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The Role of Drone Appearance and Capability in Human Trust: A Comparative vs. Isolated Analysis

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Abstract— **Advancements in autonomy, navigation, and sensor systems have led to the increased deployment of drones in high-risk applications, such as mapping operations. While drones can mitigate the dangers associated with these missions, human trust in drones is essential for their effective use. This study explores the influence of key factors, including drone appearance, capabilities, protective cage, and noise on human trust. We implemented two different methodologies: (1) an isolated approach, in which the effects of each drone's appearance and capabilities were studied independently, and (2) a comparative approach, where participants evaluated two drones with different appearances and capabilities in direct comparison. The experiment results indicate that while drone appearance influences human trust, drone capabilities have a significantly greater impact. Additionally, comparing the two methodologies revealed that the comparative approach directs participants' attention more effectively to the studied factors.**

One of the primary contributions of this work is the introduction of a tested and effective method to investigate the effects of different factors on trust between humans and drones. Our findings can help robot designers develop drones suited for diverse scenarios by identifying the features most valued by human operators.

I. INTRODUCTION

Advances in microcomputers, microprocessors, and battery technology have significantly increased the use of flying robots, or drones, across various applications [1]. Drones are now employed in everyday activities such as film production, agriculture, entertainment, and delivery [2]. However, their utility extends beyond these domains. Drones are particularly valuable in high-risk situations, where they can replace or assist officers and first responders in area clearing, search and rescue, and evacuation [1], [3], [4], [5], [6].

Despite their growing use, human-drone trust remains under-explored. One key challenge in studying human-drone trust is repeatability—ensuring that drones exhibit consistent behavior across trials during human-drone interaction (HDI) experiments. Unlike other robots, a drone's navigation process is more complex, leading to variations in takeoff, speed, acceleration, flight balance, altitude, and path. Even autonomous drones, which are programmed to follow a set path, exhibit behavioral variability on each flight [7], [8], [9]. This variability complicates in-person HDI experiments, as drones may behave differently for each participant. A potential solution is to use prerecorded videos of drone interactions, ensuring a controlled and consistent experience across participants.

This study explores factors influencing human trust in drones used as assistants for mapping missions in underground tunnels. Specifically, we examined the effects of appearance (e.g., high-tech aesthetics and the presence of a protective cage), noise, and task capabilities. We implemented two methodologies—one isolated and one comparative, with minor procedural differences but significant differences in outcomes.

We conducted an online study with 180 participants across four experimental conditions and two control conditions, with 30 participants in each. The key findings are:

- Drone task capabilities significantly impact trust.
- Drone appearance, including a protective cage and high-tech design, influences perceptions of trustworthiness and competence.
- Higher pitch and tone of drone noise negatively affect human trust.
- Comparative methodologies provide a more effective assessment of these factors than isolated experiments.

II. BACKGROUND, RESEARCH QUESTIONS AND HYPOTHESES

Drones are being employed in a wide range of applications, including unknown region exploration [10], ocean exploration [11], area mapping and photogrammetry [12], [13], [14], traffic surveillance [15], [16], [17], reconnaissance [18], [19], search and rescue [20], [21], tactical missions [22], and pipeline monitoring [23], among others. Advances in autonomy, navigation, microprocessors, and sensor systems have made drones lighter, smaller, and more functional. Their indoor flying capabilities are also improving [24], [25], enabling drones to be used in applications such as object tracking [26], indoor search and rescue [27], clearing operations [1], and indoor mapping [28], [29], [30], [31], [32].

The need for research on natural interaction in drones is supported by the existing literature on human-robot interaction and trust [33], [34]. However, drones differ from ground robots in significant ways, such as having moving propellers that prevent touch-based interaction, flying at various altitudes, and exhibiting unique proximity behaviors. These differences, combined with the distinct tasks drones are assigned to perform, raise questions about the applicability of current human-robot interaction and trust models to drones [2].

