Exploring Proxemics for Human-Drone Interaction

Alexander Yeh[1], **Photchara Ratsamee**[2], **Kiyoshi Kiyokawa**[3], **Yuki Uranishi**[2],
Tomohiro Mashita[2], **Haruo Takemura**[2], **Morten Fjeld**[1], **Mohammad Obaid**[4]
[1]Department of CSE, Chalmers University of Technology, Gothenburg, Sweden
[2]Cybermedia Center, Osaka University, Osaka, Japan
[3]Nara Institute of Science and Technology, Nara, Japan
[4]Department of Information Technology, Uppsala University, Uppsala, Sweden
alex@yeh.nu

ABSTRACT

We present a human-centered designed social drone aiming to be used in a human crowd environment. Based on design studies and focus groups, we created a prototype of a social drone with a social shape, face and voice for human interaction. We used the prototype for a proxemic study, comparing the required distance from the drone humans could comfortably accept compared with what they would require for a nonsocial drone. The social shaped design with greeting voice added decreased the acceptable distance markedly, as did present or previous pet ownership, and maleness. We also explored the proximity sphere around humans with a social shaped drone based on a validation study with variation of lateral distance and heights. Both lateral distance and the higher height of 1.8 m compared to the lower height of 1.2 m decreased the required comfortable distance as it approached.

ACM Classification Keywords

H.5.2. User Interfaces: User-centered design.

Author Keywords

Human-Drone Interaction; Social Drone; Proxemics.

INTRODUCTION

In the near future, robots of different types are expected to populate urban environments with the purpose of supporting human activity. While there is ongoing research addressing social ground robots [10, 12, 23, 25], such robots are still limited when it comes to perceiving, understanding, and interacting in a crowded environment [23], [27] (pages 335-356). Today drones are widely used for aerial video recording, first-person view racing, or military surveillance, but are not yet considered as something humans would socially interact with, but rather control. In order for drones to approach humans, the latter's acceptance of the former needs to be better understood.

Figure 1. Humans and a social drone.

As shown in Fig. 1, we assume three advantages drones could have over social ground robots:

- A drone can maneuver unobtrusively above the ground towards a target user without disturbing human movement in busy and densely crowded areas.
- From a drone's-eye view, it has a better capacity to recognize humans who need help. The drone's perception also benefits crowd tracking and robot path planning. Social ground robots suffer from occlusion.
- Humans can easily recognize a drone and interact with it from a far distance.

Based on these assumptions, we introduce a concept of social drone which we propose as a suitable solution to the question of what type of robot is best fit for a crowded human environment. We explore the possibility of using a drone as an agent in human crowd environments by pioneering fundamental components such as social drone design, human acceptability and proximity between drones and humans. Our intention is to decrease the acceptable distance between a social drone and humans by conducting proxemic studies. This paper offers a design study section, followed by a focus group section, a prototyping section, and a two-part proxemic study section (Fig. 2).

RELATED WORKS

Human-Drone Interaction (HDI) is an emerging research area within the robotics community. For example, Obaid et al. [20]

HAI '17, October 17–20, 2017, Bielefeld, Germany

DOI: https://doi.org/10.1145/3125739.3125773

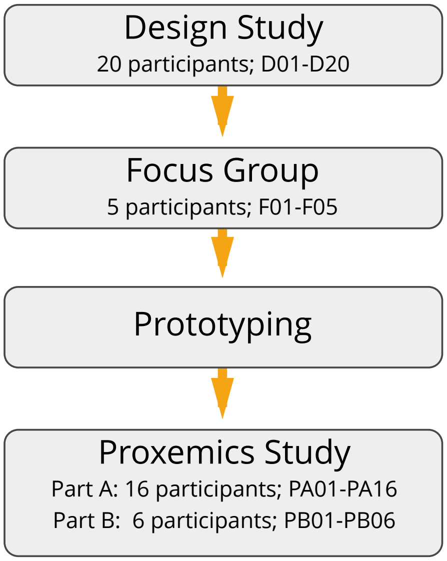


Figure 2. Human-centred design process.

proposed a drone agent to help humans keep the environment clean, by persuading a user to pick up trash, leading him/her to the nearest trash bin and then communicating with him/her when the job is done. Cauchard et al. [4] proposed an elicitation study on how to naturally interact with drones. Similarly, Obaid et al. [19] investigated user-defined gestural interactions to control a drone. Emotional states to drones have also been studied. Cauchard et al. [5] report that several of their participants compared the drone to a pet, which entitles it to anthropomorphic status in that situation.

