellness and their perception of the robot's impact on their daily life.

Procedure: After the ongoing-during phase, the researchers will conduct the exit phase. In this phase, participants will be giving the robot back to the researchers.

One of the researchers will arrive at the participant's home at a pre-scheduled time (by taking proper precautionary measures – wearing masks and gloves and maintaining appropriate social distancing). The participant will be instructed to put the robot inside a box and keep it on their doorstep. The researcher will then disinfect the robot using disinfecting wipes and wrap it in plastic cover and place it in the box. The box will then be securely taped, taken back with the researcher, and put into quarantine for the next 14 days. Further, on the day of the exit phase, after the researcher is back in the lab, the researcher will meet the participant online and conduct the exit interview session.

Thank you for joining the interview session. Before starting the actual interview, I am sending you the URL for today's questionnaires. Please complete them and then we will have a short interview session.

This interview session will also be conducted using questions from the question set (Appendix A). Afterward, the researcher will debrief the overall study and give the participants a follow-up form (Appendix B) to remind them about the consent they gave for the online interview recordings.

Thank you so much for participating in this study, we really appreciate your time. Now I will debrief the overall study to you so that you clearly understand what we are doing and what we will do with the data. The purpose of the study was to investigate how having a robot may impact people who identify has living with loneliness. In this study, we let you keep a social robot and interact with it for 8 weeks. During the study phase, you have completed multiple questionnaires, diary entries and interview sessions. The questionnaires are giving us insights on the level of your social interaction with others and your general wellness. The diary entries let us have some insights on your daily interaction with the robot. Lastly, the interview sessions were conducted to understand your perspective and thoughts of having a social robot in your home and how it impacted your everyday life. From the data collected throughout the weeks, we are analyzing them to investigate if any of the measurements had any significant changes or not after you interacted with the robot. The audio recordings from the interview sessions will be transcribed into text and analyzed by researchers. The research outcome will be used in publications to contribute towards future research. Now that I have debriefed the overall study, do you have any questions at this point?

Today we are taking the robot back with us. You have spent a great deal of time with the robot, and so some people find that they have become attached to it. You may feel sad at no longer having the robot. We will send you an email with links to free mental health and counselling resources, in the case that you feel you would like to talk to someone about it. (will email: https://umanitoba.ca/student-supports/counselling-resources-students, https://sharedhealthmb.ca/covid19/providers/mental-health-resources).

If the participant does not have any question, the researcher will thank the participant again, remind them about the follow-up interview session for the next week and leave with the box.

Follow-up Protocol

Expected Outcome: This phase will provide insights on how participants are going on with their lives after having a robot in their home for a long time.

Procedure: A researcher will conduct this phase one week after the exit phase. The researcher will meet participants online on a pre-scheduled time and conduct this session. Before starting the interview, the researcher will send them the very last online questionnaire set for the study. After they are done filling that up, the researcher will conduct the final interview session. This session will also be done using questions from the questionnaire set (Appendix A).

After the interview session, the researcher will end the study.

Appendix G- Demographic Questionnaire

Candidate ID: ____

1. What is your gender?
   ☐ Male ☐ Female ☐ Non-Binary ☐ Others

2. Which age range are you associated with?
   ☐ 18-29 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60-69 ☐ 70-79 ☐ 80-89 ☐ 90+

3. How many people lives with you in your home?
   ☐ I live alone
   _________ people

4. Did you ever have any pets?
   ☐ Yes ☐ No if "Yes", please specify: ____________________________

5. Do you have any hobbies?
   ☐ Yes ☐ No if "Yes", please specify: ____________________________

6. How often do you contact your friends/relatives?
   ☐ Never
   ☐ A few times a month
   ☐ Once a week
   ☐ More than once a week

7. How often did you visit your friends'/relatives' house before Covid-19?
   ☐ Never
   ☐ A few times a month
   ☐ Once a week
   ☐ More than once a week

8. How much time do you spend on social networks (e.g., Facebook, Twitter) each day?
   ☐ I do not use any social networks
   ☐ Less than 30 minutes
   ☐ 1-2 hours
   ☐ More than 2 hours

