Social Drone Companion for the Home Environment: a User-Centric Exploration

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ABSTRACT
Recent research has focused on how to facilitate interaction between humans and robots, giving rise to the field of human robot interaction. A related research area is human-drone interaction (HDI), investigating how interaction between humans and drones can be expanded in novel and meaningful ways. In this work, we explore the use of drones as companions in a home environment. We present three consecutive studies addressing user requirements and design space of companion drones. Following a user-centered approach, the three stages include online questionnaire, design workshops, and simulated virtual reality (VR) home environment. Our results show that participants preferred the idea of a drone companion at home, particularly for tasks such as fetching items and cleaning. The participants were also positive towards a drone companion that featured anthropomorphic features.

ACM Classification Keywords
H.5.2 User Interfaces: User-centered design; Prototyping.

Author Keywords
Human-drone interaction; design; companion; social drone.

INTRODUCTION
Robotic agents have been on the rise over the last decade, entering our society in different ways and forms. Research on Human-Agent Interaction (HAI) and Human-Robot Interaction (HRI) has advanced to include several domains with a social interaction focus, such as educational agents [4], service agents [20], and personal companions [18]. This interest has been motivated by one of the early research outcomes conducted by Dautenhahn [6], where a robotic companion is defined as a form of social entity that can be personalized and adapted to the users' needs, preferences, and behavior [6]. Accordingly, HAI and HRI research have investigated a wide variety of embodiments and appearances for social robotic agents, including humanoids [9], virtual agents [14], and animal or machine-like forms [22].

Recently, drones (flying robotic agents) have been emerging as a new form that can be utilized as a social robotic agent [1, 2, 3, 5, 11, 17], thus resulting in a whole new research area on Human-Drone Interaction (HDI). The HDI investigations are mostly based on established drone platforms such as AR-Drone [12] and Phantom [21]; less work has explored users' expectations of social drones in regards to embodiment, task, and role.

Since drones are considered to be robotic agents, a drone's flight and locomotion properties act as a main influence during interactions with humans. These properties greatly affect the user's mental and physical expectations when interacting with a drone, which can be considered to be different from the expectations of ground based robots. Thus, the ability of drones to maneuver around users requires a careful investigation of user-defined design preferences and interactions.

Our study investigates social drones as companions and aims to define user expectations, preferences, and needs. We contribute to the HAI field by: (1) investigating the user requirements for the design of a drone companion in a home environment, (2) collecting user insights on the design space of drone companions via design workshops and prototypical evaluations, and (3) presenting attributes and reflections for the design of a drone companion.

RELATED WORK
Early research into robot companions was presented by Dautenhahn et. al. [7]. Their study addressed attitudes among people of having a robot as a companion in a home environment. It showed that interest into having a companion robot as an assistant or servant is relatively high compared to having it as a friend. Later, Woods et al. [23] studied how the personality of a robot can be matched with a human being by having a comparative experiment with participants where they interact with a robot which had two different behavior styles. Their study reports that personality of social robots is an important domain for designing robots. Similar personality treats were studied for companion robots supporting walking [10]

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and jogging [15]. The communication of intent in assistive drones through motion primitives was motivated by the needs presented inside a spacecraft [19]. While robot companions have been shown to be of relevance to diverse settings, here we focus on robots for domestic use.

More recently, several researchers took a user-centered approach to investigate and adapt robot interactions to human preferences. For example, Obaid et al. [16] investigated a user-defined gestural set to navigate a humanoid robot. Moreover, Lee et al. [13] chose a user-centered approach to conduct a comparative study to investigate domestic robot designs in South Korea and the United States. Their research aimed to find cultural variability in the user needs and expectations of domestic robots. The methodology was to ask participants to draw their own interpretations of what an ideal robot design in a domestic context would look like. The outcome was categorized into four different themes: look and feel, interaction mode, social features, and preferred tasks. Their results indicated that there are differences in attitudes between countries, and some factors could have an influence on design differences for each of these markets.