Most off-the-shelf drones do not promote close interaction due to fast rotating propellers being an immediate danger to humans. Some researchers have addressed the safety aspects of interacting with a drone, such as the picocopter [24] and the collisions-resilient flying robot [2], where light drones with cages are made safe to coexist with humans. A small quadcopter [17] to be used in a ball to manipulate speed and behavior for new sports interaction has also been proposed as a safe way for humans to interact with it. Bitdrone [7] is a drone that allows for many types of physical interaction between the user and the drone.

The features of the drone make them a suitable subject to investigate as a social entity, although there is very little research on identifying the social properties of a social drone. However, the Human-Robot Interaction (HRI) field has explored social robots to a large extent in the past decade; one of the main topics being the impact of social proxemics (inter-personal distances) between robots and humans. Takayama et al. [26] conducted research on a robot approaching humans, and humans approaching the robot. Kamide et al. [9] presented not only proxemic research in the HRI field but also comparing proxemic results using virtual reality (VR) of a robot. Obaid et al. [21] looked at the influence of posture on the human-robot proximity, while Mutlu et al. [16] investigated the influence of eye-gaze and likeability aspects on human-robot proximity. Moreover, other researchers have taken a user-centered approach to identify robotic features or attributes such as the work presented by Lee et al. [11], who compared cultural differences in designs of future domestic robots created by participants from Korea and United States. Woods [28] examined children's perspectives, feelings and attitudes towards robots concluding with a discussion about design implications for robots, and their use in the educational context. Obaid et al. [18] presented a summary of robotic attributes extracted from a study where interaction designers, children with robotic knowledge, and children without robotic knowledge drew pictures of robots.

In this paper, we follow the trend from previous HRI research to investigate the impact a social drone would have on human-drone proxemics. We first explored the social drone attribute, then conducted two human-drone user-studies.

DESIGN STUDY

In order to achieve a socially acceptable drone, we needed to identify the social requirements from its users. Thus, we conducted a survey to gather information from participants on what a social and friendly drone would look like. This was then presented in a survey of different key attributes in a graph.

Requirement Analysis

With a human-centered design [6] approach in mind, we wanted to understand what kind of shape and design of a social drone would make humans more comfortable with interacting with a drone. We discovered early that a drone itself was hard to approach due to the danger of the propellers and the loud noise. Woods [28] presented several categories and attributes such as body shape, looks and likes, and facial features. Obaid et al. [18] added more attributes (interaction, size and characteristics). However, both of these works concerned ground robots not drones. In order to design our study and identify specific attributes for a social drone, we used the methods from Obaid et. al and Woods to conduct our own design study.

Drawing Session

To gain an understanding of how users envision a social drone, and to allow them to elaborate on their preferred features, we conducted drawing sessions. The session started by handing out an A4 sheet of paper that had a silhouette illustration of the DJI Phantom 3 Drone [13]. In addition, we showed on the original drone where they could interact with it and gave some basic instructions on how it operates. This was followed with a brief explanation of the context of the task and the participants were asked to their vision of a social drone hovering in a human crowded environment. At the end, the participants were asked the drone size they preferred from smaller, original size, or bigger than the original.

In total, we had 20 participants (13 Female, 7 Male), where the majority (14) were Japanese, with age range between 18 to 31 years (M = 22.2, SD = 4.05). Most were students of Osaka University, and most were not working within the technological field (19 non-technical, 1 technical). Only one participant had any prior experience with drones.

To categorize the outcome of the drawing session, we used some of Woods' categories such as body shape and facial features [28]. Obaid et al. proposed some further categories and sub-categories such as interaction, size, and characteristics [18]. Following the design study, safety and extensions were added (Fig. 3). For each attribute and sub-attribute, a counter was incremented when it was observed in a drawing.

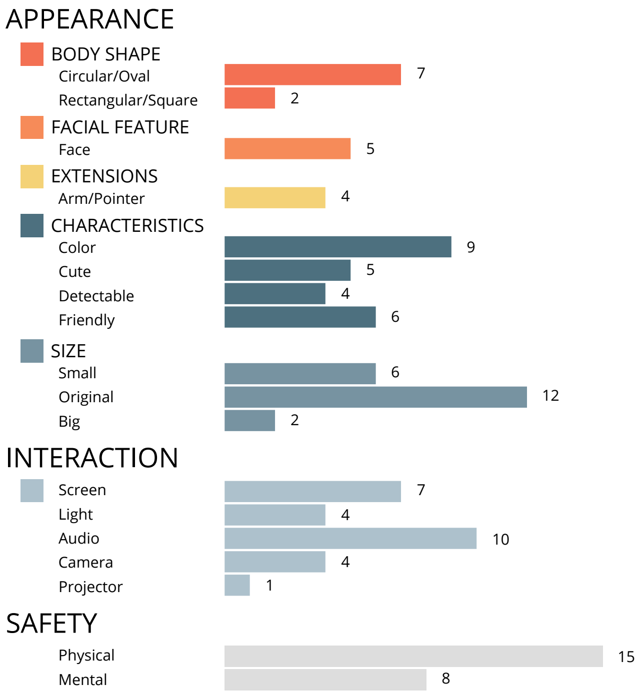


Figure 3. Drone attributes were categorized into appearance, interaction, and safety. Appearance has five sub-attributes.

