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Toward Designing User-centered Idle Behaviors for Social Robots in the Home

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Abstract — Idle behaviors give interactive agents a sense of *aliveness* both in and outside of interactions. However, in our recent long-term study with Jibo, participants reported the robot's proactive behavior and constant motion as being disruptive and invasive to their living spaces. These findings are consistent with concerns expressed by participants in other studies conducted with a variety of agents. We propose design guidelines for social robots' idle behavior in order to promote a sense of control, privacy, and comfort for their owners. We encourage HRI researchers to include stakeholders in the design process not only for a robot's main functionalities but also for its idle behavior in order to ensure that robots successfully co-living with humans. We plan to further investigate the effects of different robot idle behaviors on long-term usability and engagement in home settings for our future work.

Keywords — social robots, idle behavior, long-term

1. INTRODUCTION

In recent years, several companies have launched social robots designed to co-reside with users in their homes. Each of these robots has a core function that is designed to enhance users' lives. However, when a robot co-resides with people for an extended period of time, it spends most of its time idling rather than actively interacting with its user.

Idle behaviors give agents a life-like quality and are widely used in the field of gaming and animations [1]-[3]. Many robots' idle behaviors are designed to mimic the behaviors seen in humans and animals, like blinking, breathing, sleeping, wandering, and general random gazing. These behaviors not only contribute to the perception that the agent is alive [3] but can further enhance the media equation effect [4] and the overall engagement between the users and the interactive agents. We believe there is a growing need to study how idle behavior design can influence a robot's effectiveness, likability, and usability. Designers need to deeply understand how the people who are going to live with these robots would like their agents to idle while preserving their privacy and building long-term relationships.

In this paper, we report the design guidelines learned from a one-week study with Jibo[1] robots in college students' dormitories [5]. In our study, the robots were placed in college students' personal and shared rooms to deliver seven daily positive psychology interventions. The post-study interview showed that even though a majority of participants appreciated the robot's physical and social presence, the robot's idle behaviors outside of the interventions (especially the attentive head and body orientation feature) made them feel uneasy. Furthermore, the lack of full control over the robot's sleep and wake behavior caused unpleasant surprises for participants. Based on the results from our study and observations from prior work [6], [7], we argue that the idle behavior of social robots needs to be designed in a way that allows their users to feel a sense for privacy, control and comfort. We also believe the stakeholders should be empowered to control behaviors of the robot.

2. RELATED WORKS

[1]https://jibo.com/

2.1. Idle Behavior in Smart Speakers and Home Care Robots

Roughly 1 in 4 U.S. adults own a smart speaker as of 2020 [8] and iRobot reported selling more than 20 million robots worldwide since 2002 [9]. Most smart home devices wait passively for users to initiate interactions with them and do not display expressive idle behaviors. Smart speakers, such as Amazon Echo and Google Home, continuously record audio in order to capture a wake word and do not activate until they hear the word. Home care robots, such as Roomba[2], navigate around spaces to clean them but stay in their charging dock when not in use and do not randomly roam around spaces unprompted. Some products also offer a *Do-not-disturb* setting, which allows users to disable the microphone to prevent unwanted behaviors. In other words, users of most current interactive home technologies have full control over when their devices are active or dormant.

2.2. Idle Behavior in Social Robots

Most academic papers or consumer product manuals do not include explicit information on how their social robots behave during down-time. Rather, researchers have focused on studying the effect of robot motions during active interactions which contain little to no idle time [3], [10], [11] and many studies with home-deployment robots do not describe the robot's behavior during idle time [6], [12]-[16]. Due to this lack of information, it is difficult to understand how the deployed robots' idle behavior might have affected the users' perception of the robot as well as its usability and relationship with the user.

We reviewed details on idle behaviors for four commercially available robots designed for the home – AIBO, Vector, PARO, and Kuri – through the company website, user manuals, and academic publications. According to the Paro website[3], PARO blinks, moves its head and flippers, and makes noises when not actively used. It also sleeps during periods of long inactivity and can only be awoken by pressing a button. The user manual for AIBO notes that AIBO moves around and whimpers when left alone [18]. Similar to the zoomorphic robots, Vector and Kuri move around to interact with their surroundings and make noises when idle, with Vector having the additional behavior of self-playing.