In the relatively new research field of HDI, similar user-centered approaches have been proposed. For example, Cauchard et al. [2] studied user preferences to the modalities they would choose to control a drone; including gestures, speech, or both. They conducted an elicitation study with 19 users and showed that gestural control is preferred when controlling a drone. They showed that "people interact with drones as with a person or a pet, using interpersonal gestures such as beckoning the drone closer". Their work was further extended by Jane et al. [8] who investigated cultural differences in interaction techniques with drones. Similarly, Obaid et. al. [17] describe an investigation to define a set of gesture controls for drones using an elicitation study. They chose a Wizard-of-Oz approach to navigate a drone while users performed navigational gestures. Overall, they analyzed 300 gestural data points from 25 participants. Their outcomes revealed a user-defined gesture set and a taxonomy on how users prefer to navigate a drone.

Kim et al. [11] on the other hand, investigated whether the concept of having drones as companions could help people to overcome some preconceived psychological resistance against them. They carried out unstructured in-depth interviews with 10 participants, in which they asked them to draw their interpretations of a drone on paper. Their results revealed that if the drones had a certain degree of autonomy and showed some emotional traits, then they would more likely to be accepted. In addition, the work revealed some task and functional preferences such as running errands, playing games, having several functions, and carrying out the role of a servant. Kim et al. [11] also conducted tests where the participants interacted with a drone using Wizard-of-Oz technique to address user experience. We build on this research to further involve users in the design process of a social drone companion by getting them to make tangible mock-ups on the top of plain drawing. We also study human-drone interaction preferences through a Virtual Reality (VR) environment that can be easily modified to apply alternative designs of the drones.

This papers builds on research into robot companions and recent HDI literature; investigating user preferences of a drone companion to be used at home. Similar to earlier studies in the HRI field, the work follows a user-centered approach to determine user preferences in three consecutive stages: (1) an online questionnaire, (2) design workshops, and (3) a user-drone interaction study in a simulated virtual reality home environment. The simulated environment offers basic drone flight properties. Figure 1 illustrates our process.

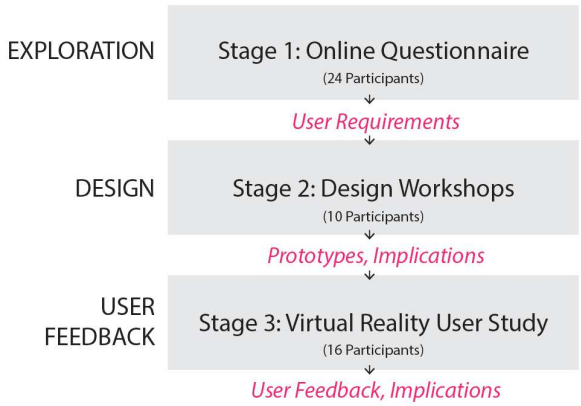


Figure 1. User-centered design process followed in this paper.

STAGE 1: ONLINE QUESTIONNAIRE

The aim of the online questionnaire was to investigate the user requirements that would lead us to defining a prototypical platform for a design space to be used in the workshop stage. It also helped us question the requirements of what people expected from HDI within the home context.

Procedure

A requirement elicitation questionnaire was sent out to people with various educational backgrounds and occupations. The questionnaire covered, besides demographics, the following questions in relation to drone companions; (1) What role might the drone have?; (2) What kind of tasks would you like a robot companion to have?; (3) What size should the drone companion be?; (4) Should the drone companion follow you around?; (5) How would you like to interact with it?; and (6) Would you like the drone companion to display emotions or not? All questions had several options to choose from, and/or an open ended free text field. The online questionnaire did not show the participants any picture of a drone or refer to a certain kind of drone. The information given was that a drone is a flying robot which usually consists of four propellers and can either be controlled by a user or be autonomous.

Participants

A total of 24 participants (12 male, 12 female) answered a multiple choice questionnaire that was distributed via personal social media networks. Participants had a mean age of 27 years (SD=3.5). To avoid any cultural impact on the results, all participants recruited came from Sweden. The participants'

occupations were diverse, such as unemployed, engineers, and university IT and Interaction Design students. Finally, 40% of the participants had some experience with a drone; either using or seeing one used before.

