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DroDelivery: User-Centered Concepts for Intent-Based Communications of a Delivery Drone in Public Spaces

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DroDelivery: User-Centered Concepts for Intent-Based Communications of a Delivery Drone in Public Spaces

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ABSTRACT

Drones will deliver packages in public spaces and interact with humans as recipients of the packages and as bystanders passing by. Clear communication of drone intentions is critical for reducing uncertainty and ensuring public safety. Limited research exists on interface designs addressing communication with diverse human roles. This user-centered study introduces six interface concepts utilizing lights, displays, and projection technologies to communicate delivery intentions with both recipients and bystanders. The concepts also offer cues for vertical movements, proximity-based warnings, and spatial guidance. An online survey demonstrated that all six concepts were perceived as more intuitive, clearer, and socially acceptable than having no interface. Projections were favored for requiring less visual scanning, displays for conveying direction and progress, and lights for offering familiar cues. Specifically, helipad-like projection was appreciated for providing information that could guide recipients toward the package and signal bystanders to maintain distance. Future research should address practical implementation challenges and potential interpretation issues, particularly for bystanders positioned farther from the drone.

CCS CONCEPTS

• **Human-centered computing → HCI design and evaluation methods**.

KEYWORDS

Aerial Robot, Human-Drone Interaction, Delivery Robot, Interface, User-Centered Design, Public Space

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1 INTRODUCTION

Robots (e.g., drones) are increasingly becoming integral to public life, particularly in package delivery. Companies like Amazon and Wing are using drones to transport medical supplies and food worldwide [9]. Such drones will enter public spaces to interact with humans during the delivery of packages. Global academic and industry experts predict delivery will dominate public-space applications for Human-Drone Interaction (HDI; a sister domain to Human-Computer Interaction(HCI)) in the next decade [17], highlighting its growing relevance and the frequency of interactions between drones and humans. In public spaces, humans can typically interact with delivery drones in two roles: recipients, who directly engage with the drone to receive packages, and bystanders, who are passive observers in the vicinity [17]. In both roles, humans may experience uncertainty about a drone's intentions during interactions, often due to unfamiliarity with drone technology and delivery processes. Based on an outdoor user-based study [6] and an expert interview study [17], designing to reduce uncertainty about the drone intentions is critical for improving natural, safe and trustworthy HDI across diverse cultural contexts and public spaces. Clear communication of a drone's intentions presents a possible approach to reduce feelings of uncertainty, improve usability, and increase public acceptance [7, 22, 25].

Prior HCI research [3, 10, 13, 14, 22, 26, 28] has investigated communication cues through robot behavior and Human–Machine Interfaces (hereafter referred to as "interfaces") such as visual and auditory interfaces, among others. Although robot behavior can implicitly convey intent in drone delivery scenarios, recipients expressed a need for explicit signals, particularly auditory and visual, to feel more certain during HDI [18]. Audio interfaces present practical challenges: the loud propeller noise of current large-scale delivery drones can obscure audio signals, reducing their effectiveness. Visual interfaces have been explored as a means to effectively communicate drone intentions using lights [8, 26], displays [11, 30], and ground projections [22]. Previous HDI studies have primarily investigated how drones convey "emotions" to engage recipients [11, 30] or communicate intentions on lateral dimension [8, 22, 26]. However, these efforts offer limited exploration of communication during vertical movements, which is typical of drones that descend into public spaces [18]. In addition, previous work has predominantly focused on recipient-facing HDI, users who anticipate drone delivery, while paying limited attention to bystanders, who may not expect or actively seek interaction in shared environments.

Limited research has addressed the needs of diverse human roles in the design of visual interfaces that communicate drone intentions during critical delivery scenarios, particularly those involving vertical movements of a drone. Addressing this gap is essential to reducing uncertainty, building trust, and supporting the safe integration of drones in public spaces. This study aims to design and evaluate six interface concepts to convey drone intentions visually to both recipients and bystanders in a public space delivery context. The concepts were developed through a user-centered design process and then evaluated using an online survey. We hope that the applicability of the concepts extends beyond package delivery, as they are designed to convey the drone's real-time intentions and support interaction with diverse human roles across various public-space applications.

