Published: 10 November 2025

HAI '25: International Conference on Human-Agent Interaction
November 10 - 13, 2025
Yokohama, Japan

POSTER

Thumbs up or Pointing? Guiding a Delivery Drone under Uncertainty in Public Space

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Open Access Support provided by:

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https://doi.org/10.1145/3765766.3765837
ISBN: 9798400721786

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Abstract

Drones will soon deliver packages to recipients in public spaces, where drones may encounter difficulties identifying safe drop-off locations. Such uncertainties can reduce trust and raise safety concerns. This augmented reality study investigates how recipients perceive being asked to guide the drone in uncertain situations using hand gestures, and to what extent they feel comfortable with different levels of involvement. Results show that participants preferred a basic level of involvement, which received higher trust and usability scores than either no or high involvement. We recommend involving recipients in the final stage of delivery to not only support drone operations but also improve recipient trust and clarity in uncertain conditions.

CCS Concepts

• **Human-centered computing → Gestural input**.

Keywords

Human-Drone Interaction, User control, Public, Delivery application, Augmented Reality

ACM Reference Format:
Shiva Nischal Lingam, Jakub Woziwodzki, Mohammad Obaid, Marieke Martens, and Pavlo Bazilinskyy. 2025. Thumbs up or Pointing? Guiding a Delivery Drone under Uncertainty in Public Space. In *13th International Conference on Human-Agent Interaction (HAI '25), November 10–13, 2025, Yokohama, Japan.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3765766.3765837

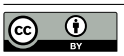
1 Introduction

Agents such as autonomous drones will enter public spaces for services like package deliveries and interact with humans as recipients ordering the packages [7, 10]. In public spaces, drones can face difficulty identifying safe drop-off locations due to sensor limitations or environmental variability. When facing such uncertainty, agents must communicate their state transparently to enhance user awareness and trust [6]. Drones can convey state information, for instance, through signals such as LEDs or audio cues [2, 8, 13, 15]. Besides signaling intent in uncertain situations, drones may also seek input from humans to maintain trust and ensure safety. Human-Drone Interaction (HDI) domain experts [7] and public users [10] expressed a possibility to give recipients control when drones encounter operational challenges, which are difficult for remote operators to comprehend. Limited knowledge exists regarding the extent to which recipients can control drones, given their lack of experience and associated safety concerns. Prior HDI research has explored human input for high-level control via hand gestures [4, 12, 16] and pointing gestures [11]. While existing literature explores drones signaling their intentions and humans using gestures for control, there is a research gap regarding the extent to which recipients feel comfortable using gestures to guide drones under uncertainty. Addressing this gap is critical for designing drones that can operate reliably under real-world uncertainty, thereby improving ecological validity, safety and trust in HDI.

To fill this gap, our research investigates how recipients perceive varying levels of involvement during drone deliveries under uncertain conditions in a public space. Building on Parasuraman's framework of human–automation interaction [14], we examined three levels of recipient involvement: (a) no input, where the drone departs after signaling uncertainty; (b) confirming or rejecting the drone's chosen landing spot; and (c) help the drone select a landing spot. Recipient perception is investigated with perceived safety, trust and usability.

2 Methods

The Augmented Reality (AR) experiment was conducted in an outdoor environment to maintain ecological validity, while ensuring participant safety by integrating virtual drone elements within the participants' field of view. The drone model was developed using



HAI '25, Yokohama, Japan

ACM ISBN 979-8-4007-2178-6/25/11
https://doi.org/10.1145/3765766.3765837

Blender (version 4.2) and Unity3D (version 6). Participants were welcomed, were informed about the purpose of the experiment, provided informed consent, and completed an intake questionnaire. They wore a Meta 3 headset and experienced scenarios involving a drone delivering a package. In each scenario, the drone entered the space, hovered 7 m from the participant [9]. The drone signaled uncertainty about its landing intention using onboard LEDs and audio cues, which participants had been briefed on before the experiment. Depending on the scenario, the drone then either (1) aborted the task and departed [low involvement], (2) requested a gesture such as thumbs-up to confirm, and thumbs-down to redirect and repeat [medium involvement], or (3) asked the participant to point to a safe landing spot and confirm with an 'okay' gesture [high involvement]. When a gesture was recognized by the headset, a hand-locked UI element displayed the detected input. Scenario order was randomized. After each scenario, participants completed Likert scale questionnaires on trust [5], perceived safety, and usability [1] of the three levels, followed by a semi-structured interview. The study design was approved by the Ethics Review Board of the TU Eindhoven.