Questionnaire Results

We classified the results from the questionnaires in subcategories based on the prominent answers collected. Next, we share the results of some important categories.

Social role in the drone companion

As presented in Fig.2, we found that twenty-one of the participants (87.5%) saw a drone companion as an assistant and nineteen (79.2%) saw it as a toy. Those who did not see the drone companion as an assistant saw it as a tool that either delivers things or guards the home. Twelve of the participants (50%) that saw the drone as a toy did not mention any playful traits that could indicate it as a toy, but more as a helper that does different tasks.

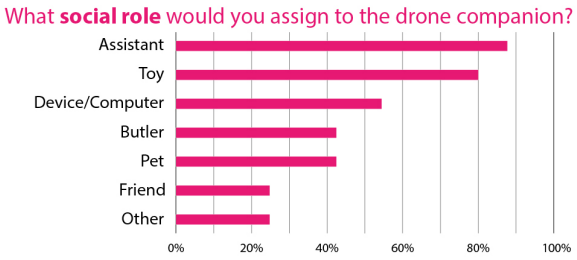


Figure 2. Social role users assigned to the drone companion.

A total of six participants (25%) saw the drone as a friend. Four of them did not want the drone companion to show emotions, four of them wanted it to follow them around, and five of them wanted to have the drone as company. Of the participants that did not want to have the drone companion as a friend or a pet, some still wanted to have conversations and play with the drone. Also, there were some who would like to have daily updates from the drone about things such as reminders, weather conditions, and other daily updates.

Why or why not have a drone companion at home

A couple of comments indicated that with the current technology it is not realistic to have drones as companion. However many commented positively on the idea of having a drone as companion and would like to have one that helps with household tasks. Many also mentioned that they would think it a fun and a cool idea to have a drone companion.

Seven out of ten participants that were negative towards a drone companion indicated in short answers without much elaboration, but those who did were concerned about the fact that the drone might frustrate the user, or it might just become a gimmick and cause discomfort having a drone nearby. One person thought that the drone would best work for people with disabilities as a means of help while another was concerned about the propellers which may hurt the user.

In term of having a drone as a companion at home, presented in Fig. 3, we found that fourteen (58.3%) of all participants answered yes for having a drone as a companion. Half of these commented initially that they wanted the drone to help them with everyday tasks, four participants preferred the drone to get items for them, and one person preferred the drone to act as a butler. Furthermore one person would like a drone to help him/her with experiments. Of these fourteen participants, only three wanted the drone to be very human-like or somewhat human-like.

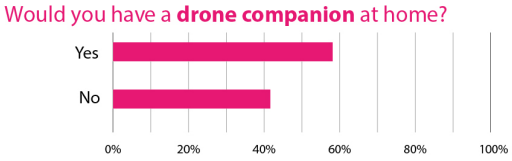


Figure 3. The percentage of users preferring to have a drone companion at home.

Task of the drone companion

While there was a variety of tasks participants preferred to assign to the drone companion, one task was ranked particularly high: “Bring things to you”. “Clean after you” and “Help with daily life” were also frequent answers. Fig. 4 shows the distribution of the participants’ preferences.

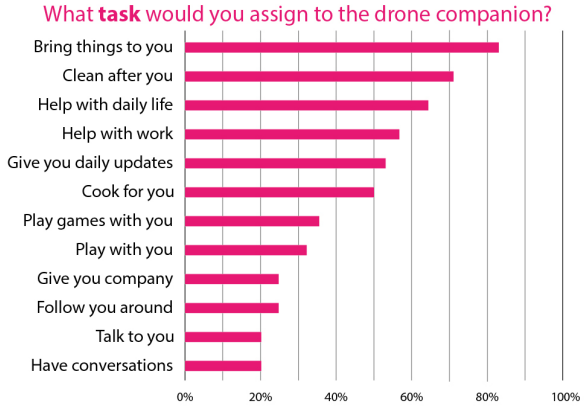


Figure 4. Home tasks assigned to the drone companion.