Appearance

We identified that most of our participants (45%) suggested some sort of a shape around the drone. They favored a circular/oval drone over a rectangular/square drone, which is similar to ohkura et al. [22] whose study showed that rounded objects and blue color rated highly for cuteness. In terms of facial feature, a number of participants (25%) drew pictures of the drone with a face, and in some cases in combination with a screen. An unexpected observation was that a few participants (20%) wanted some sort of extension of the drone, like an arm, in order for it to help them with various tasks. Many of the participants mentioned that they would have wanted the drone to carry their bag. "I would like it to carry my bag" and "It would be nice if it could carry my shopping bag" representative of the comments.

The characteristics of the drone are closely related to many of the other attributes listed in the graph. However, we defined them differently as a more "look and feel" of the overall drone. For instance, colorful (45%) and cute were often mentioned in the survey. Some participants reported that they thought the drone should have some anthropomorphic attributes. Many of these fell into the category of friendliness (30%) or cute (25%), some were drawn and some were mentioned in the survey.

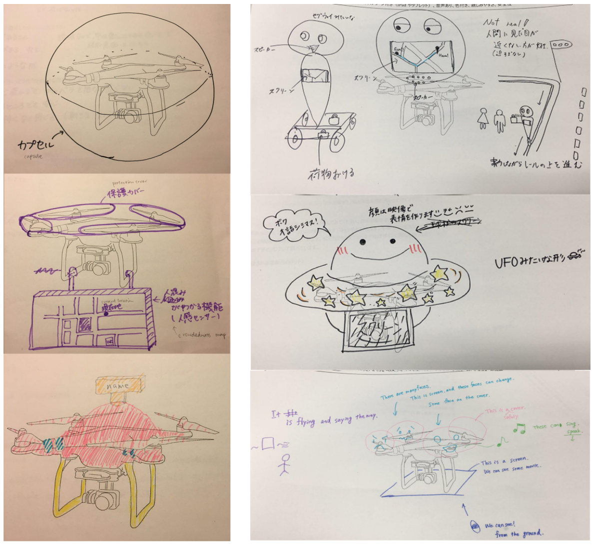
The survey results show that the original size (60%) of the drone selection was preferred over the smaller size (30%) and the bigger size (10%). Some participants mentioned that it might be dangerous if the drone did not make any sound or was undetectable at a first glance as it might startle people.

Interaction

A number of screens (35%) were drawn for navigation and in combination of using it as a face, but one of the more important aspects of interaction was to be able to speak to it or get information via audio. Some participants either drew maps inside the screen or explained that they would like to have a map as well for the social drone to guide them around in the vicinity.

Safety

One of the concerns was related to safety issues when using drones. In this work, we identified mentions and drawings on noise and unexpected movement of drones as an attribute of environmental safety (40%). Direct observation as propellers could be dangerous or cause accidents were categorized in physical safety (75%). Safety issues mentioned were the noise of the drone or the way it looked, and how dangerous the propellers appeared to be. However, most participants did not mention the propellers or the noise it would generate at all, which could perhaps be attributed to most of our participants having little experience with drones and not knowing how it would sound during flight. Some participants also raised their concerns in the survey about cameras and surveillance, as they did not want to be monitored.



(a) (b)

Figure 4. Drawings from design study where participants were not given attributes (a). Drawings from focus group where participants were given attributes and sub-attributes (b).

FOCUS GROUP

Using the results from the drawing session, we held a small focus group in two different occasions to find out what some of the most popular attributes would benefit a social drone design. Our participants were given approximately 20 minutes with some of the attributes to design a social drone. The two focus groups had 5 participants in total (non-technical); all students at Osaka University (3 Male; 2 Female), all Japanese, and aged between 21 to 32 years (M = 23.6 SD = 4.78). On a scale from 1 to 5 in drone experience only one participants answered 3; the rest of them had no drone experience.