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This study investigates the effects of key factors on trust in HDI. Specifically, it explores how drone characteristics influence user trust in drones. We build upon prior research on HRI [35], [36].

A. *Effects of drone noise on human trust in a drone*

When designing robots, manufacturers and engineers must consider various factors related to aesthetics, motion, and expressiveness, particularly how these elements influence human trust in the robot's behavior and capabilities [37]. However, sound-related aspects, such as the noise generated by the robot, are often overlooked in the design process [38].

Research on the impact of robot-generated noise in HRI remains limited. Trovato et al. [39] found that pneumatic actuator noise from the ARMAR-IIIb robot negatively affected HRI, reducing likability. Their comparative study examined three sound conditions—original robot noise, no noise, and manipulated noise—and analyzed how these variations influenced human proximity behaviors [38]. However, their findings are not broadly generalizable across different robots or scenarios.

Similarly, Hald et al. [40] explored the effects of motor noise on human trust in close-contact interactions. They tested participants' trust levels with and without ear protection but found no significant differences.

Given the limited research on drone noise in HDI, we propose the following research question:

Research Question 1: Do changes in the intensity and pitch of drone noise affect human trust in the drone?

B. *Effects of drone appearance on human trust*

Research on robot appearance has shown that it significantly influences users' evaluations, expectations, and perceptions of a robot's capabilities and behavior [41], [42], [43]. However, most studies focus on matching a robot's appearance to its task [44], [45], [46] or the effects of anthropomorphism and zoomorphism on HRI [47], [48], [49]. These findings are less applicable to drones, as their appearance differs significantly from ground robots.

While limited, some studies have examined drone appearance in HDI. Baytas et al. [50] emphasized that a drone's appearance influences HDI. Tan et al. [51] suggested that a "modern appearance" makes people more comfortable with drones, though they did not define the term. Karjalainen et al. [52] found that people prefer drones that appear round and safe and generally favor machine-like designs over human- or animal-like ones. However, whether a drone's appearance affects perceptions of its capability and trustworthiness remains unclear.

This gap leads to our second research question:

Research Question 2: Does the presence of a protective cage and a high-tech appearance affect human trust in drones?

C. *Effects of drone's capability on human trust*

According to Khavas et al. [37], robot-related factors have the strongest influence on trust in HRI, with performance-related factors being the most critical. Several studies have examined how a robot's performance affects trust [53], [54], [55], [56], often focusing on faulty behavior across different tasks, missions, or environments [57], [58]. Some studies have also explored the timing, frequency, and magnitude of performance drops [59].

However, lower performance does not always imply errors or faults. A robot may simply be less capable than another, producing lower-quality results or completing a task at a slower pace. Despite extensive research on robot performance and trust, the impact of varying capability levels (rather than malfunctions) on trust remains understudied.

This leads to our third research question:

Research Question 3: Does drone capability in performing a task affect trust?

D. *Hypotheses*

H1 Drone sounds with increased strength (i.e., in terms of loudness) and annoyance (i.e., roughness or noisiness) cause people to trust the drone less. Therefore, the Elios drone's noise harms peoples' trust in the drone.

H2 The high-tech and fancy appearance of the Elios drone causes people to perceive it as a more capable drone. Therefore, participants report higher trust in the Elios drone than the Mavic drone as an assistant for performing the mapping mission.

H3 Added light by the Elios LEDs and also higher quality of the Elios videos in the dark environment cause people to trust the Elios better than Mavic as an assistant for performing mapping missions in dark environments.

III. METHODOLOGY

A key contribution of this study is the development of a tested and effective methodology for examining factors influencing human trust in drones. We conducted two online studies using manipulated video scenarios to analyze the impact of key drone-related factors on trust. This section details the experimental design and methodologies used.

A. *Experiment Design*

1) First Methodology: Isolated Methodology: In the isolated methodology, participants first read a brief scenario describing a mapping mission in the ruins of a subway line, where obstacles, victims, and hazards may be present. The scenario included an option to use a drone to assist in mapping by capturing videos and photos.