In addition to these tasks, participants were able to add other tasks that they would like the drone companion to do. One of these was to do simple tasks at home, such as turning on/off lights, opening doors, and turning on/off music. Two more would like the drone companion to do everyday tasks such as making calls, answering when telemarketers call, and informing the user in situations like someone knocking on the door. One participant stated that he/she would like to have general reminders while another would like it to guard the house. Furthermore, one participant indicated that they would like the drone companion to help with directions, and another would like it to teach things.

Size of the drone companion

Fourteen (58.3%) of the participants would like the drone to be “medium” in size. Both of the other alternatives, “small” and “large” had 5 participants each as their preferred size. Two participants who wanted the drone to be large in size indicated

that the use of drones would be more of a tool instead of a companion. Their answers pointed towards practical usage such as home security or delivery services, which may both imply a larger size.

Drone companion should follow one around or not

Seven (29.2%) of the participants did not want the drone to follow around; they thought it could be annoying and intrusive, and they would feel surveilled. However many of those who said they did not want it to follow around still wanted the drone to come if commanded. Of those that wanted the drone to follow around, some liked the idea to have the drone close at hand, while others wanted it to be optional.

How to interact with the drone companion

Twenty of the participants wanted to interact with the drone via speech (83.3%), while thirteen (54.5%) also wanted the drone to be able to recognize non-verbal communication through gestures. There were also eleven (45.5%) participants that would like to use some extra devices (such as smart-phones) to communicate with the drone companion.

Emotions of a drone companion

Twelve (50%) of the participants would like to have emotions in a drone companion, but some of these also did not want the drone to have too many emotions. The twelve (50%) that liked the idea of drone companions with emotions thought that it was a fun/nice idea and could be helpful e.g. showing low battery (Fig. 5).

Some of those who did not want the drone to express emotions did not like the idea of machines/dead objects with emotions. One person also thought it was not necessary, but would not mind if it possessed emotions. Eight (66.7%) of these were those who actually did not want to have a drone companion in the first place. The four participants (33.3%) who liked the idea of having a drone companion without emotions answered that it would be scary, unnecessary, or did not specify why.

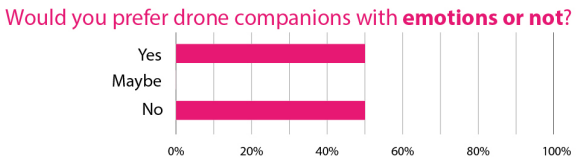


Figure 5. Participants' preference of a drone companion with emotions.

The results and analysis of the questionnaire provided functions and other properties connected to a drone companion, which then gave some input to the introduction presented in the follow up workshops (Stage 2).

STAGE 2: DESIGN WORKSHOP

Based on the insights collected from Stage 1, we defined a workshop brief. The aim of the workshop was to understand and elicit appearance requirements of a drone companion. From the workshops several design concepts and appearances were extracted and modelled as a foundation to the prototype.

Procedure

Two workshops were conducted in a conference room at a science center with different participants each time. The participants had access to paper, cardboard, chicken wire, color pens, and metallic wire. With scissors, cutter, glue, and tape the participants could build their mock-ups around a drone skeleton that had been provided. The skeleton was made of foam, sticks, and paper so all participants would have a starting point to build on. The workshops started by introducing a short story about drones as companions, followed by the explanation of what a companion is, and in which environment the drone would be used in this context. Then the participants had 50 minutes to sketch and build their prototypes. After the sessions, the four themes (look and feel, social role, desired task, and interaction mode) described by Lee et. al. [13] were discussed with the participants to elaborate on their drone designs.

Participants

There were ten participants (P1-P10) in the two workshops (3 female and 7 male) with a mean age of 27.4 years (SD=2.8). Six of the participants were students (60%), while the others were a car painter, a product manager, a developer/designer and a postman. Seven participants (70%) had no past experience with drones. All participants came from Sweden, and the workshop was conducted in Swedish.

Workshop Results

We conducted these workshops to collect preliminary user insights on the concept of having a drone companion. Fig. 6 shows the prototype drones designed by participants. Below we share some critical insights from the study.