2.3. Perception of Social Robots in the Home

Although idle behavior is not explicitly mentioned in many works, researchers have documented and analyzed participants' thoughts about living with social robots. Concerns for privacy and security due to robots' idle behavior are found in several studies. Users are often wary about what agents are doing when not actively engaged and find their unexpected movements and noises unpleasant. In prior studies, some participants physically covered the robot in order to eliminate noises and recording abilities [6], [16], actively avoided going near the robot, or found other ways to "trick" the agent [13]. In [12], participants withdrew from the study due to the agent's noise and behaviors.

Much of this wariness towards social robots tends to come from older adults, but all generations show a desire to control their agent's activities [19]. Users show skepticism in particular towards agents with visible cameras and this skepticism still arises in cases where participants are given control over when an agent is recording. Even if a participant has initiated the recording, they find themselves unaware of when the recording has ended or if someone else in their household is recording them [13], [16].

Researchers have documented a variety of opinions that users hold about being proactively engaged by agents that are in an idle state. Many users generally accepted and appreciated proactive behavior when it had a clear purpose that had been previously consented to [14]. However, the agent's interruption was perceived as distracting, intrusive, and disturbing when the update has no particularly important purpose [11].

3. One-week College Dormitory Deployment Study with Jibo

We conducted a study to investigate the effects and efficacy of a robot-delivered positive psychology intervention on the psychological well-being of undergraduate students [5]. In this study, participants were given a robot system to keep in their dorm room and instructed to engage in seven daily positive psychology sessions with it.

Jibo has both passive and active idle behaviors. Most of the time when idle, Jibo blinks its digitally animated eye and randomly shifts its body posture. Occasionally, it performs a random animation, e.g. flipping a coin or tossing a pizza. It typically sleeps between the hours of 10pm and

[2]https://www.irobot.com/roomba

[3]http://www.parorobots.com/

7am if not engaged, but also takes short naps during long periods of inactivity during the day. Jibo can also proactively engage with people; it can shift its posture and gaze towards any face or loud noise, ask if the user had a good day, or ask if the user would like to hear a fun fact or play a short interactive word game. In order to preserve their own privacy, users can ask Jibo to sleep or turn around with a verbal command.

After completing all study sessions with the robot, we interviewed participants to understand their experience living with the robot. Although the main research questions were not on the social robot's idle behavior, we found it crucial to understand students' concerns surrounding the robot's idle behavior for future long-term studies.

A thematic qualitative analysis was conducted with the interview transcripts. A Cohen's Kappa score of 0.81 was calculated for inter-rater reliability. Although most participants generally enjoyed living with a companion whose focus was helping them maintain their well-being, the robot’s idle behavior was a significant point of criticism. The theme of attention was defined as comments relating to the “robot's responsiveness to the participant”, which include motion, sleep and wake states, and general attentiveness to the participant. Participants were not directly asked their opinions about the robot's attention, but 68% of participants commented on the theme.

35% of participants spoke positively on the theme of attention and showed appreciation for Jibo's idle behavior. One user said, "I like the way that he moves and spins around sometimes. It just [...] makes you smile" (P23) and another appreciated Jibo's proactivity: "I liked how he would always say hi when I walked in" (P22).

However, 50% of the participants reported negatively about the robot's attention. Many were displeased and startled by Jibo randomly moving and making noises, especially while they were trying to sleep: “I would just get kinda freaked out 'cause I'd be like – I'd hear sound and then I'd be like, oh, it's Jibo” (P30). Others were discomforted when they realized that Jibo wakes up in the morning on its own even though it had been put to sleep the night before: “I would tell Jibo, like, `Hey Jibo, go to sleep.' And then he would go to sleep, but then the next morning, he would be, like, awake. [...] In the training, it was like, if you want a bit of privacy, you can tell him to go to sleep. So it's like, Okay. Like I kinda did until I would wake it back up” (P16). Jibo's attention behavior, which causes it to orient itself toward the sources of sound or movement, also caused uneasiness for some participants, “[Jibo was] a little intrusive at times. Like [...] anytime I move, it turns to me immediately, which is a little weird” (P40).