Participants then watched a short video demonstrating the drone assisting in the mission. Afterward, they completed two questionnaires assessing their trust in the drone as their mission assistant.

2) Second Methodology: Comparative Methodology: In the comparative methodology, participants read the same scenario as in the isolated methodology. However, instead of evaluating a single drone, they were informed that they would view two different drones performing the same mapping task in the same environment.

After watching both drone videos, participants were asked to choose their preferred drone and provide a reason for their selection. This step was incorporated based on prior research linking robot trust and user preferences in decision-making [60], [61], [62].

To control for order effects, the video sequence was counterbalanced:

Half of the participants viewed Drone A first, followed by Drone B. The other half viewed Drone B first, followed by Drone A. Participants were then randomly assigned to the first drone they viewed. After the assignment, they completed two trust questionnaires evaluating their trust in the selected drone.

B. Drones

We employed two drones with distinct physical attributes and capabilities in performing a mission in a dark environment for this task.

- Elios Drone: The Elios 2 is a caged drone with a high-tech design, developed by Flyability and released in 2019. It generates a high-pitched noise during operation, prompting recommendations for users to wear earmuffs for ear protection. The drone is equipped with a visible camera and an LED lighting system to enhance visibility in dark environments [63].
- Mavic Drone: The Mavic Air 2 is a compact, non-caged quadcopter drone manufactured by DJI and released in 2020. It features advanced noise-reduction technology that decreases aircraft noise by up to -0.5 dB, resulting in a quieter flight experience compared to other DJI models [64].

Fig. 1. The drones that are used in this experiment

Figure 1 shows the drones we used in this study.

C. Experiment Conditions

We generated eight videos for this study, all filmed in the same location: the basement of the New England Robotics Validation and Experimentation (NERVE) Center at the University of Massachusetts Lowell NERVE. Each video begins with the drone powering on, activating its propellers, and taking off. The drone then proceeds to perform a mapping mission in a narrow corridor. Figure 2 shows the environment where the recordings took place.

For the first experiment (isolated methodology), we used four videos: two control condition videos, one for the drone appearance condition, and one for the drone capabilities condition. Each video contained slight modifications to specific elements compared to the control condition video.

For the second experiment (comparative methodology), we used four videos: two for the drone appearance condition and two for the drone capability condition.

1) Isolated Experiment Conditions: In the isolated experiment, we had two experimental conditions and two baseline conditions, with 30 participants assigned to each condition.

- **Baseline Condition – Drone Appearance:** The Elios drone was used in this video. The environment was bright, serving as the baseline for the drone appearance condition. The top image in Figure 2-A shows a screen capture of this video.
- **Baseline Condition – Drone Capability:** The Elios drone was also used in this video. However, the environment was dark, serving as the baseline for the drone capability condition. The bottom image in Figure 2-A shows a screen capture of this video.
- **Drone Appearance – Uncaged Drone:** The baseline video featured the Elios drone, a high-tech, cage-protected drone. To examine whether drone appearance influences human trust, this condition compared Elios and Mavic, focusing on their visual differences. We used a video of the Mavic drone performing a mapping mission in a bright environment, with drone-captured footage overlaid on the main video. Notably, both drones had equal capabilities and video quality in this setting.
- **Drone Capability:** The Elios drone has four LEDs that enhance brightness, allowing it to capture higher-quality footage in dark environments. The Mavic drone lacks this capability. This condition compared the video quality of Elios and Mavic in low-light conditions. A video of the Mavic drone performing a mapping mission in a dark environment was used, with its low-quality footage overlaid on the main video.

2) Comparative Experiment Conditions: In the comparative experiment, we had two conditions, each consisting of two short videos—one featuring the Elios drone and the other featuring the Mavic drone, both performing a mapping mission. Participants watched both videos, and each condition included 60 participants. After viewing the videos, 30 participants were assigned to the Mavic drone, completing questionnaires based on their experience with it, while the remaining 30 were assigned to the Elios drone, completing questionnaires for Elios.