The contributions of this research are two-fold:

- Incorporates two user perspectives, recipients and bystanders, in the design and evaluation of interface concepts for flying robots in public spaces.
- Presents six designs that visually communicate not only drone states, but also directional movement, ground proximity, and spatial guidance for HCI.

2 BACKGROUND

This section discusses the background concerning human roles in public spaces, the necessity of communicating drone intentions, and the use of visual interfaces for communication.

2.1 Human roles in public space HDI

HDI domain experts [17] identified three primary human roles in public space interactions with drones: operator, recipient, and bystander. Among these, recipients and bystanders comprise the majority of public users, often with limited or no prior experience interacting with drones. Previous HDI research [11, 18, 22, 26, 30] has focused primarily on recipients. Drones in HDI are rarely designed to include the perspective of bystanders [16]. Recipients typically have prior knowledge of the drone's purpose and intentions, which may reduce their feelings of uncertainty during the delivery process. Bystanders, who are likely to encounter delivery robots more frequently than recipients [23], often have less familiarity or information about the intentions of the drone. This limited understanding, as highlighted in the user interviews conducted by Lingam et al. [19], can increase bystanders' feelings of uncertainty compared to recipients. Kramer et al. [16] made an initial effort to incorporate bystander perspectives by conducting design workshops on medical delivery drones, specifically addressing the state before approaching recipients for drop-off. However, the authors did not integrate the perspectives of both recipients and bystanders in the design of interfaces and did not address critical interaction states. These critical states include: during, and after the package drop-off [19]. These states will involve drones descending to low altitudes in close proximity to people, which can increase perceived uncertainty and safety risks among those nearby [18]. Neglecting these critical scenarios and the inclusion of different human roles in the drone designs can increase perceived uncertainty, reduce public trust in drone delivery and raise concerns about the applicability of existing design recommendations for HDI in public spaces.

2.2 Need to communicate drone intent

Clear communication of drone intent can reduce perceived uncertainty, enhance trust and improve perceived safety for humans interacting with drones in public environments [18]. Past HCI research [18, 19, 24, 31] has examined user needs and suggested communicating drone intentions throughout the delivery process. Insights from user interviews and focus groups [19] reveal that recipients value transparent information about estimated arrival time, directional movement, retraction, and landing location, as these cues contribute to feelings of safety and certainty when retrieving packages. Two user studies [24, 31] identified recipient preference for clear directional cues to support natural and intuitive HDI. Existing experimental HDI studies offer limited empirical insights and design guidance on how drones should communicate their intentions with interfaces during the critical stages of delivery.

2.3 Visual interfaces for drone communication

HCI literature has explored the use of visual interfaces such as LEDs, displays, and projection technologies for communicating the intentions of a drone with recipients in close encounters [11, 22, 26, 30]. Szafir et al. [26] conducted an indoor study demonstrating that LEDs communicating the drone's lateral movements improved the ability of recipients to predict the drone's intentions compared to a baseline without LEDs. While existing mental models of vehicular signals support the interpretation of lateral movements, it remains unclear how these findings translate to the communication of vertical movements, which are specific to drones descending in public spaces. Herdel et al. [11] used a drone display to convey five emotions, eliciting empathy from the recipients and narratives about the drone's intentions. Similarly, Yeh et al. [30] demonstrated that displaying emotions on a drone using a cartoon-like face (with eyes and a mouth) made recipients feel more comfortable, leading them to approach the drone compared to a drone lacking such expressive displays. These emotionally engaging drones differ in form and function from delivery drones, which can lead to differing human expectations. Emotionally engaging drones are designed to foster emotional connections with humans, whereas delivery drones are expected to communicate functional intentions, such as signaling landing or drop-off [18].

These distinctions between drones designed for lateral communication or emotional engagement and those used in delivery scenarios challenge the direct applicability of prior findings. They highlight the need to incorporate context-specific user needs when designing visual interfaces for delivery drones.

3 DESIGN STUDY

The concepts were designed through a series of focus groups with participants, drawing inspiration from prior HCI studies [5, 13, 15, 30]. Following the focus groups, the concepts were translated into virtual prototypes with the assistance of a designer experienced in real-time 3D interaction, shader programming, and Unity-based systems. His background in interactive system design supported the technical development and ensured the adaptability of the concepts for the user research.