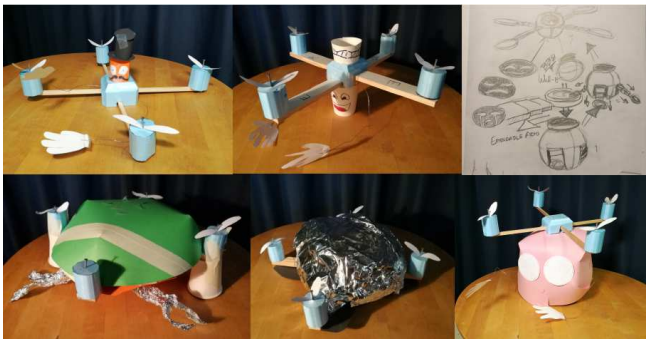


Figure 6. Drone companions designed during the workshops.

Look and Feel

Six (60%) of participants mentioned or designed drones with round-shapes or round-shaped features. Four (40%) of the participants did not want a face on their drone companions, however four (40%) would like to have some kind of face to show emotions, while two (20%) thought that the appearance did not matter. Only two (20%) of the participants mentioned that the drone should be quiet.

Participants highlighted several specific features and attributes for their companion drone designs. For example, P1, P2, P6 all mentioned points regarding the appearance of their design, for example, P2 highlighted that aesthetics do not matter in

a drone, while P6 and P1 expressed that it should not be with realistic looking features. On the other hand P6 and P7 said that the appearance of the drone should be round. P7 added that the drone should be caring, have a star shaped underside, and a white color. Moreover, P3 and P8 expressed that the drone design was inspired from Sci-Fi movies, such as BB8 (Star wars), Wall-E (Disney), and a Swedish summer TV-program.

Several participants mentioned what tasks they would like their drone to be able to do, including P7 demonstrating that the drone should be able to check on animals, children, and the elderly. In addition, P7 stated that the drone should have arms to carry large and small items. P7 and P8 wanted the drone to have neither a face nor show emotions, while both P1 and P9 wanted the drone to show and have emotions. In particular P9 said that the drone should have some anthropomorphic features such as a face.

Social Roles

Six (60%) of the participants would like the drone to be an assistant, while three (30%) also saw it as a helper at home and two (20%) as some sort of butler. A drone as a pet was one suggestion, another thought the drone could be a companion and a friend, and one could see the drone as a caretaker. Generally, participants wanted the drone to do service roles for them, such as P6 and P7 stating that it could care for their animals; P8 suggesting having the drone as a safeguard or protector, and P8, P10, and P6 illustrating the need for a robot as a helper.

Preferred Tasks

Five (50%) of the participants in the workshops mentioned that the drone should help out with tasks around the house while four (40%) wanted help especially with pets. Five (50%) wanted the drone to bring them items and one would like the drone to follow the user around. These results are in line with the online questionnaire results where we managed to elaborate more on the answers. Similar to the social roles, most of the preferred tasks were focused on service related tasks such as the ability to bring items (P1, P7, P8, P9), follow service commands (P3, P6, P8), and clean up (P3, P9). P1 and P6, however, wanted to have a drone with a conversational task where they could intelligently discuss topics of interest. Entertainment was another task that some participants wanted; for example, P6 and P8 expressed that playing games would be a task that the drone should do.

Interaction Mode

In both of the workshops the interaction mode was described in four categories; voice controlled, smart-phone controlled, autonomous, and gesture controlled. Six (60%) wanted the drone to be voice controlled, three (30%) wanted it to be controlled with a smart-phone, two (20%) wanted it to be autonomous and two (20%) also wanted the drone to be able to respond to gestures. Participants P1 and P4 indicated that gestures would be a suitable way to control a companion drone. P7, on the other hand, wanted to control the drone with a remote control device, while P9, P8, P6, P3, and also P1 wanted to have the drone with speech abilities. Two of the participants, P1 and P9, wanted the drone to express facial expressions as a form of face-to-face interaction.