- **Drone Appearance Condition:** In this condition, participants viewed videos of the Elios and Mavic drones performing a mapping mission in a bright environment, allowing them to clearly observe drone appearance differences.
- **Drone Capability Condition:** This condition was identical to the drone appearance condition, except that the mapping mission took place in a dark environment. The bright setting in the drone appearance condition ensured participants could assess the drone's visual features, whereas the drone capability condition focused on comparing the quality of footage captured by the

Fig. 2. Screen capture of the videos of different experiment conditions, A) baseline, B) Tele-operation, C) Bright environment, D) Silent and Loud drone, E) Drone appearance, F) Drone capability

Elios and Mavic drones in low-light conditions.

D. Measurements

Trust questionnaires - We assessed changes in human trust using two post-survey 7-point Likert scale questionnaires. These two questionnaires are:

1) Checklist for trust between people and automation (i.e., Jian's questionnaire) [65].
2) Human-computer trust measure (i.e., HCTM) [66], which has been modified by some researchers to be used for measuring trust in HRI [67].

User selection and logic - This experiment has an additional trust measure based on participants' selection among the two drones and the logic for their choice.

E. Recruitment and Compensation

We recruited 180 participants for this experiment from Amazon's Mechanical Turk (MTurk)[1]. We compensated participants who completed the task with $3.50. On average, the survey took 14.3 minutes (SD = 8.5 minutes) from participants.

IV. RESULTS

A. Isolated Experiment Results

1) Drone Appearance: Analysis of H1 and H2: : We hypothesized that the fancy appearance of the Elios drone would lead people to perceive it as a high-tech, powerful drone, thereby boosting their trust in it. On the other hand, we hypothesized that the Elios drone's high tone and pitch noise harms people's trust in the drone. As described in the Experiment Conditions section, we tested these hypotheses by comparing Mavic and Elios in a bright environment. The mean cumulative trust scores for the Mavic and Elios drones in the bright environment were as follows:

- HTCM questionnaire: Mavic = 53.39 (STD = 9.6), Elios = 52.82 (STD = 11.88).
- Jian's questionnaire: Mavic = 42.53 (STD = 8.70), Elios = 42.36 (STD = 7.96).

A t-test on the cumulative trust scores revealed no significant differences between the two drones:

- HTCM results: $t(57) = 3.16$, $p = 0.42$
- Jian's questionnaire results: $t(57) = 3.18$, $p = 0.71$

Since the results are not statistically significant, our findings do not support H1 and H2. But since we tested both the effects of appearance and noise, one of which was expected to affect trust positively, the other negatively, these results cannot reject H1 and H2, we need to study each of these factors in an isolated study.

2) Drone Capability: Analysis of H3: Our third hypothesis proposed that the Elios drone's capabilities in mapping missions in dark environments—specifically, its ability to increase brightness using mounted LEDs and capture clearer videos in low-light conditions—would lead to greater trust in the Elios drone compared to the Mavic drone. Note that the effects of appearance and noise are still affecting people's perception of the drones in this condition. As described in the Experiment Conditions section, we tested this hypothesis by comparing participants' reported trust in the Elios and Mavic drones in a dark environment.

The mean cumulative trust scores for the Mavic and Elios drones were:

- HTCM questionnaire: Mavic = 52.48 (STD = 7.9), Elios = 55.86 (STD = 9.41).
- Jian's questionnaire: Mavic = 41.1 (STD = 8.70), Elios = 45.06 (STD = 7.45).

A t-test on the cumulative trust scores revealed:

- A trend toward significance in the results of the HTCM questionnaire ($t(58) = 2.98$, $p = 0.07$).
- A statistically significant difference was found in the results of the Jian questionnaire ($t(58) = 3.18$, $p = 0.05$).