Participants were recruited through an advertisement shared on social media. They were provided with basic information about the study aim, drone delivery process, use of interfaces for intent communication, and a few constraints were laid out to direct and focus the design process. The roles of recipient and bystander were introduced to participants, adapted from a user study on delivery drones [19]. Participants were provided with pens and paper and asked to individually brainstorm concepts for three interface types—LEDs, display, and projection—and to explain the rationale behind their designs. These visual interfaces were selected to keep the study focused and were based on the recommendations from prior research on HDI [19, 26, 30] and delivery robots [10, 14]. The concepts addressed three critical states of the drone delivery process [18, 19]: (1) drop-off (of the package), (2) take-off, and (3) preparation for drop-off and take-off. During the action states (1 and 2), the drone was in motion, while in the preparation state (3), the drone hovered. To reduce reliance on learned associations, we intentionally refrained from using color, text, or culturally specific symbols [5]. Instead, we encouraged participants to propose intuitive metaphors and light-based animations that could be universally understood without requiring users to interpret unfamiliar visual 'languages'. Cyan was later chosen for the light animations as it was considered a neutral color in the literature, without inherent associations with robotic states, such as those used for automated vehicles on public streets [2, 4, 29].

Participant inputs were audio-recorded, transcribed, and complemented by sketches produced during the initial focus groups. The first author summarized these inputs and shared them with the designer, who created virtual models using Blender software. These models were implemented in Unity 3D using a virtual environment adapted from a study on delivery drones [18]. The resulting videos of the models were presented to participants, and their feedback was gathered. This process was repeated until all participants expressed satisfaction with the proposed concepts.

3.1 Participants

Seven participants (3 male, 4 female), aged 25 to 32 years (M = 28.5, SD = 2.23), joined the three focus groups: two with two participants each, and one with three participants. All the participants had limited experience with ground robots and drones, with no prior experience with delivery drones. The group comprised individuals from three cultural backgrounds: four Indian, two Chinese, and one Dutch.

3.2 Concepts

Six concepts are presented below, two for each interface: lights, display, and projection. The concept illustrations are provided in Figure 1, and the videos are provided in the supplementary material.

3.2.1 Indicator lights. This design uses two vertically placed LED lights on the drone's "face" to signal the direction of vertical movement, inspired by motor vehicle turn signals on roads [13, 21]. The bottom LED activates and blinks during drop-off preparation and continues blinking through the drop-off phase as the drone descends. Once the package is placed, it deactivates. During take-off preparation, the top LED activates and begins blinking, continuing through the take-off phase as the drone ascends. Both lights turn off once the drone leaves the vicinity. The design aims to intuitively communicate the drone's vertical motion to users throughout the delivery process.

3.2.2 Rotor lights. This design involves one LED beneath each rotor, drawing on the familiar visual style of the DJI Mavic Mini 2. This concept incorporates rotor position awareness to enhance safety and communicate the drone's intent. The LEDs operate in unison, with blinking frequency reflecting the drone's proximity to the ground. In drop-off preparation, all LEDs emit a steady light. During drop-off, the LEDs blink with increasing frequency as the drone approaches the ground. After drop-off, the drone enters take-off preparation, returning to steady light. During the take-off, the LEDs blink again, and this time with decreasing frequency as the drone ascends. The high blink rate near the ground is intended to signal recipients and bystanders to maintain distance, thereby improving situational awareness and safety. Once the drone exits the area, all LEDs turn off.

3.2.3 Direction display. A front-mounted screen displays arrows to signal vertical movement, inspired by elevator displays and prior work using arrows to indicate robot motion on the ground [13, 28]. Animated arrows are proposed to depict real-time movement, as they are intuitive and easy to interpret. During drop-off preparation, a static downward arrow appears, becoming animated during drop-off to represent descent. A static upward arrow is used in take-off preparation, which then animates during take-off. The arrows deactivate after take-off, indicating that the landing area is clear for human occupation once the drone has exited the vicinity. This simple visual language will help users understand the drone's current state and intended movement with minimal ambiguity and without the need to track multiple interface elements.

