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Exploring the Social Proxemics of Human-Drone Interaction

Jeonghye Han[1], Dylan Moore[2], Ilhan Bae[3]

[1]Cheongju National University of Education, Republic of Korea
hanjh@cje.ac.kr
[2]Stanford University, USA
djmoore3@stanford.edu
[3]Korea Advanced Institute of Technology, Republic of Korea
damire@kaist.ac.kr

Abstract

Drones will evolve from military to personal or social purposes. How can people socially interact with a drone that is familiar to them? This study explored the social proximity of human drone interaction with safety glass wall between participants and drone. The experiment results showed that drone's altitude, size and gender factor did not significantly affect social proxemics as to what extent participants got closer to hovering drones by the limitation of the distance from the safety wall. However, it shows a tendency that participants more closely approached an eye-level drone compared with an overhead drone, and females tended to approach more closely males. This study consequently demonstrated that most participants are nearly ready to allow a near field operation of social drone under safe conditions.

Key words: *Human-Drone Interaction, altitude, size, social proxemics*

1. Introduction

Drones are expected to have very diverse applications in the future, even though fast spinning propellers and the potential for high-flying drones to fall both present dangerous risks. Just as cars posed a risk, similar drone regulations for people flying drones are based on safety, privacy, and public security because they cause concern when flying close to humans, falling down to the ground, or presenting privacy concerns over their recording ability.

The various uses of social drones have already been revealed such as taking a wedding photo looking down from the sky, chasing a jogger like a bodyguard, and allowing waiters and table workers to remain closer to customers in a restaurant. However, while drones offer many opportunities, the field lacks research on human-drone interaction (HDI). Even though flying a drone requires following local and federal guidelines in public spaces, social drones may have potentially different issues.

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Corresponding Author:damire@kaist.ac.kr
Tel: +82-42-350-1257, Fax: +82-42-350-1250.
Korea Advanced Institute of Technology, Daejeon, Republic of Korea

We are just beginning to explore how these spaces translate from human-human interactions (HHI) to HDI. To ease adoption of drones in our cities and homes, we investigate social proxemics in human and drone tele-operated by a familiar individual (known to the participants) by the following questions:

(1) How do the size and the flying altitude of the social drone affect the proximity?
(2) How different is HDI behind a safety wall from HHI?
(3) Are there gender differences in the proximity of HDI?
(4) What privacy concerns exist about camera-ready and social drones?

2. Related Works

2.1 Proxemics in HRI

An early founder of proxemics, Edward Hall [1] qualitatively theorized that we use interpersonal distances to mediate interactions with other people, dividing the space around us into four discrete zones: intimate (< 2 ft), personal (2-4 ft), social (4-12 ft), and public (> 12 ft), supported by empirical study [2]. Numerous contextual factors mediate comfortable distances between including the environment, culture, gender, age, and of course, one's relationship with others in the room—people stand closer to friend than a foe [3]. Our awareness of a space, particularly height, plays a large role in our perception of stimuli. At the same time, some suggest that there is no social proxemic effects for objects [4].Technology is neither a human nor an inanimate object, so there's an unexplored middle ground that must be understood before interactive systems can seamlessly enter our lives. Greenberg et al. describe how interfaces can incorporate a user's distance and orientation into the design [5]. Also, Fiore et al. [6] demonstrated that cues associated with the robot's proxemic behavior significantly affect participant perceptions of the robot's emotional state and social presence. Participants in the above HRI studies treat robots as if those were human, and personified cues of a robot such as its height, gaze and personal experiences affect their proxemic interactions with the robot.

2.2 Proxemics in HDI

Would social proxemics in interactions with a drone be similar to those with humans? People feel much more risk approaching a hovering drone than a human or a robot on the ground. This inherent risk leads to critical differences in social proxemics in interaction with a drone. Naturally, researchers in Human-Drone Interaction (HDI) focus on how the risk of approaching drones in various situations affects the social proxemics between people and a drone. Abtahi et al. [8] found that participants would more closely approach and interact with a drone through touch if they knew that the drone was designed to be safe to do so. While in close proximity with a system, Acharya et al. [9] demonstrated that participants moved twice as far away from a hovering drone than a robot on the ground. Wang et al. [10] found that people still want drones to be out of their personal space for comfort even in public places. A study by Jane et al. [11] suggested that culture shapes how close people feel comfortable approaching a drone; Chinese participants were more likely than American participants to allow a drone to enter their intimate space (< 1.5 ft). Jensen & Hansen [12] showed that people want drones to communicate they see and acknowledge a specific person by rotating the drone body toward specific person much earlier than they encounter with robots. Yeh et al. [13] found that drones with personalized greeting voices significantly reduced the distance people felt comfortable approaching it. According to the results of the proximity from a hovering drone by Abtahi et al. [13], we consider the flying altitude of a drone an important potential factor to consider. In addition, height of a teacher robot may be related to the size of the drones as another potential factor from Han & Bae [15]. To find out the social proximity of human and familiar (identified) drone, a drone operator, who was a friend of the participants, greeted each participants, similar to Yeh et al [13].