The results from this phase were mainly used as an inspirational phase where we tried our best to design a social drone. From Fig. 4 we can see that the focus group's drawings were much more anthropomorphic than those from the first study. Safety was also taken into consideration as most of the drawings had something to either cover the propellers or make them non visible.

PROTOTYPING

Combining both the attributes chart from the survey and the results from the focus group, we tried to develop a design that would be social and accepted by humans.

Social Shape

From the results presented in the previous sections we tried to design a shape around our drone that would give it a more social and friendly feeling. Following our results presented in Fig. 3, inspiration from focus groups Fig. 4 and Ohkura et al. [22] study, we designed a blue oval-shaped drone as shown in Fig. 5(b). The social shape was to function as a safety guard as well.

Face

Following Mori's [15] hypothesis, the uncanny valley, and the previous studies, we wanted to develop the face so that the social drone would have an anthropomorphic character of a cartoon. Using an android tablet we could display a friendly face with similar color to the social shape. The blue color of the face was also chosen as the social shape to keep the color consistent throughout the study, which also corresponds to the Ohkura et al. [22] study.

Voice

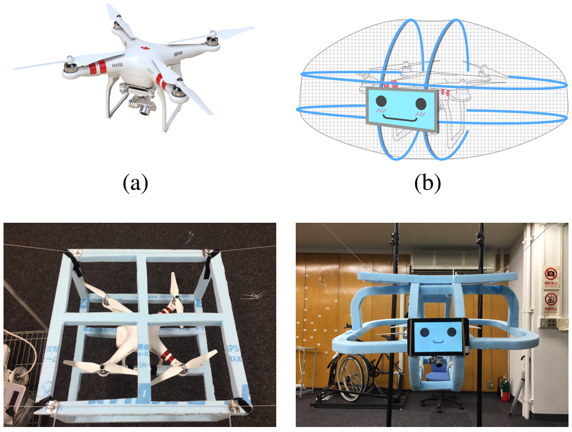
As several participants mentioned audio or voice as an important interaction channel to feel the presence of the drone, we added a greeting voice by using a text to speech application. Breazeal [1] proposed several synthesized speeches for an anthropomorphic robot, where a relatively fast, high mean pitch and wide pitch range was analyzed and categorized as a "happy" voice.

Nonsocial Shape

We also tried to design a drone that would be safe for the future participants to not get hurt on. This was made to be just an rectangle box, see Fig. 5(c).

PROXEMICS STUDY

Apart from appearance design, the range of interaction between the social drone and human have to be considered for smooth social interaction. Hall [8] proposed a model that states that the public space between two human beings starts at 7.6 meters; within 3.6 meters is the social space; within 1.2 meters is the personal space; and the intimate space is at 0.45 meters.


(a) (b)

(c) (d)

Figure 5. Prototyping departed from an off-the-shelf drone (a) combined with the outcome of the design study and focus group (b). A nonsocial safety guard (c) and a social safety guard (d) were prototyped for the off-the-shelf drone.

To our knowledge, there have not been any proxemics-based studies on drones. Proxemic studies in the HRI field have previously been conducted with ground based robots [9, 26]. Compared to other proximity based papers in HRI, which uses unmanned ground vehicles [9], distance between humans and robots can vary depending on the robot's purpose and what kind of interaction is required. In this section we will describe our proxemic studies, setup, participants, and the results.