3.2.4 Progress display. This display combines a drone symbol with a progress bar to show delivery state progression. Drawing from mobile phone battery indicators and research on light-based robot communication [1, 8], the interface shows a drone with a package during drop-off preparation and drop-off, and a drone without a package during take-off preparation and take-off. The progress bar remains static during preparation phases and animates during action phases, filling with white as the drone completes each phase. Once the drone departs, the interface deactivates. The design intends to offer feedback on the progression of each drone state without requiring interpretation from the drone behavior.

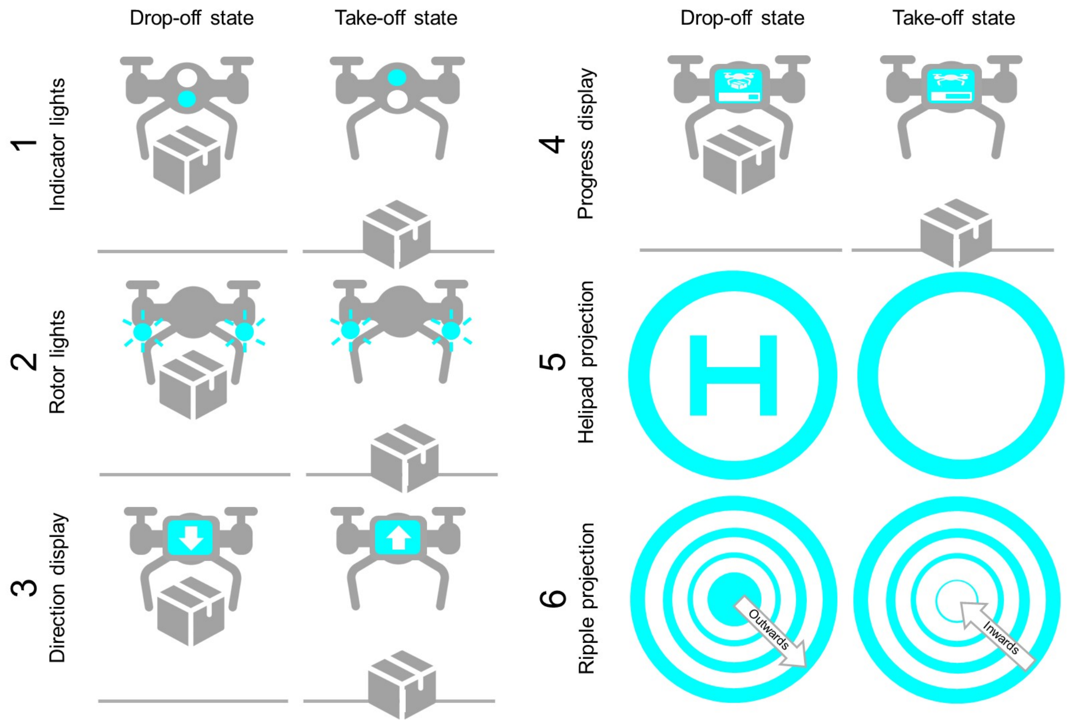

Figure 1: Six interface concepts developed for intent-based communication of a delivery drone in public spaces. Each concept includes both a drop-off and a take-off state, categorized as follows: (1) Indicator lights, (2) Rotor lights, (3) Direction display, (4) Progress display, (5) Helipad projection, and (6) Ripple projection. Concepts 1 and 2 use lights, concepts 3 and 4 utilize a display, and concepts 5 and 6 employ ground projections to convey the drone's intentions.

3.2.5 Helipad projection. This concept uses ground projections to visualize both the landing spot and a safety zone, alongside signalling the drone's state. The projection includes a blinking "H" and a surrounding ring, building on the intuitive helipad symbol. The projection of the letter "H" informs about the landing spot for the package, while the circular ring signals to maintain a safe distance and avoid interfering with the drone. For safety purposes, the size of the ring remains constant regardless of the drone's state. During drop-off preparation, the "H" remains visible, then blinks throughout drop-off to signal the drone's descent. The ring remains static throughout to define a safe boundary for recipients and bystanders. In take-off preparation, the "H" disappears, indicating the package has been delivered. During take-off, the ring begins blinking and fades as the drone leaves the area. Helipad projection design aims to visually delineate the drone's landing intentions and the area it will occupy.