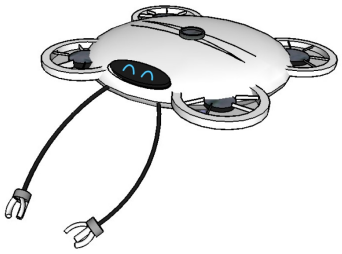


Figure 7. Drone A: Drone with anthropomorphic features.

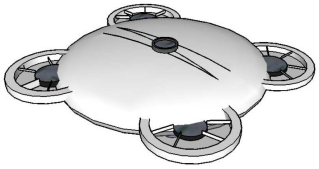


Figure 8. Drone B: Drone without anthropomorphic features.

Virtual Prototype

Based on the results from the questionnaire and workshops two drone designs were envisioned as shown in Fig. 7 and Fig. 8 respectively. The design of the covered propellers of the drone (Fig. 8) was partly envisioned from the results of the questionnaires where participants wanted the drone to be safe, and partly it was support from some of the workshop designs. Moreover, the eyes represented on the drone (Fig. 7) were to convey to the user that it has anthropomorphic features, where 50% of the workshop participants wanted explicitly facial features on a drone.

As shown in Fig. 7, the drone has hands, which is a feature revealed in the questionnaire results reporting that twenty (83.3%) of the participants wanted the drone to be able to bring items to users, and workshop results showing that five (50%) of the participants wanted the drone to have arms, with three (30%) explicitly specifying hands.

The core body part of the drone (Fig. 8) is round and has a machine-like look, as six (60%) of the workshop participants wanted it to be round, and six (60%) wanted a machine-like look. Finally, the arms illustrated in (Fig. 7) are featured since five (50%) of the workshop participants explicitly wanted the drone to have arms. There are also some features on the drone not shown above, such as that the drone is voice controlled, which twenty (83.3%) of the questionnaire participants and five (50%) of the workshop participants wanted.

STAGE 3: VIRTUAL REALITY USER STUDY

To investigate users' perception and attitudes towards the envisioned drone prototypes in a simulated home environment, we designed and conducted a user-study in a VR environment. The setup consisted of an HTC Vive VR headset and two

motion-tracked handheld controllers; the study was conducted in a room adapted for VR. The controllers represented an object for the drone to pick up and the drone itself. The study was conducted using a Wizard-of-Oz approach where the conductor moved the drone in a preset pattern during the simulation. While we acknowledge the importance of a drone's flight and locomotion properties, our simulation offered basic items only. The aim of the study was to give more insights into the perception of the prototype and its anthropomorphic features, thus allowing us to gain further understanding on the idea of having a drone companion at home. We chose both the face (eyes) and the arms of the drone as the two main anthropomorphic features to manipulate for two versions of the drone: a drone companion (A) with anthropomorphic features (Fig. 7) and (B) with no anthropomorphic features (Fig. 8). The idea of having these two versions of prototypes was to see user reflections on both options rather than comparing them. The two conditions were counterbalanced during the VR study.

Procedure

The participants were first introduced to the VR-environment where they could interact with a drone. They were then asked to: (1) call the drone, (2) ask the drone to bring a coffee mug, and (3) tell the drone to give a status from social media. The same procedure was followed for both condition (A and B) and the participants answered questionnaires which collected their opinions about the drones' appearance, features, and behavioral characteristics.

Participants

Sixteen people participated (V1-V16) in the user study: Seven were female and nine were male with a mean age of 25 years (SD=2.6). Ten were students and the other six had a wide of variety of occupations. Eight of the participants had no experience with drones before.

From the demographic questionnaires, seven participants reported that they strongly liked the idea of having computer technology at home, seven rather liked the idea, and two were moderately interested in having computer technology in the home. The idea of having a drone companion at home was less popular than having computer technology at home, but was still quite popular, ten participants said that they rather liked the idea of having a drone companion at home, five were moderately interested, and one liked the idea a little.