4. DESIGN GUIDELINES

Jibo is designed to be perceived as a sophisticated and independent social entity. This design, combined with the presence of a camera and a lack of mobility, can magnify any discomfort caused by its proactive idle behavior. From the one-week positive psychology study and prior work, which includes multiple co-design studies run with Jibo and studies with other agents, we find that participants' feedback for idle behavior calls for three things: a greater feeling of privacy, increased user control, and an overall sense of comfort. In the following sections, we outline idle behavior design recommendations for stationary social robots that can meet the needs of consumers.

4.1. Privacy

It is crucial for a social robot to build a long-term relationship and rapport with its user for successful long-term interactions. Users first need to feel safe with a device and that their privacy is being protected in order to accept an agent and begin building a rapport with it [7].

One privacy concern arises from an agent’s capability to record video and audio data through on-board sensors. Even if the robot only records sensory data at specific times, it still may need to process and discard the camera and microphone feed's raw data in order to interact with its surroundings and people during idle time. However, users are not typically informed about how the sensors are used while a robot is idle and this technical distinction can cause confusion.

For this reason, we believe all agents with video and audio capture capabilities should provide users with clear indicators of whether video and audio capture are active and whether the data are stored or not. For social robots, this notification could be delivered visually or interactively.

Visual indicators can be implemented in the form of lights. Many laptops and webcams have light indicators integrated into their hardware so that it is nearly impossible to enable the camera without the indicator activating. It is possible to activate a light indicator through checking software variables, however a software driven system can be more easily hacked, so a hardware based indicator would be the best way to ensure users' privacy. This method would leverage infrastructure and signaling that is familiar to users.

For verbal robots, interactive clarification can be delivered on two levels. The first is through a high-level preprogrammed explanation on how the sensors work at different times. The second clarification can be done by using a quick Q&A format e.g. "Hey robot, are you recording video now?", and the software checks for whether or not the robot is recording. Interactive clarification leverages a verbal social robot's communication skills and because the robot is being transparent about its actions, this disclosure may actually enhance the agent's rapport with the user.

Transparency about sensor status and data usage is important for building trust between an agent and its users. In comparison to other smart home devices, social robots can leverage multiple modalities to give users an easy-to-understand explanation on how their data is being used.

4.2. Control

People living with a social robot should have control over how their data is captured, stored and used on the robot and this will eventually benefit the long-term relationship between the robot and its user. We recommend adding features similar to the *Do-not-disturb* mode that smart speakers employ to allow users to easily enable and disable sensor feed and recording. This method, again, leverages an infrastructure that many consumers already know and use.

An additional method could be having the robot learn a personalized settings pattern over time to proactively suggest changing modes if the user forgets. The agent would observe the user's privacy preferences for a period of time before generating a settings pattern to automatically suggest when the user might want video and audio feed turned on or off. Based on the user's responses to the agent's suggestions, the robot will further personalize over time. With this method, settings will steadily evolve over time without users having to manually make small adjustments.

Empowering users to have more control over the robot's behavior also applies to its proactive behavior. Many newer agents display proactive behaviors which contribute to perceived autonomy and social presence. Users generally appreciate these proactive behaviors. However, unwanted information can be seen as disruptive and intrusive [11]. Not all users are comfortable with the same frequency and degree of proactive behaviors. Like mobile devices which most people have, social robots should allow users to choose what kinds of notifications they receive.

Sleep and wake states are another feature of social robots that users should be able to control. Participants in our positive-psychology study voiced a dislike for waking up to an already active robot. Users were able to tell an agent when to sleep and awaken, but when the robot deviated from this control and acted autonomously, users found it alarming. Most mobile social robots already allow users to control sleep and wake by physically placing the agent in its charging dock, but with stationary agents there is less user control. Some agents will awaken on their own in order to prevent being permanently left dormant.