3.2.6 Ripple projection. This concept builds on concept 5 by featuring a ground projection with a circular design, and it introduces animated concentric rings that resemble water ripples to indicate drone activity. This ripple-like animation provides intuitive spatial clarity on the drone's intentions without relying on textual cues. The inner circle represents the landing spot, while the outer ring indicates the drone's spatial footprint. During the drop-off preparation phase, both elements are projected statically with fixed radii. In the drop-off state, the rings animate outward from the center, repeating the motion to signify descent until the package is placed. In the take-off preparation phase, the inner circle disappears, indicating that the package has been delivered. The outer ring remains to remind humans to keep a safe distance and not interfere with the drone. During take-off, the rings animate inward, collapsing toward the center to signify departure. Ripple projection design intends to communicate the drone's state and landing spot information.

4 USER-EVALUATION EXPERIMENT

The online survey was conducted in English. Participants were recruited through the Prolific platform and were assigned one of the two human roles (i.e., recipient, bystander). The survey began by outlining with basic information on the study aim and delivery drones. Participants were briefed on the (assigned) human role [19], similar to thebriefings provided in Section 3. They provided consent, demographic information, and their prior experience with drones. Participants were shown seven videos: six depicting design concepts developed through the design study and one Baseline condition (no interface). In each video, the drone entered the public space, maintained a distance of 7 m [18], and performed the package delivery task by executing the three states (i.e., preparation, drop-off, take-off). The presentation order of videos and the assignment of human roles were randomized. After viewing each video, participants rated seven items on a 7-point Likert scale measuring intuitiveness [27], clarity of intent, and social acceptability

(SAS) [13]. An open-ended question prompted participants to elaborate on their subjective impressions and the rationale behind their ratings. Reliability check questions were incorporated to verify that participants understood the context and remained attentive throughout the study [4]. All participants passed the checks. The entire experiment took approximately 20 minutes, and participants were compensated with £3. The study design was approved by the Ethical Review Board of Eindhoven University of Technology.

4.1 Participants

Sixty participants (30 female, 29 male, 1 non-binary), aged between 21 and 76 years (M = 36.6, SD = 13.9), completed the survey. Most participants (n = 59) had previously seen a drone, and 13 reported owning one. Additionally, 51 participants had observed a drone flying in proximity (within 10 m distance), and 29 had experience piloting a drone. Overall, participants expressed a generally positive attitude toward interacting with technology (M = 4.2, SD = 1.5). Thirty participants were assigned to each of the two roles: recipient or bystander.

4.2 Analysis

The Likert scale data (N = 60) were aggregated across the three measures for each participant and condition, and analyzed using parametric tests to achieve statistical accuracy, consistent with prior HCI studies [4, 13, 18]. A mixed ANOVA was conducted to examine the within-subject effects of interface type and the between-subject effects of human role, followed by Bonferroni-corrected pairwise comparisons. Only statistically significant results are reported below for brevity. The textual responses were subjected to reflexive thematic analysis to understand the participants' subjective impressions about the concepts. Participant quotes were reported with "R" and "B", respectively for recipient and bystander roles, followed by ID number.

4.3 Results

4.3.1 Likert scale data. Figure 2 illustrates that all six concepts received higher ratings for intent clarity, intuitiveness, and SAS compared to the Baseline. Among the six concepts, greater variability in scores was observed for the two light-based interfaces. A mixed ANOVA revealed a significant main effect of interface with a large effect size ($F(6, 59) = 19.85$, $p < .001$, $\eta^2 = .21$), while no significant main effect of role or interaction effect was found. Significant and main effects of interface were observed for intuitiveness ($F(6, 59) = 18.9$, $p < .001$, $\eta^2 = .2$) and SAS ($F(6, 59) = 24.02$, $p < .001$, $\eta^2 = .24$) . Pairwise comparisons revealed significant differences between the Baseline and each of the six interfaces ($p < .001$); however, no significant differences were found among the six concepts themselves.

4.3.2 Thematic analysis of textual responses. Analysis revealed three themes such as the *importance of clear drone intentions*, *reflections on concepts*, and *reflections based on roles*.