3. Methods

3.1 Participants and Experimental Design

Since this experiment could cause serious injury from close proximity to the drone, participants were informed about the process of the experiment and the possibility of the risk, and the experiment was conducted only for the participants who agreed. Participants (N = 32, Mage = 22.6 years old) were selected from undergraduate students who are willing to attend. 23 participants were female, and 9 were male. To ensure reliable hovering altitude, and to prevent accidents, a professional drone pilot was invited to fly the drone. Next to him, a classmate of participants was selected to converse. Two research assistants recorded video and interviewed each participant after the experiment, and two researchers organized and monitored the whole experimental process. After we secured the drones, there was extensive preparation before the experiment to ensure participant safety: IRB approval and approval of drone flight from regional air base / Recruiting experiment participants (N = 32) / Agreement from participants after explanation of the experiment / Acquisition of drone fight insurance.

To explore proxemics in HDI, we designed a simple 2x2 experiment with two size conditions, small drone and big drone, and two altitude conditions, eye-level and overhead (See Figure 1). We chose two types of drones with cameras of different sizes: The big drone was the Inspire 2 and small drone was the Phantom 4 Pro. These drones measured 2 feet and 1.2 feet diagonally across, respectively. Both drones were equipped with cameras, and were controlled wirelessly. We setup the experiment on a soccer field, with a soccer goal rim that served as protection for the participant. We installed a transparent safety wall on the soccer goal rim between the hovering drone and participants. On the ground where the participant stood, a color circle with a radius of 2 m was placed to measure the approach distance. The distances between the participant, safety wall, and drone in each condition are shown in Figure 2.

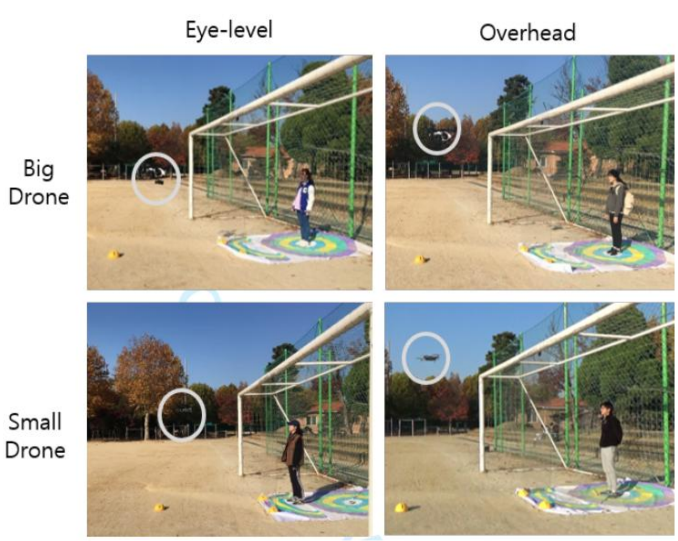

Figure 1. Experimental Design (2X2)

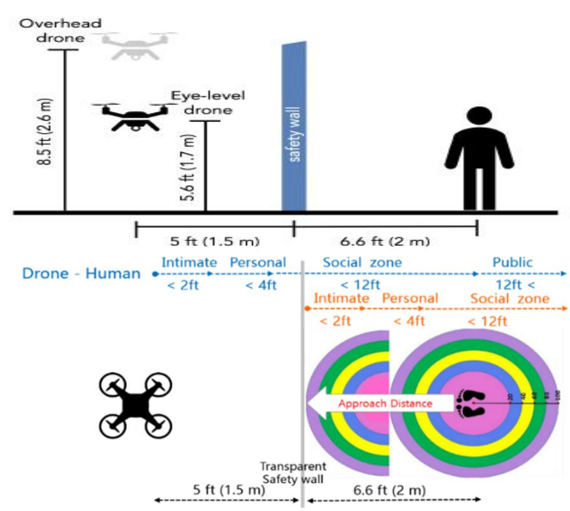

Figure 2. Experimental setup: Side & Sky view

The drone operating team consisted of a hired professional drone pilot to ensure safety of participants, and a classmate of participants. To find out the social proximity of HDI, the classmate and friend of the participants served as the voice of the drone over a cell phone, projected through a loud speaker system considering the finding from Yeh et al. [13] that personalized greetings made people approach a drone more closely. The drone operating team could see the soccer field well, and stood out of sight of the participants. After the participant was safely behind the goal post, on a cue from the research team, the drone appeared and approached. In every condition, a voice from the hovering drone initiated conversation. After the participant recognized the classmate's voice on the drone, the participant was asked to move closer to the drone to hear the operator better (For a live demonstration, see the video clip by Han & Bae [15]).