These findings provide weak support for H3, indicating that the improved visibility and video quality of the Elios drone in low light conditions contribute to greater trust compared to the Mavic drone.

B. Comparative Experiment Results

As outlined in the Experiment Design section, in the comparative experiment, after the participants viewed the videos of the two drones, they were asked to choose one drone as their assistant for the mapping mission described in the scenario and provide their reasoning for this choice. In the following section, we present the findings from the comparative experiment, highlighting how participants' choices and their reasons offer deeper insight into trust dynamics.

[1]https://www.mturk.com/

- **Drone Appearance**: This condition aimed to test H1 and H2, which hypothesized that participants would trust the Elios drone more than the Mavic drone due to its high-tech appearance. However, the high tone and pitch noise of Elios may affect trust inversely and neutralize the effects of its high-tech look. We recruited 60 participants from MTurk for this experiment condition, with 30 participants assigned to use the Elios drone and the other 30 assigned to use the Mavic drone. After excluding 2 participants who failed the manipulation check questions, we analyzed data from the remaining 58 participants.
  Analyzing the drone preference data showed that out of 58 participants, 33 (56.8%) preferred the Elios drone, while 25 (43.2%) preferred the Mavic drone as their assistant for the mapping mission. However, running a Binomial test revealed no significant difference in the number of participants who chose each drone ($p = 0.35$). Among the 33 participants who selected the Elios drone, 35 reasons were mentioned, with 29 related to appearance or noise (27 appearance-related and 2 noise-related). For the 25 participants who chose the Mavic drone, 23 reasons were mentioned, with 21 related to appearance or noise (14 appearance-related and 7 noise-related). In total, 41 reasons (80.57%) were appearance-related, while 9 reasons (19.42%) were noise-related. A Binomial test comparing the number of appearance-related to noise-related reasons yielded a statistically significant result ($p < 0.001$), indicating that appearance-related factors had a considerably greater influence on participants' preferences than noise-related factors. Figure 3 illustrates the percentages of participants who chose either Elios or Mavic and the reasons they provided for their choices.

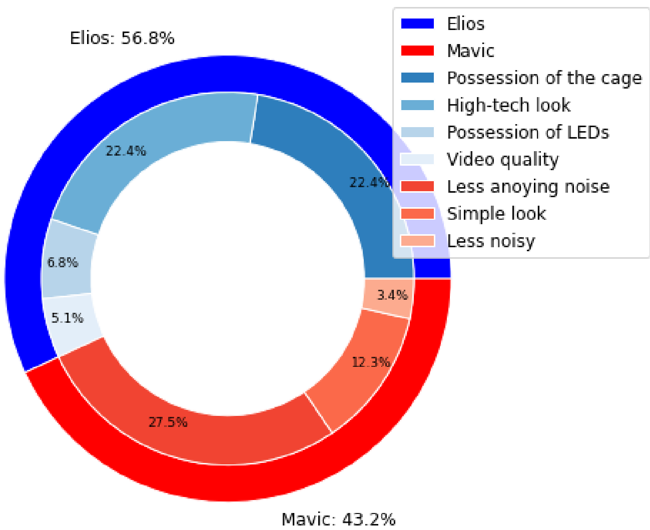

Fig. 3. Participants' preference among Elios and Mavic in the bright environment and percentages of the reasons mentioned by participants for their choice