Twelve participants (nine male, three female), aged 18 to 34, with limited drone experience, participated in the study. Five had completed secondary education, five held a bachelor's degree, and two had a master's degree.

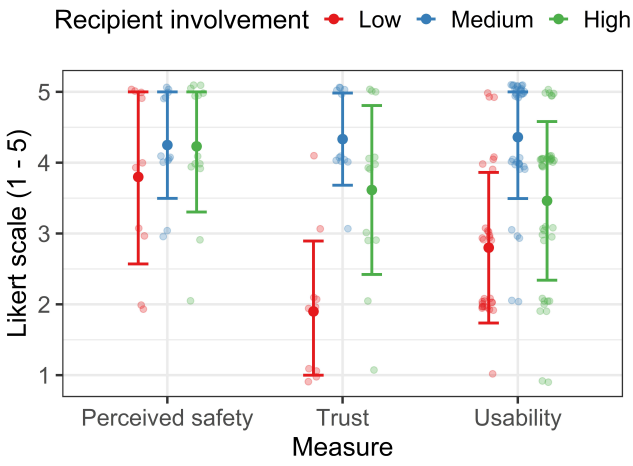


Figure 1: Mean and standard deviation of perceived safety, trust, and usability for the three levels of recipient involvement with overlaid individual data points. Likert scale items ranged from 1 (strongly disagree) to 5 (strongly agree).

3 Results

Figure 1 shows that medium involvement received the highest trust and usability scores, while low involvement received the lowest scores for perceived safety, trust, and usability among the three involvement levels. A significant effect of involvement level was found on trust ($F(2, 11) = 17.51$, $p < 0.001$) and usability ($F(2, 11) = 19.47$, $p < 0.001$), but not on perceived safety ($F(2, 11) = 0.74$, $p = 0.49$). Post-hoc pairwise comparisons with Bonferroni correction revealed that the low level involvement scored significantly lower than both medium and high levels for trust ($p < 0.001$) and usability ($p < 0.05$). Medium involvement received the highest usability scores among the three levels.

Thematic analysis [3] was conducted on the interview transcripts. Participants appreciated sharing medium-level control with the drone: "Medium involvement (...) was very clear what I had to do. The interaction was very simple." (P2). They struggled to predict the drone's actions when recipient input was not considered in low involvement. Departures without explanation caused frustration, with safety aborts viewed as service failures. While flexibility in pointing to the landing spot was valued in high involvement, participants felt uncomfortable piloting the drone, describing it as them having "too much control" (P3) and feeling "more responsible if it (drone) fails" (P9). Participants requested intent communication beyond uncertainty states, seeking clear updates on the actions.

4 Discussion & conclusion

The AR study found that participants preferred to guide the drone at a basic level, such as confirming the drop-off spot suggested by the drone under uncertainty. This input can provide the drone with situational awareness that remote operators may lack and can support safer deliveries in uncertain conditions. Basic involvement improved participants' clarity about their role and the drone's intentions, increasing trust and making the thumb gesture seem usable and simple. In contrast, a lack of user involvement led to confusion and frustration, and safety-related departures were perceived as service failures, which reduced trust and usability. We recommend involving recipients in the final stage of the delivery process, not only to help confirm the drop-off location, but also to improve clarity and trust. Participants reported lower usability and discomfort when they had to take on more control, for instance, when using pointing gestures to specify a landing location. They associated higher involvement with greater responsibility for the operation, leading to a sense of accountability for potential disruptions, which motivated them to avoid taking on such responsibility. Future research should examine appropriate levels of user involvement, the boundaries of user responsibility, and effective ways to communicate these to recipients. Participants noted a lack of clarity regarding drone actions, especially under the low-involvement condition. Future research should focus on improving intent communication by conveying not only states of uncertainty but also actions through flying behavior [9], lights and audio cues [8, 10].

The study is limited by its small sample size, student-dominated population, and the absence of bystander perspectives, which restricts the generalizability of the findings. The perceived safety scores did not differ significantly, and one possible explanation could be that the AR setup minimized the sense of physical risk. Future work should replicate our study with larger, more diverse samples and incorporate bystander viewpoints in controlled public environments. In conclusion, a basic level of recipient engagement, through a single confirm or redirect gesture combined with clear communication of drone state, can support drone operations in uncertain situations while improving clarity and trust of the user.

Acknowledgments: Dutch Research Council funded this research through the project "Safety Solutions for Autonomous Vehicle Integration in Urban Mobility: Efficient and Reliable Acting in an Uncertain and Unreliable World" (NWA.1292.19.298).

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