3.2 Measurements

We video recorded each participant to measure the approach distance, or how closely subjects moved towards the drone. The starting distance was 12 feet (3.5 m) away from the drone. On the recommendation from the professional drone pilot, we set the transparent safety wall at 5 ft away from the drone. He asked us to maintain a minimum distance of 5 ft from the safety wall to avoid the worst case of a drone malfunction due to wind or falling leaves. Using a colored mat underneath the feet of the participants in Figure 2, we measured the distance in centimeters that subjects moved after being asked by the operator to move closer.

After interacting with the drone, researchers asked participants a series of questions about their experience, rating their agreement to each of the following statements on a scale of 1 (Absolutely disagree) to 7 (Absolutely agree): *I felt strange about the drone that I talked with./ I thought it was scary when the drone flew around me./ I thought the drone was watching me with a camera./ I felt the drone was a threat*. Finally, participants were also asked two questions about their general attitude towards drones: *What should be the altitude of delivery drones? / What concerns do you have about a drone with a camera?*

4. Results

As shown in Figure 3, the average proximity of human and drone was 8.34 ft for small and eyelevel, 7.99 ft for small and overhead, 8.57 ft for big and eye-level, 8.06 for big and overhead. All the subjects stayed within the social space of the drone when their friend talked to them and they safely approached. Participants more closely approached the drone when it was flying at eye-level, rather than overhead, $F(1, 29) = 2.304$, $p = .14$, $\eta^2 = .069$. Subjects moved slightly closer to the small drone than the big drone, $F(1, 29) = 0.237$, $p = .63$, $\eta^2 = 0.008$. That is, the proximity to the big drone was slightly less than the small drone, and the proximity to the eye-level drone was slightly less than the overhead drone, however the differences were not highly statistically significant. We also provide effect sizes, η^2 which are medium to large.

Table 1. Proportion of participants

	Drone -Human	Safety wall -Human
Intimate Space (<1.5 ft)	N/A*	0%
Personal Space (<4.0 ft)	0%	84%
Social Space (<12 ft)	100%	16%
Public Space (>12 ft)	0%	0%

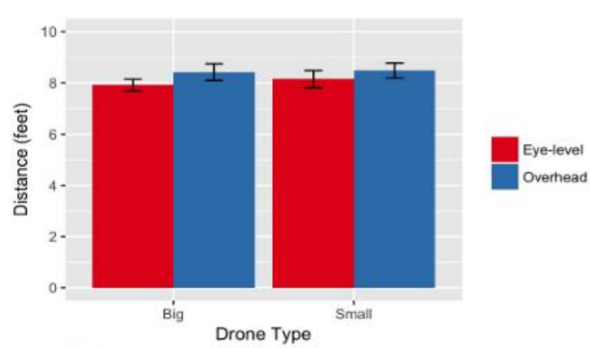

Figure 3. Approached Distance

We believe the marginal results are due to the distance between the drones and the safety wall at 5 ft, which was required to ensure participant safety. If the distance between the drone and the safety wall was less than 5 ft, there could have been a more significant effect. Three people even tried to enter the personal space (<4 ft) putting their faces and bodies on the safety wall as close as possible. Seven people seemed to approach the safety wall while leaving a somewhat comfortable space with the wall, and possibly they could be closer to the drone if the safety wall was not there. 84% of subjects were within the personal space of the safety wall as shown in Table 1. Therefore, if the safety wall was located closer (< 5 ft) to the drones, it would be more likely that the average distance to the drone could be less than 8 ft, and within the personal space.

Since the distance between the drones and the safety wall was already 5 ft away, farther than the personal space zone (< 4 ft), other analysis results are also not significant, but we will discuss the trends in these data. Females tended to move closer to a big and eye-level drone than males (Figure 4), however there was no significant interaction between drone type and gender, $F(1, 28) = 0.011$, $p = .92$, $\eta^2 = .001$ or flying height and gender, $F(1, 28) = 632$, $p = .43$, $\eta^2 = .02$.