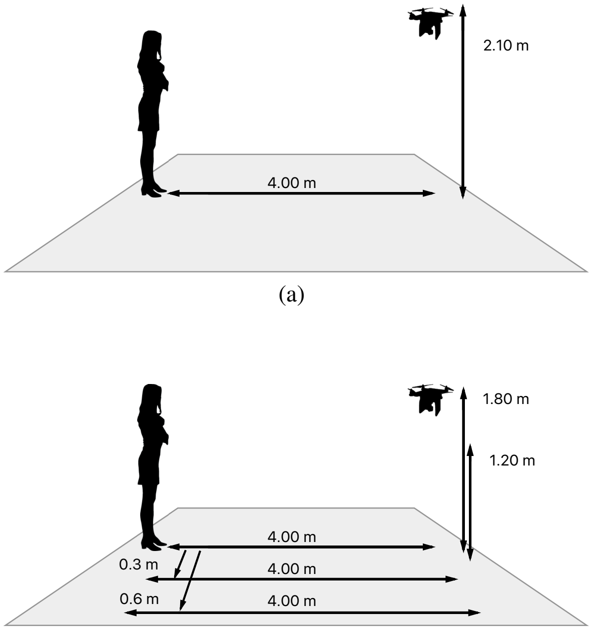
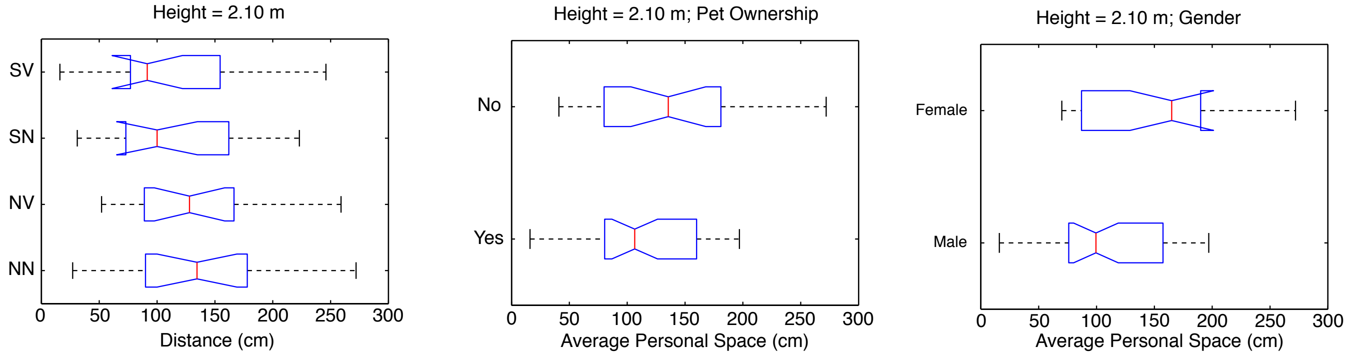


Figure 6. Setup of proxemic study, part A, where participants stood 4.00 m away from the drone that approached slowly at the height of 2.10 m (a). In part b, participants stood 4.00 m away from the drone that approached slowly at the height of 1.20 m or 1.80 m with different lateral distance of 0.3 m or 0.6 m (b).



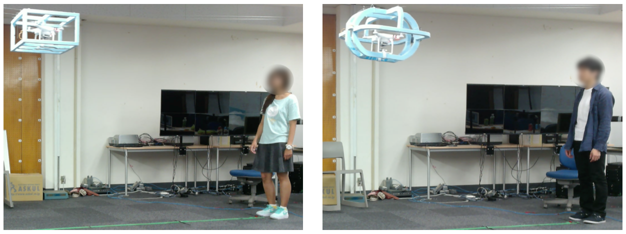
(a) (b) (c)

Figure 7. (a) An average distance where the participants wanted the drone to stop. SV: Social shaped drone approaching with greeting voice; SN: Social shaped drone approaching with no voice; NV: Nonsocial drone approaching with greeting voice; NN: Nonsocial drone approaching with no voice; (b) Average personal space with pet ownership. (c) Average personal space depending on gender.

Setup

As presented in Fig. 6(a) and Fig. 6(b), we setup a face to face confrontation between participant and robot along a single dimension. The drone used did not have Vision Positioning System (VPS), and therefore would slightly drift off and in some occasions move unpredictably. By adding zip-lines to the drone, we could have it fully controllable and greatly minimize the risk of collision with either its environment or the participant. Kamide et al.'s [9] extensive proxemic study was used as an inspiration while designing our own. Previous study has shown that people felt uncomfortable with a speed of 1 m/s [3], but instead were comfortable with all kind of speeds that was slower than a normal paced human walking. Mean velocity was 0.30 m/s.

For the social drone to approach and interact with humans, we decided to place the drone at the height of 2.1 m for the first experiment. In the second experiment we set two heights; 1.8 m and 1.2 m respectively. We were interested to find the difference between the different heights with a drone at almost same eye-height level with the participant.



(a) (b)

Figure 8. (a) The participant is approached by a drone with nonsocial safety guard. (b) The participant is approached by a drone with a social safety guard.

Part A: Social Shape and Greeting Voice

Our aim was to find out if our social drone could decrease the distance from humans, compared to a nonsocial drone. In our first experiment we had a total of 16 participants. There were 14 with technical and 2 with non-technical background. Participants' mean height was 1.69 m (SD = 9.72). On a scale 1 to 5 the participants stated their drone experience on an average of 1.625 (SD = 0.885). Ten of the participants were or had been pet-owners, while the other six had never had a pet. This part examined four alternative drone states (Table 1). The setup is presented in Fig. 6(a) where participants stood at 4.00 meters away from the drone. The drone approached them at a low velocity. We asked the participant to raise their hand and say stop when they no longer felt comfortable with the drone coming closer. The Balanced Latin Square method [14] (pages 177-180) was used, as some participants might get used to the drone by the end of the experiment.