Importance of clear drone intentions: Participants preferred receiving information through visual interfaces, as the absence of such cues hindered their ability to interpret and anticipate the drone's intentions. The lack of clarity contributed to feelings of uncertainty and concerns about safety, making it difficult to determine when and how to act (e.g., whether to approach the landing spot or not): "Lack of interface can cause uncertainty about timing and safety. I'd stay alert and maintain distance until the drone finishes its action" (R30). Participants clearly understood the drone's delivery intentions through the interfaces and supported their use, noting that "even minimal visual cues would greatly improve clarity and make the interaction feel safer and more predictable" (B17).

Reflections on concepts: Participants found projections more intuitive and "attention-grabbing" (B4) than lights or displays, largely because the projection appeared on the ground within participants' line of vision. The helipad projection was criticized for its less intuitive symbol "H" (B7), while some found the animation speed and meaning of the ripple projection difficult to interpret. The visibility of projections on the ground in bright daylight was a concern: "when the Sun is scorching, it will [be] hard to tell the [projection] lights" (B10). The displays were perceived as intuitive. The directional display helped to "signal the direction of the drone" (B1). The progress display informed on each state's progression, and the recipients "immediately understood when it was safe to approach and retrieve [the] order" (R5). Lights were valued for their familiarity. Indicator lights were seen as "universally used" (B10), and rotor lights helped recipients feel confident to "only approach once lights stabilized, confirming safe retrieval" (R5). However, indicator lights needed "additional attention for differentiating the two [LEDs], which might be confusing" (R28), and rotor lights lacked clarity on "how close I [participants] could stand [from the drone]" (B30).

Reflections based on roles: Interfaces that displayed clear static and animated cues, such as the ripple and helipad projections, were generally appreciated by both recipients and bystanders. Recipients valued the predictability and clarity of the projections, particularly when retrieving packages, and were observed approaching the projected landing spot once the "animation stopped" (R5). Bystanders noted that the projections "drew attention without being intrusive" (B17) and "made it obvious where I [bystander] could not walk" (B6), especially with the helipad projection. These cues sparked interest in the delivery service itself, with a few bystanders expressing a desire to "order an item and have the drone deliver it" (B14).

Recipients reported difficulty spotting the blinking lights located on the front of the drone, although lights mounted on the rotors were easily identifiable. Bystanders preferred cues visible from multiple angles, as they intended to position themselves at a safe distance from the drone. However, this distance sometimes led to challenges in reading the interfaces. Some bystanders noted that indicator lights and progress displays were not easily interpretable from afar and emphasized that readability "rests on [interfaces] being noticeable and recognizable from a distance" (B9). The drone symbol above the progress bar was not easily noticeable for bystanders. In contrast, bystanders rarely reported readability issues with the directional display, and appreciated its simplicity and capacity to "enhance safety, awareness, and bystander comfort" (B1).

5 DISCUSSION & FUTURE WORK

This study introduces six concepts, designed and evaluated with users, to visually communicate drone intentions in a public space delivery context. Using lights, displays, and projection technologies, the concepts were developed through a user-centered design