Appendix H – Diary Entry Form

Participant ID - ______ Date - ______________

1. Did you interact with the robot in the last 3 days? If you did, how was it?

2. Do you feel that the robot had a positive (or negative) influence on your daily activities?

3. Did you talk to anyone about the robot in the last 3 days? If you did, what did you discuss about?

4. Is the robot helping you in any way?

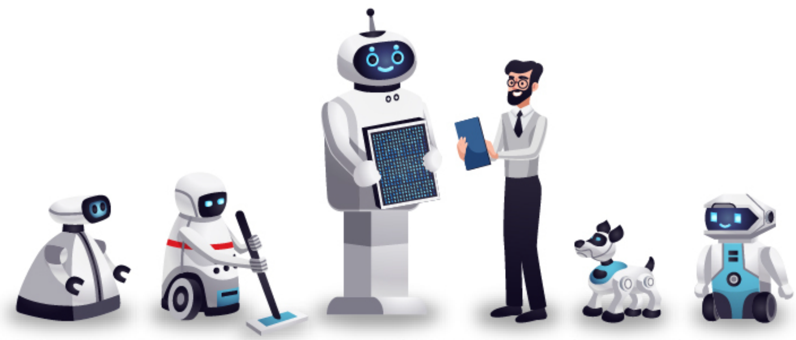
Thesis Advisor | Author

James E. Young | **Danika Lorraine Passler Bates**

Write anything that you want to add extra to your diary entry -

Appendix I – Recruitment Poster

Are you interested in keeping a robot in your home for up to 8 weeks to contribute to science?



We are looking for people to participate in a long-term study (approximately 10 weeks) to investigate how social robots impact people's overall wellness. We are recruiting people who live alone, and who feel that they are lonely. Unfortunately, at this time we cannot accept participants who have been diagnosed, or suspect they may be living with, serious conditions such as depression, or un-managed stress and/or anxiety, as we are not trained to appropriately help in these situations. If you feel that you could use help or would like to talk to someone, please visit the following website that lists local resources:

- https://umanitoba.ca/student-supports/counselling-resources-students
- https://sharedhealthmb.ca/covid19/providers/mental-health-resources

In this study, you get an opportunity to keep a social robot in your own home for approximately 8 weeks. During the study, you will complete weekly questionnaires and bi-weekly online interview sessions. Participation in each of the bi-weekly interview sessions will take approximately 30-45 minutes of your time. Completing the questionnaires and diary entries will take you around 10 minutes each time. You will receive a $20 (Canadian dollars) initial compensation plus an additional $20 each week for maximum amount of $200 for 10 weeks as you continue the study.

We are following all the necessary university-mandated protocols for COVID-19 and the procedures will be described on intake. To qualify for the study, you need to be at least 18 years old. If you are interested to be a part of the study, please contact -

Danika Passler Bates
passlerd@myumanitoba.ca

Principal Investigator - Dr. James E. Young

This research has been approved by the Research Ethics Board at the University of Manitoba, Fort Garry campus. The Research Ethics Board can be reached by phone (204) 474-6791 or email humanethics@umanitoba.ca

Appendix J – Focal Points

RQ1: How does a lonely person report that adopting a cuddly robot impacts their loneliness and wellbeing?

report on loneliness and wellbeing / change in

changes in social behaviour (CSB)

changes in general mood / happiness

Discussion on time use / change in time use

Mentions of time / change during study

RQ2: What are the patterns of interaction that lonely people have as they go through the process of adopting a cuddly robot?

precursors to interaction with robot

self report interaction frequency / duration

interaction context / time of day

negative comments

end of interaction

social interaction w/ other people

emergent behaviours / appropriation

Changes in interaction over time

<u>RQ3</u>: How successful are my design goals (physical comfort, social engagement, requiring care) in encouraging their targeted behaviours (cuddling and hugging the robot, repeatedly interacting with it, and caring for it)?

Physical comfort

Cuddling and hugging the robot

Holding the robot

Sitting next to / being next to the robot

Social Engagement

Noticing/reacting to the robot’s horn colour

Noticing/reacting to the robot’s arm twitch

Noticing/reacting to the robot’s tail moving

Caring for it

Charging it

Warming it up

Hugging it (for care)

Letting battery die

RQ4: What do participants think of the design goal approaches (physical comfort, social engagement, requiring care).