Table 1. Drone states.

state	shape	audio
SV	social drone	greeting voice
SN	social drone	no voice
NV	nonsocial drone	greeting voice
NN	nonsocial drone	no voice

Part B: Height and Lateral Distance

The aim of this part of the experiment was to explore the proxemic sphere around a human when a drone passes by. The drone had 6 initial positions and only the social shaped drone was used without a greeting voice. The setup is presented in Fig. 6(b) and Table 2 respectively. This part comprised six participants; all of them students with a technical background. Participant mean height was 1.70 m (SD = 5.27). On a scale 1 to 5 the participants stated their drone experience on an average of 1.833 (SD = 1.169). Two participants had current or past experience with pet ownership.

Results

Results from the proxemics studies part A and B will be presented in this section. Note that *M* represents mean and *SD* represents standard deviation.

Part A: Social Shape and Greeting Voice

As presented in Fig. 7(a), with the social shape, we found a difference between the mean values of personal space between

Table 2. Drone positions.

pos	lateral distance	height
A	0.0 m	1.8 m
B	0.3 m	1.8 m
C	0.6 m	1.8 m
D	0.0 m	1.2 m
E	0.3 m	1.2 m
F	0.6 m	1.2 m

human and social drone. The average distance with social shape is found to be M_{SV} = 1.06 m; SD_{SV} = 0.61; and M_{SN} = 1.14 m; SD_{SN} = 0.57; while nonsocial shape is found be M_{NV} = 1.33 m; SD_{NV} = 0.55; M_{NN} = 1.38 m; SD_{NN} = 0.61;. On average, the personal space of social drone with greeting voice is reduced by 30% when compared to nonsocial drone without greeting voice.

We also analyzed data by comparing the results between pet owners and non-pet owners. The average distance with all drone states of personal space of pet owners is M = 1.13 m while the personal space is M = 1.39 m for non-pet owners; see Fig. 7(b). Although the number of participants without having or have owned a pet is not significant, the numbers do indicate that having a pet allows a drone to come closer to the user. Finally, the average distance with all drone states of personal space for females (M= 1.50 m) is greater than the average distance with all states of personal space for males; which is M = 1.10 m; see Fig. 7(c).

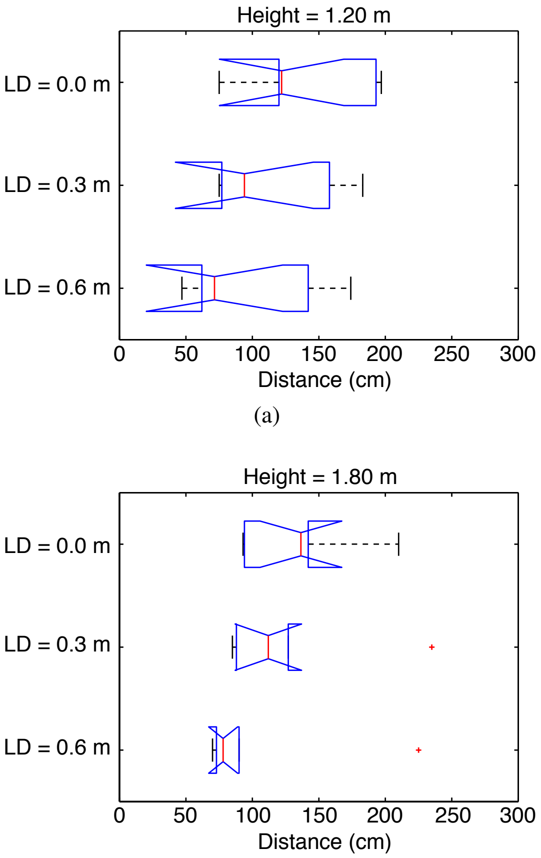
Part B: Height and Lateral Distance

As a comparison between 2 height levels (1.20 m and 1.8 m) in Fig. 9(a) and Fig. 9(b), social drones that fly at the height of 1.20 m have an average distance (M_D = 1.14 m; SD_D = 0.46; M_E = 1.02 m; SD_E = 0.61; M_F = 0.95 m; SD_F = 0.51) lower than at the height of 180 cm (M_A = 1.35 m; SD_A = 0.43; M_B = 1.38 m; SD_B = 0.48; M_C = 1.27 m; SD_C = 0.56).In terms of change in lateral distance at the height of 1.20 m, we can clearly see that increased lateral distance gradually decreased the distance between the social drone and human ($M_D > M_E > M_F$).