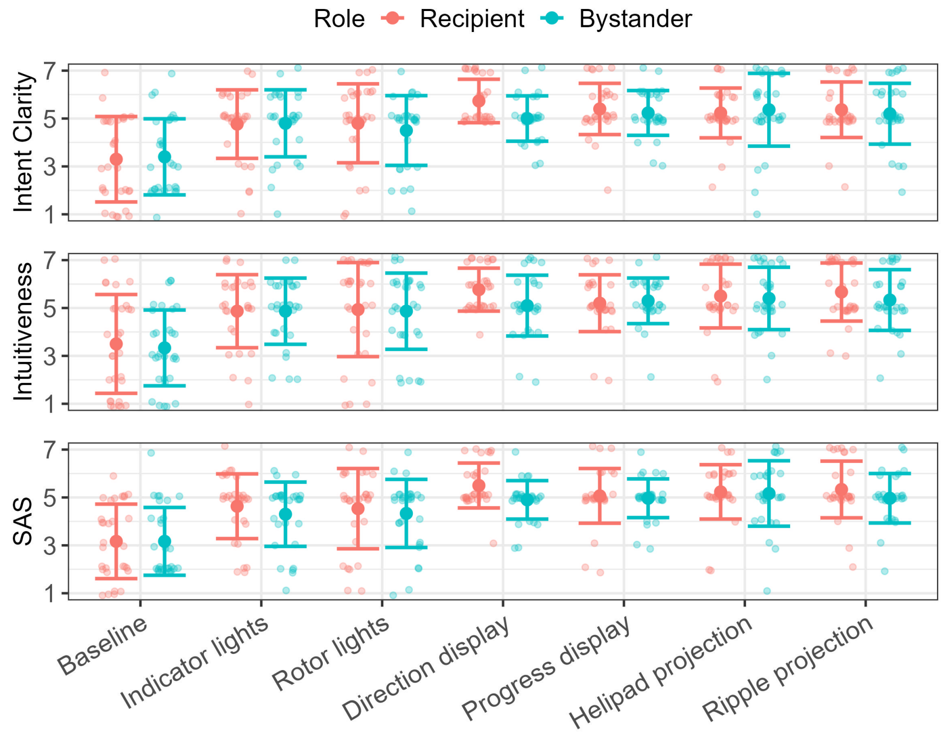

Figure 2: Mean and standard deviation for intent clarity, intuitiveness and SAS (social acceptability scale) across six concepts and baseline , shown separately for recipient and bystander roles. Individual data points are overlaid. The Likert scales ranged from 1 (strongly disagree) to 7 (strongly agree).

process and evaluated through an online survey that captures the perspectives of both recipients and bystanders. All six concepts improved clarity, predictability, and social acceptability compared to a drone without an interface. Specifically, projections were appreciated for their intuitiveness and attention-grabbing qualities. Role-specific feedback revealed practical concerns regarding both the implementation of concepts and the distance between users and the drone. Although all concepts primarily communicate the drone's drop-off, take-off, and preparation intentions, they add value by conveying information through varied formats and levels of specificity. Table 1 summarizes the advantages and shortcomings of the six concepts.

5.1 Projections: convey landing location & spatial footprint

One projection concept draws inspiration from a helipad-like design, while the other features a natural water ripple effect. Both concepts aim to provide intuitive and visually salient cues for conveying not only the drone's state but also spatial information. The two concepts communicate drone's status, intended landing location, and spatial footprint on the ground, while also requiring low visual scanning due to their placement within the human line of sight. Findings from the survey study indicate that landing spot information supports recipients in approaching for package retrieval, while the spatial footprint, particularly of the helipad projection, helps bystanders identify areas to avoid for safety. This extends the current capabilities of projection-based interfaces in HCI, building on prior applications such as guiding recipients in garbage pickup and disposal [22] and communicating personal space to improve pedestrian safety [28]. User feedback revealed areas for refinement prior to practical implementation. Future research should address these by, for example, replacing the "H" with a non-textual symbol (e.g., circle) in the helipad projection and adjusting the animation speed and form in the ripple projection to improve clarity. As the lighting conditions in public spaces can affect the visibility of projections, future research should examine how varying light levels of a public space (e.g., park) affect concept interpretability and calibrate the brightness of the projection sensor accordingly.

5.2 Lights & display: convey directional information, state progress and proximity

Indicator lights and direction display use lights and arrows on a display, respectively, to convey directional information regarding the drone's vertical movement during the delivery process. In line with participants who described the directional signals as universally familiar, previous HCI research has shown that flashing lights and displaying static arrows effectively communicate the lateral movements of a robot [13, 20, 21]. Building on this foundation, our

Table 1: Summary of six concepts with key advantages and shortcomings.