  Analyzing the post-survey questionnaire data showed that the mean cumulative trust score gained by the Mavic and Elios drones in this experiment was 51.0 (STD = 7.78) and 51.93 (STD = 8.12) in the HTCM questionnaire and 40.86 (STD = 5.96) and 40.83 (STD = 7.33) in the Jian's questionnaire. Running a t-test on the arrays of cumulative trust scores revealed no significant differences between the HTCM ($t(58) = 4.06$, $p = 0.26$) and Jian's questionnaire ($t(58) = 4.29$, $p = 0.38$) results. These results are similar to the results obtained in the drone appearance condition of the isolated experiment.
  H1 and H2 inference: Results of this experiment condition show that a drone's appearance and noise can affect people's trust in the drone and people's preferences among multiple drones. However, these results do not provide enough support for accepting H1 and/or H2, as neither the post-survey questionnaire results nor the drone preference results show any evidence of higher trust in the Elios or Mavic drone. However, the significantly higher number of appearance-related reasons mentioned by people for selecting either drone revealed that drone appearance impacts trust much more than drone noise.
- **Drone Capability: Analysis of H3**: Our third hypothesis states that the added brightness by the Elios LEDs and the better quality of the Elios videos in the dark environment cause people to trust Elios better than Mavic as an assistant for performing mapping missions in a dark environment. We recruited 60 participants for this experiment condition from MTurk, with 30 participants assigned to use the Elios drone and the other 30 assigned to use the Mavic drone. We removed 1 participant who did not answer the manipulation check questions and analyzed the data of the remaining 59 participants.
  Analyzing the drone preference data showed that among 59 participants, 45 participants (76.27%) chose the Elios and 14 participants (23.73%) chose the Mavic as their preferred assistant to perform the mapping mission in a dark environment. Running a binomial test on the number of people who chose each drone as their preferred assistant returned $p < 0.001$. This indicates that the number of people who chose the Elios is significantly higher than those who chose the Mavic.
  Among the 53 reasons cited by 45 participants who selected the Elios drone as their preferred assistant, 37 were related to capability. The remaining 16 reasons pertained to appearance and noise, which were not the primary focus of this experimental condition. Among the 12 reasons provided by 14 participants who chose the Mavic drone as their preferred assistant, there were 4 capability-related reasons and 8 related to appearance and noise. In total, there were 41 (63.9%) capability-related reasons and 24 (36.1%) appearance and noise-related reasons. A binomial test comparing the number of capability-related reasons to appearance and noise-

related reasons returned p = 0.02. This indicates that capability-related reasons have a significantly higher impact on participants' preference for drones and, consequently, on their trust in a drone compared to appearance and noise factors. Figure fig:performance pie depicts the percentage of participants who chose the Elios and Mavic, as well as the reasons they mentioned for selecting each drone.

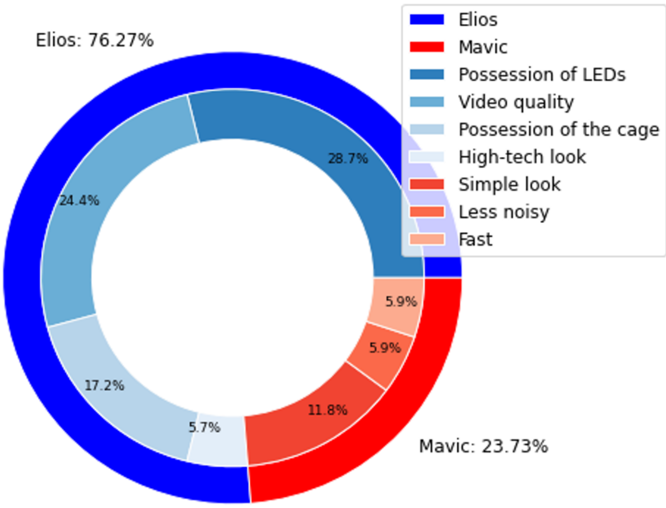

Fig. 4. Participants' preference among Elios and Mavic in the dark environment and percentages of the reasons mentioned by participants for their choice

Analyzing the post-survey questionnaire data, we were looking for evidence that supports or rejects H3. The mean cumulative trust score gained by Mavic and Elios in this experiment was 44.96 (STD = 13.43) and 58.58 (STD = 10.33) in the HTCM questionnaire and 35.62 (STD = 9.69) and 43.93 (STD = 7.65) in Jian's questionnaire. Running a t-test on the arrays of cumulative trust scores revealed significant differences between the HTCM ($t(59)=1.80$, $p < 0.001$) and Jian's questionnaire ($t(59)=2.25$, $p < 0.001$) results.