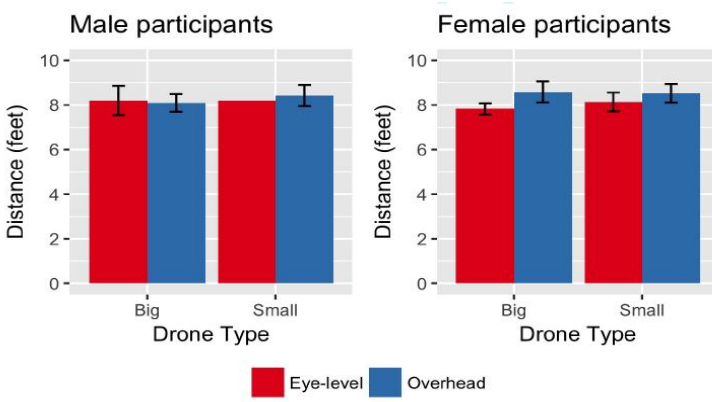

Figure 4. The approach distance by gender

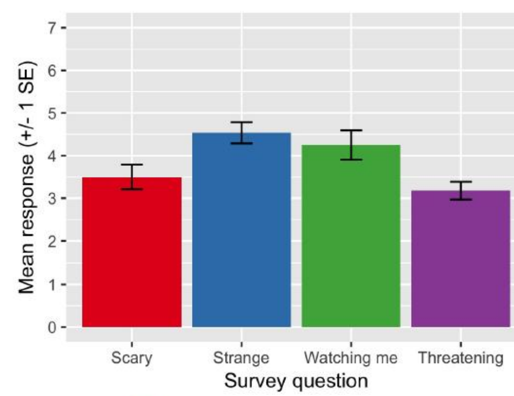

Figure 5. Interviewed about the experience

As shown in Figure 5, subjects generally did not feel the interaction with a classmate-drone was that scary (M = 3.5 out of 7) or threatening (M = 3.2). This means the participants had a generally neutral to positive social interaction with the drone. However it was slightly more strange (M = 4.5) to have a drone with a human-voice, and some did feel the drone was watching them because of the camera (M = 4.3). But five participants did not notice the camera on the drone it as it was not very easy to see.

We asked which flying altitude the participants wanted the drones in when they delivered the goods. 58.3% of participants responded that delivery drones should approach at eye-level, 41.7% responded drones should approach from overhead. The reasons they chose the eye-level social drones were that it would be hard to lift things, and dropping goods from a high altitude could cause accidents and more damage to products. In addition, it would be easier to hand the product over to and interact with the customers. For the last survey question (What do you think of a drone with a camera mounted on it in our living environment?) with multiple responses, safety, privacy, and altitude are mentioned. 35% reported safety concerns due to falling crashes and altitudes, and 75% reported privacy violations due to watching, video-recording, or hacking, and 17.9% reported both problems. Some participants thought safety was the most important, but most seemed more interested in the privacy because they assumed or expected there would be regulations put in place before drones entered society. Thus regulators should keep this concern over safety as well as privacy in mind.

5. Conclusion and Discussions

This study only explored how hovering altitude and size influences a person's comfort interacting with a drone through voice in HDI. This small exploratory study found that participants stayed in the social space during an interaction with a drone that projected the voice of a friend. When the drone encouraged the participants to come closer, participants (protected by the safety wall) felt familiarity with the drone and approached closer. They were more comfortable approaching eye-level than overhead social drones, which also aligns with the survey data we collected suggesting that delivery drones should approach at eye-level rather than overhead. This result is in agreement with a previous study [1] that participants' desire to interact with drones at eye-level may also ease other methods of interaction, such as through gesture and sound.

In this study, the size and hovering altitude of the drone did not statistically significantly impact participants' approach distance. However, there are trends in the data, and the hovering altitudes seem to produce slightly different comfort levels across participants, with females more closely approaching drones than males. This might be due to the limitations of the experiment due to safety concerns, namely that participants could not get closer than 5 ft to the drone. This puts participants outside of the intimate and personal spaces of the drone. There was also variance in the height of the drone (on the order of a couple of feet) due to wind and other environmental factors. With appropriate controls, future work could potentially explore how the interaction with the drone could be different in a more naturalistic setting without a safety wall. However this experiment did not push participants to the limits of close proxemics such as intimate and personal spaces.

It consequently demonstrated most young Korean participants comfortably got closer to drones of different sizes and altitudes, and entered the drone's social space if drones were at least 5 ft away and separated by a safety wall. It seems to have revealed a useful tip in near field drone operation in daily life. The size and altitude of the drones did not matter. Most participants felt comfortable interacting with social drones under the above conditions. If social space that works in HHI is also applicable and safe in HDI, people might be ready to freely interact with social drones in proxemic zones analogous to humans.

Cauchard et al. [14] found that people also use gestures when interacting with drones, and this study did not incorporate that modality. Combining these interactions with other modalities may influence how comfortable people feel approaching the drone mid-flight. Future studies could explore the impact of other interaction methods of social proxemics of HDI such as gesture and voice.

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