DISCUSSION

From our surveys, we found that safety regarding drones is a major concern for participants. However, they still prefer a medium size of social drone due to visibility. We discovered that the noise of the drone added to the mental stress of any human in the vicinity of the drone. To our knowledge, silent drone technology has yet to emerge. We decided not to make it our challenge to try to decrease the noise of the drone. Several hypotheses were assumed about how noise cancellation could perhaps improve the social drone's penetration of a human's personal space.

Based on current technology, flying a drone indoors is still highly unstable when weight is added on; even if the drone has a small additional weight (e.g. styrofoam cup), it would still behave somewhat unpredictably. Due to that we would not be able to have a consistent experiment or study operating a drone in an indoor environment, we decided to connect zip lines to be able to reproduce our experiment and studies. There were also concerns that the nonsocial drone would affect the drone from its current state, as it would look safer than a drone without a styrofoam cup. One of the participants said that "having the drone inside a protective cage feels safer than the drone flying without". Another participant mentioned after the proximity study "I concentrated more on the face of the drone and therefore did not think so much about the propellers". Nevertheless, the social drone performed significantly better in closing the distance than what the nonsocial drone could do.



(a)

(b)

Figure 9. Part B: Height and lateral distance with the height set at 1.20 m (a) or at 1.80 m (b).

Finally, in comparison with human personal space (within 1.2 m) proposed by Hall [8], an average personal space of the social drone and human was closer when compared with the personal space between human and human. This result shows positive signs of having social drones in human environments.

CONCLUSION AND FUTURE WORK

We have presented a social drone design and proxemic study aiming to be used in human crowd environments. Our experiment was preliminary in nature where the factors were evaluated together. Future work will include more extensive experiments on each factor to emphasize how strong each component help reduce personal space. A study concerning how color feature could affect proximity between human and social drone or ground robot, will also be conducted. The authors hope that this paper will contribute design and proximity insights to several different continuous studies and further development in various social agents interacting with humans.

ACKNOWLEDGEMENTS

This work was partially funded by the Gadelius scholarship from the Sweden-Japan Foundation and supported in part by the programs of the Grant-in-Aid for Challenging Exploratory Research No. 16K12501. We are also grateful to Philippa Beckman, Adam Dunford, Mafalda Samuelsson Gamboa, Philip Tham, Velko Vechev, and Osman Malik for proofreading.