H3 inference: The results of this experiment condition confirmed that a drone's capability to perform a task affects individuals' trust in drones. These results provide enough support for H3 and agree with the results of the other works on the effects of a robot's capability on human trust.

V. Discussion

The contribution of this work is twofold. First, we provide empirical findings on how different factors influence individuals' trust in a drone. Second, and more importantly, we introduce and evaluate a novel experimental design that can be applied to future studies to assess the factors influencing human trust in robots.

A. Results

Drone capability is the most significant trust factor, followed by appearance, with noise having the least influence. These findings highlight the dominant role of capability in shaping trust, while appearance and noise act as secondary but still important factors.

1) Drone Noise: In the comparative experiment, only 16.9% of participants mentioned noise as a factor in their drone selection, while 83.1% focused on appearance. This suggests that appearance influences trust approximately four times more than noise. Additionally, both tone and pitch of drone noise affected trust—quieter drones were perceived as less intrusive.

2) Drone Appearance: A high-tech appearance had mixed effects: some participants viewed it as a sign of advanced capability, while others found it complex and difficult to use. Protective cages significantly improved trust, mentioned 12 times in the appearance condition and 15 times in the capability condition, even though they did not impact task performance. In dark environments, the protective cage was valued not only for drone protection but also for human safety, as participants feared injury from exposed propellers.

3) Drone Capability: As expected, capability had the strongest influence on trust, with Elios being preferred due to its superior performance in dark environments. Capability-related reasons were cited more frequently than appearance-related ones. Mavic's simplicity was a key reason for selection in the appearance condition but was rarely mentioned in the capability condition, indicating that performance outweighs ease of use when functionality is critical.

Overall Insights: These findings highlight the dominant role of capability in shaping trust, with appearance and noise acting as secondary but still important influences.

B. Experiment Design

Both experiment designs in this study followed a similar approach and materials, but the comparative method yielded more comprehensive results. While we tested drone appearance and capability using both isolated and comparative designs, the comparative experiment more effectively revealed trust differences across conditions. Additionally, participants' preferences and reasoning provided valuable insight into the factors influencing trust and their relative importance.

The comparative experiment outperformed the isolated experiment for two key reasons:

- Direct Comparison: In the isolated experiment, participants viewed only one drone, limiting their ability to assess the impact of drone appearance on trust. In contrast, the comparative method allowed participants to evaluate both drones side by side, leading to clearer distinctions in trust levels based on direct comparisons.
- Reasons for Choice: In the comparative experiment, participants explained their reason for selecting each of the drones as their preferred assistant, clarifying which features (e.g., protective cage, LEDs, video quality, noise) influenced trust. This approach helped determine the relative importance of each feature, which was unclear in the isolated experiment.

Overall, the comparative experiment provided richer insights into factors affecting trust in drones. This methodology is not limited to human-drone interaction but can be applied more broadly to human-robot trust and interaction studies.

VI. Conclusion and Future Work

We evaluated trust in two drones with different features, including appearance, noise levels, protective cages, LEDs, and capabilities (e.g., video quality in low-light conditions). However, these factors were not analyzed separately, leaving their impacts unclear. A promising direction for future research is to isolate each factor and assess its effect on trust independently under controlled conditions. Additionally, researchers could explore how drone appearance influences trust erosion by using different drones with identical failures. Further, the effectiveness of trust-repair strategies could be tested by demonstrating varying recovery behaviors after failures [35], [36].

Our findings offer insights for robot designers on designing trust-enhancing exteriors while balancing factors like size, weight, noise, battery life, and capabilities. Finally, this research presents a methodology that future studies can apply to evaluate human-robot collaboration systems in real-world contexts. These results also guide researchers in designing experiments for more insightful results.

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