Concepts	Advantages	Shortcomings
Indicator lights	Directional information; universally familiar cues.	Front-facing lights are not always easy to spot & differentiate; visibility & readability challenges from different angles or directions.
Rotor lights	Indicates drone proximity to the ground; encourages safety distancing; visible from multiple directions.	Ambiguity about the precise distance to maintain.
Direction display	Directional information, familiar cues; easy to interpret.	Visibility challenges from different angles or directions.
Progress display	Conveys drone state and timing; signals when to approach the package.	Limited readability from a distance; drone symbol is less clear; visibility challenges from different angles or directions.
Helipad projection	Indicates landing location & spatial footprint; attracts human attention; Clearly guides recipients to approach package and alerts bystanders to maintain distance.	"H" symbol is less intuitive; visibility challenges under bright lighting conditions.
Ripple projection	Indicates landing location & spatial footprint; attracts human attention.	Animation speed and meaning are less clear; visibility challenges under bright lighting conditions.

concepts extend these principles to vertical motion by incorporating animations that offer dynamic feedback on drone intentions, thus reducing ambiguity around drone movements. The visibility of indicator lights and the direction display can become challenging when users are positioned beyond the front-facing view or more than 7 m away, particularly for bystanders who tend to keep their distance for safety. This challenge is more pronounced for the indicator lights, which have been reported to be difficult to detect and distinguish. Future research should evaluate these concepts through empirical studies in real-world settings to examine how distance and viewing angle affect users' understandability and predictability, and then further refine the designs accordingly.

Progress display offers visual updates that communicate the drone's actions and the timing of each step. The survey results suggest that the concept improved situational awareness for both recipients and bystanders, with recipients quickly understanding when to retrieve their package. By providing real-time feedback throughout the delivery process, the display demonstrates the potential to reduce human anxiety. It advances prior research on progress bars in HCI [1, 8] by incorporating symbolic representations that communicate the drone's drop-off and take-off intentions alongside the progress bar. However, bystanders raised practical concerns about the display's readability, particularly at a distance. Future research should explore the optimal size and design of displays and symbols to effectively convey drone intentions not only to nearby recipients but also to distant bystanders.

Rotor lights prioritize safety by providing clear visual cues about the drone's proximity to the ground through varying blinking frequencies and improving user confidence in navigating the drone's operational environment. While the concept effectively communicates warnings, participants reported a lack of information regarding the specific distance they should maintain from the drone. Future research could address this limitation by incorporating spatial indicators, such as circular rings from the projection concepts, to visually define a safety zone in conjunction with the rotor lights.

5.3 Future recommendations

Although the concepts were developed through a user-centered design process and evaluated in an online experiment, the concepts have not yet been empirically validated to understand the impact on the feelings of uncertainty. Future research should investigate whether these designs improve the predictability of drone actions, reduce uncertainty, and build trust for both human roles. Moreover, it is important to investigate how these designs influence human approach behavior, as premature approaches to the landing spot can pose safety risks. To extend their applicability, the concepts should also be tested across different delivery methods (e.g. landing vs. cable drop while hovering), as implemented by companies like Wing and Amazon. In the next phase, we plan to experimentally validate selected concepts in various delivery scenarios and with a larger participant pool to better understand their effects on perceived uncertainty and approach intentions of recipients and bystanders in HDI.

Indicator lights and direction display concepts focus on providing directional information, while rotor lights, helipad, and ripple projection concepts address the safety intentions of the drone. These aspects are crucial to facilitate effective and safe interactions between drones and humans in public spaces, extending beyond the delivery context to applications such as emergency response, public gathering management, and urban cleanliness [12, 22]. Future research should explore the applicability of proposed concepts in the broader HDI contexts (e.g., medical emergencies, crowd management, search and rescue), validating their effectiveness across a range of HDI applications.

6 CONCLUSION

This study introduces six conceptual designs that aim to communicate the intentions of a delivery drone in public spaces. The concepts were iteratively developed through focus groups and evaluated via an online survey involving both recipients and bystanders. The concepts incorporate lights, displays, and projections to communicate not only delivery intentions but also directional cues, proximity to the ground, state progression, and spatial guidance. By offering information in varied formats and levels of specificity, the interfaces reduce visual scanning demands and draw on universally familiar signals, supporting intuitive interpretation across diverse human roles. Specifically, the helipad-like projection was appreciated for providing information that could guide recipients to the package and signal bystanders to maintain distance. Based on role-specific feedback, future research should address practical concerns regarding the implementation of the concepts and bystanders' distance from the drone. This study contributes to the MobileHCI community by presenting empirically grounded interface concepts that account for different public user roles, address the complexities of HDI, and improve social acceptance for drones in public environments. Although developed within a delivery context, the concepts show promise for broader applications such as emergency response, public gathering management, and urban cleanliness.

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