User Reflections Results

Participants' impression of the drone in both sessions (with and without the anthropomorphic features) was positive; where several indicated attributes such as cute (V9, V14, V15, V16), good looking (V8), looks cool (V4), friendly (V3, V14), futuristic (V6), and gives a happy feeling (V3). In addition, several participants expressed that the drone looked as they expected a drone at home to look like. On the other hand, some of the participants had some doubts about the drone's appearance, when looking at both versions of the drone. For example, V15 expressed that drone A was like an insect with arms and that is always happy, which is not what he/she expected.

Nine participants of sixteen (56.3%) favored the drone with anthropomorphistic features, and this was largely due to the inclusion of the facial features and the happy emotion expressed on it. Although the remaining seven participants (43.7%) said the drone without any anthropomorphistic features was the better drone, some still said they wanted anthropomorphistic features to be added to it such a face. One participant (V15) indicated that he/she liked the drone without anthropomorphistic features because of its compact design.

Six of the participants reported that the drone with anthropomorphic features gave them the impression that it was a companion, while the others thought it was more like a tool. The participants who saw it as a companion indicated that having a face and voice on a drone gave them the impression that it had human-like features; in addition participant V4 thought it was a companion because it had emotions. The ten participants that saw it as a tool attributed this to its assisting features and lack of expressed emotions. Other participants (V5, V12, V14) thought that the drone lacked emotions and human like features, which rendered it just as a tool. There was also a comment that it looked too much like a machine (V10).

Overall VR Study Results

After interacting with the two drones, participants reported seeing the drone companion as an assistant, a device, or a toy. The most prominent tasks that the participants would like the drone companion to do were to bring things (14 participants), clean (13 participants), help in the daily life (13 participants), and give daily updates (10 participants).

When asked on a 5 point Likert scale about how animal-like the drone should look, participants were slightly neutral about the animal like appearance, with an average of 2.5 (SD=1.36). On the other hand, when asked how machine-like the drone should be, participants were slightly leaning towards a machine-like appearance, with an average of 3.3 (SD=1.35). Even though participants indicated that a human-like look is not an option, they still seemed to want some human-like behavior (scoring an average of 3.25 (SD=1.1)) in their drone when asked on a 5 point Likert scale.

CONCLUSION AND FUTURE DIRECTIONS

The purpose of this paper was to investigate the design aspects of a drone companion in a home environment. We report on a three-stage investigation collecting requirements (online survey), prototyping drones (design workshop), and evaluating alternative drone designs (VR user study). Results reported indicate that participants preferred a drone companion in a home environment and that the preferred social role was as an assistant. The most preferred tasks that the drone companion would perform were to bring items to the user and clean for the user. The participants also favored the idea of a drone companion with emotional characteristics. The preferred drone appearance was a round shape and with a face. Overall, reported results indicate that participants viewed a drone companion as a tool with social and task-oriented attributes. In conclusion, Fig. 9 summarizes design implications considered as important drone attributes.

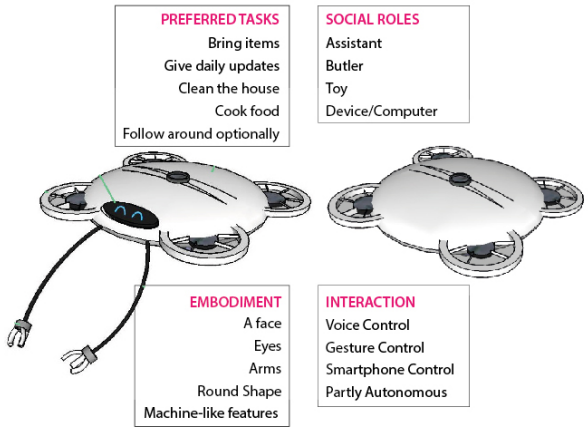


Figure 9. Summary of all design implications collected.

The presented work yields several future items for the design of drone companions. First, a larger survey would help towards deeper understanding of user preferences. Second, the layout of the studies was oriented around a home environment; one could instead explore further options in outdoor settings. Third, in order to make an even more realistic simulation in VR environments, the drone's flight and locomotion properties could be developed, as well as audio added. Finally, while our studies included Swedish participants only, future studies could investigate cross-cultural ramifications for drone design.

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