REFERENCES

1. Cynthia Breazeal. 2001. Emotive qualities in robot speech. In *Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Vol. 3. IEEE, 1388–1394.
2. Adrien Briod, Przemyslaw Kornatowski, Jean-Christophe Zufferey, and Dario Floreano. 2014. A Collision-resilient Flying Robot. *Journal of Field Robotics* 31, 4 (2014), 496–509.
3. John Travis Butler and Arvin Agah. 2001. Psychological effects of behavior patterns of a mobile personal robot. *Autonomous Robots* 10, 2 (2001), 185–202.
4. Jessica R. Cauchard, Jane L. E, Kevin Y. Zhai, and James A. Landay. 2015. Drone & Me: An Exploration into Natural Human-drone Interaction. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. ACM, New York, NY, USA, 361–365.
5. Jessica Rebecca Cauchard, Kevin Y. Zhai, Marco Spadafora, and James A. Landay. 2016. Emotion Encoding in Human-Drone Interaction. In *The Eleventh ACM/IEEE International Conference on Human Robot Interaction (HRI '16)*. IEEE Press, 263–270.
6. Mike Cooley. 2000. Human-centered design. *Information design* (2000), 59–81.
7. Antonio Gomes, Calvin Rubens, Sean Braley, and Roel Vertegaal. 2016. BitDrones: Towards Using 3D Nanocopter Displays As Interactive Self-Levitating Programmable Matter. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 770–780.
8. Edward T. Hall. 1966. *The Hidden Dimension*. Vol. 6. Doubleday. 113–127 pages.
9. Hiroko Kamide, Yasushi Mae, Tomohito Takubo, Kenichi Ohara, and Tatsuo Arai. 2014. Direct comparison of psychological evaluation between virtual and real humanoids: Personal space and subjective impressions. *International Journal of Human-Computer Studies* 72, 5 (2014), 451–459.
10. Chi-Pang Lam, Chen-Tun Chou, Kuo-Hung Chiang, and Li-Chen Fu. 2011. Human-Centered Robot Navigation - Towards a Harmoniously Human-Robot Coexisting Environment. *IEEE Transactions on Robotics* 27 (2011), 99–112.
11. Hee Rin Lee, JaYoung Sung, Selma Šabanović, and Joenghye Han. 2012. Cultural design of domestic robots: A study of user expectations in Korea and the United States. In *Proceedings of the 21st IEEE International Symposium on Robot and Human Interactive Communication (2012 IEEE RO-MAN)*. IEEE, 803–808.
12. Min Kyung Lee, Jodi Forlizzi, Paul E Rybski, Frederick Crabbe, Wayne Chung, Josh Finkle, Eric Glaser, and Sara Kiesler. 2009. The snackbot: documenting the design of a robot for long-term human-robot interaction. In *Proceedings of the 4th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 7–14.
13. SZ DJI Technology Co. Ltd. 2016. DJI phantom 3 standard. (2016). `http://www.dji.com/phantom-3-standard` [Online; accessed 19-July-2016].
14. I. Scott MacKenzie. 2013. *Human-Computer Interaction: An Empirical Research Perspective* (1st ed.). Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.
15. Masahiro Mori, Karl F MacDorman, and Norri Kageki. 2012. The uncanny valley [from the field]. *IEEE Robotics & Automation Magazine* 19, 2 (2012), 98–100.
16. Jonathan Mumm and Bilge Mutlu. 2011. Human-robot Proxemics: Physical and Psychological Distancing in Human-robot Interaction. In *Proceedings of the 6th International Conference on Human-robot Interaction (HRI '11)*. ACM, New York, NY, USA, 331–338.
17. Kei Nitta, Keita Higuchi, and Jun Rekimoto. 2014. HoverBall: Augmented Sports with a Flying Ball. In *Proceedings of the 5th Augmented Human International Conference (AH '14)*. ACM, New York, NY, USA, Article 13, 4 pages.
18. Mohammad Obaid, Wolmet Barendregt, Patricia Alves-Oliveira, Ana Paiva, and Morten Fjeld. 2015. Designing Robotic Teaching Assistants: Interaction Design Student's and Children's Views. In *Proceedings of the 7th International Conference on Social Robotics*. Springer International Publishing, 502–511.
19. Mohammad Obaid, Felix Kistler, Markus Häring, René Bühling, and Elisabeth André. 2014. A Framework for User-Defined Body Gestures to Control a Humanoid Robot. *International Journal of Social Robotics* 6, 3 (2014), 383–396.
20. Mohammad Obaid, Omar Mubin, Christina Anne Basedow, A. Ayça Ünlüer, Matz Johansson Bergström, and Morten Fjeld. 2015. A Drone Agent to Support a Clean Environment. In *Proceedings of the 3rd International Conference on Human-Agent Interaction (HAI '15)*. ACM, New York, NY, USA, 55–61.

21. Mohammad Obaid, Eduardo B Sandoval, Jakub Złotowski, Elena Moltchanova, Christina A Basedow, and Christoph Bartneck. 2016. Stop! That is close enough. How body postures influence human-robot proximity. In *Proceedings of the 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 354–361.

22. Michiko Ohkura, Tsuyoshi Komatsu, and Tetsuro Aoto. 2014. Kawaii Rules: Increasing Affective Value of Industrial Products. *Industrial Applications of Affective Engineering* (2014), 97–110.

23. Photchara Ratsamee, Yasushi Mae, Kazuto Kamiyama, Mitsuhiro Horade, Masaru Kojima, and Tatsuo Arai. 2015. Social interactive robot navigation based on human intention analysis from face orientation and human path prediction. *ROBOMECH Journal* 2, 1 (2015), 1.

24. Paul Robinette, Alan R Wagner, and Ayanna M Howard. 2014. Assessment of robot guidance modalities conveying instructions to humans in emergency situations. In *The 23rd IEEE International Symposium on Robot and Human Interactive Communication*. IEEE, 1043–1049.

25. Emrah Akin Sisbot, Luis F. Marin-Urias, Rachid Alami, and Thierry Simeon. 2007. A human aware mobile robot motion planner. *IEEE Transactions on Robotics* 23, 5 (2007), 874–883.

26. Leila Takayama and Caroline Pantofaru. 2009. Influences on Proxemic Behaviors in Human-robot Interaction. In *Proceedings of the 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS'09)*. IEEE Press, Piscataway, NJ, USA, 5495–5502.

27. Pete Trautman, Jeremy Ma, Richard M Murray, and Andreas Krause. 2015. Robot navigation in dense human crowds: Statistical models and experimental studies of human–robot cooperation. *The International Journal of Robotics Research* 34, 3 (2015), 335–356.

28. Sarah Woods. 2006. Exploring the design space of robots: Children's perspectives. *Interacting with Computers* 18, 6 (2006), 1390–1418.