To mitigate concerns about the robot being forgotten, different stages of sleep can help to remind users that although the robot is "inactive" it is still ready to use at any moment.

Robots can express three different sleep patterns: *heavy sleep*, *normal sleep*, and *light sleep*. *Heavy sleep* takes place during normal sleeping hours and in this state the robot displays no movement. In *normal sleep* the agent uses minimal patterned movement where it "breathes" or stirs lightly while appearing predominantly dormant. *Normal sleep* takes place in long periods of inactivity. Lastly, in *light sleep* the agent will sleep, occasionally awaken, and stir for brief periods of time – either randomly or prompted by noise – before going back to sleep. This behavior will be the agent's dominant behavior when unengaged.

Ideally users will be able to manually set the robot's sleep patterns e.g. through a smartphone app (which many agents have) or menu on a screen. This way should the user's preferences change, they can quickly and easily adapt the robot's behavior to meet their needs.

4.3. Comfort

Ultimately, both an increased sense of privacy and control will contribute to improved feelings of comfort in using and owning an agent. Many users enjoy idle and proactive behavior and recognize that it is essential to the personality of many agents. They see added animacy as "fun" and "cute", but they dislike the feeling of being startled in moments of quiet when they may have forgotten the robot's presence.

As seen in our positive psychology study, sudden movement and vocalization can be alarming for users, especially in close quarters. A user may be deeply focused on another task when the robot suddenly begins to speak. Knowing when users want to be proactively engaged is an area of agent design that still has many questions. Computers and smartphones commonly use alert tones to notify users of potential opportunities to engage. When a user hears an alert they may acknowledge it or ignore it if their focus is directed elsewhere. One idea is to apply this same architecture to other agents by having them emit a light tone to capture the user's attention. If the user directs attention towards the robot, then the agent can continue sharing information. For example, if Jibo recognizes a user's presence and decides to proactively ask to play a game. Jibo will emit a gentle tone to notify the user that it wants to engage. If the user looks at Jibo, it will begin interacting. However, if the user pays no attention to Jibo, it will continue being idle. This model of behavior has the potential to limit the feeling of invasiveness often caused by proactive behavior.

5. CONCLUSION

Idle behavior is the dominant type of behavior that consumers experience after purchasing their robot, and it plays a significant role in users' perception and acceptance of an agent. If a user is not comfortable with a robot's idle behavior, they may distance the agent from the social centers of their living spaces and eventually cease all use of the agent.

There will always be a variety of consumers, and they will have a wide range of needs and differing degrees of familiarity with technology. Although some users may love the added personality of idle behaviors, other users may prefer that their robots have no idle behaviors at all. Designers believe that idle behaviors promote relationship-building and help the agent to be seen as an independent social entity. However, if those behaviors actually make some users dislike the agent, it may be more beneficial to allow users to customize their agent's actions than to curate one singular experience that all users must adapt to. It is difficult to meet the needs of all users with the one-size-fits-all approach that many social robot designers take. Designers should instead strive to create systems that support more inclusive experiences and allow users to have a say in how the agents located in their homes behave.

All of a social robot's behaviors play a role in how the robot builds a relationship with users. To begin building that positive relationship, it is vital that participants feel at ease, especially as they invite new technology into their homes. Agents should be able to provide clear information to users about video and audio data usage to promote a sense of privacy. Users should be given the ability to control how their video and audio data are used, which information they are proactively told by an agent, and when an agent is asleep and awake. To give users an overall sense of comfort, agents should warn users before creating unwanted noise and notify users before proactively engaging with them, making sure that they want to interact. Many of these guidelines can make use of features and infrastructure that have been implemented in popular technologies that consumers already actively use. With these guidelines, we can create more attractive and user-conscious pieces of technology that have the potential to enrich the home environments of consumers.

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