Physical comfort

Comments on robot being warm

Comments on robot being soft

Social engagement

Comments about robot twitching arms

Comments about tail flapping

Interpretation of tail flapping

Interpretation of twitching arms

Requiring care

Comments about having to care for the robot

Responsibility for robot

Feeling like robot really needs care

Feeling care is artificial because robot isn't alive

RQ5: What do participants see as desires/barriers to adopting a domestic companion robot for lonely people?

Desired feature/capability

Real barriers to adoption

Comments on positive/negative features of the robot

Comments on reasons for interacting/not interacting with robot

Desire to keep robot shorter/longer

Mention of risk/fear

Appendix K – Codebook

How does a lonely person report that adopting a cuddly robot impacts their loneliness and wellbeing?

lonRp	report on loneliness
lonCh	change in loneliness
sbCh	change in social behaviour
moodCh	change in mood
timeUs	time use
chTimeUs	change in time use
timeCh	mention of time or change

What are the patterns of interaction that lonely people have as they go through the process of adopting a cuddly robot?

printer	precursors of interaction
interFreq	interaction frequency
interDur	interaction duration
interCon	interaction context/ time of day
endInter	end of interaction
socialInter	social interaction with other people

emergApp	emergent behaviours/appropriation
changInter	changes in interaction over time
unexBeha	unexpected behaviour towards robot
test	testing the functionality of the robot

How successful are my design goals (physical comfort, social engagement, requiring care) in encouraging their targeted behaviours (cuddling and hugging the robot, repeatedly interacting with it, and caring for it)?

cudHug	cuddling and hugging robot
hold	holding the robot
next	sitting next to robot
noHorn	noticing/reacting to horn colour
noArm	noticing/reacting to arm twitch
noTail	noticing/reacting to tail move
charge	charging it
warming	warming it up
hugCar	hugging for care
batDead	letting battery die
pick	picking up the robot, possibly for taking care of lonely light
petting	petting the robot

What do participants think of the design goal approaches (physical comfort, social engagement, requiring care).

roWarm	comments on robot being warm
roSoft	comments on robot being soft
roWeight	comments on robot weight
roSize	comments on robot size
interTail	interpretation of tail flapping
interArms	interpretation of arms twitching
careRo	comments about having to care for robot
responsible	comments about feeling responsibility for robot
realCare	feeling like robot really needs care
artCare	feeling like care for robot is artificial
comforting	mention of robot being comforting, comfortable
cute	mention robot being cute

What do participants see as desires/barriers to adopting a domestic companion robot for lonely people?

desFeat	desired feature/capability
barrier	real barriers to adoption
feature	positive/negative features of robot
reaInteract	reasons for interacting/not interacting

keepRo desire to keep robot shorter/longer

fear mention of risk/fear

Misc:

tech talking about robot like it's technology

companion talking about robot like it's a companion

gap gap in transcription

petRo talking about robot as a pet

pet talking about real pet

curious curious about robot/robots

embar embarrassment about the robot

pick picking up the robot, possibly for taking care of lonely light

petting petting the robot

others robot could be useful for others

Codes based on framework:

Expectation:

Code	**Full Name**
questions_0	asking questions about robot
expUse_0	expected use of robot

compTech_0	compare robot to other technologies
expBen_0	expected benefits of the robot

Encounter

Code	**Full Name**
notExp	robot is different than expected
exploring_1	exploring features of robot
expInter	expecting/not expecting to interact with robot
expUse_1	expected use of robot
questions_1	asking questions about robot
compTech_1	compare robot to other technologies
benefits_1	benefits of the robot

Adoption

Code	**Full Name**
discuss	discussing robot with others
roError	challenges with robot error/perceived robot error
adjust	making changes to adjust to robot (e.g. routine with robot, robot placement)

questions_2	asking questions about robot
benefits_2	benefits of the robot
exploring_2	exploring features of robot

Adaptation

Code	**Full Name**
newFeat	learning something new about robot
learn	learning how to use/not understanding design
showRo	show robot to guests
novGone	used to robot

Integration

Code	**Full Name**
routine	routines with robot
diffDesign	using robot in way different than designed
noLess	notice robot less as it becomes part of life

Identification

Thesis Advisor

Author

James E. Young

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Code	Full Name
modification	personalizing/modifying robot
dissonance	rationalizing/rejecting robot after negative info(opinions from others?)
ignoProb	ignore problems of robot as get used to it
attachment	emotional attachment to robot