# Co-Design of Autonomous Drones for Interactions with Bystanders

EYAL GINOSAR*, Ben Gurion University of the Negev, Israel
SUSANNA KRÄMER*, University of Oldenburg, Germany
MARION KOELLE, Institute for Information Technology in Oldenburg, Germany
HEIKO MÜLLER, University of Oldenburg, Germany
SUSANNE BOLL, University of Oldenburg, Germany
JESSICA CAUCHARD, Ben Gurion University of the Negev, Israel

Autonomous drones could become a sustainable form of delivery of goods and services, but they are vulnerable to external factors such as bystander intervention. Through two co-design workshops ($N = 12$), we iteratively explored autonomous healthcare delivery drones' appearance, implicit and explicit interactions, and types of shared information. Our results demonstrate how familiar colors and iconography support goal sharing, and bystanders in recognizing the vehicle's purpose and intentions. Mapping interaction needs of bystanders, we find contextual effects to bystanders' attitudes and the effectiveness of communication modalities. By investigating acceptability of autonomous delivery vehicles, this work opens the space to considerations of trust and reliance of bystanders beyond traditional users' perspective.

CCS Concepts: • **Human Computer Interaction**; • **healthcare delivery**; • **Automated vehicles**; • **human-robot interaction**;

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## 1 INTRODUCTION

Technological progress is shaping and molding the mobility sector in which automated vehicles will play an important role. Automated drones technology, in combination with AI-driven logistics, are expected to contribute not only to a more flexible future mobility of individuals but also to a substantial contribution to sustainable delivery of goods and services. These include last-mile delivery, micro-hubs, or the use of drones for crowded urban environments or access to hard-to-reach places; these applications will result in fewer cars, traffic, and pollution in future cities [10, 19]. Besides the technical innovation, the socio-cultural embeddedness of such technology is highly important. Vehicles like delivery robots and drones will have to merge into our daily practices. The existing lived experiences of third-party-owned technology on our streets have shown that it changes norms and behaviors, not always for the better, such as people kicking delivery robots. Current releases of autonomous drones are often incapable of adequately interacting with

*Both authors contributed equally to this research.

Authors' addresses: Eyal Ginosar, Ben Gurion University of the Negev, Be'er Sheva, Israel; Susanna Krämer, University of Oldenburg, Oldenburg, Germany; Marion Koelle, Institute for Information Technology in Oldenburg, Oldenburg, Germany; Heiko Müller, University of Oldenburg, Oldenburg, Germany; Susanne Boll, University of Oldenburg, Oldenburg, Germany; Jessica Cauchard, Ben Gurion University of the Negev, Be'er Sheva, Israel.


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bystanders. Missing or ill-designed means of communication between autonomous drones and bystanders, which does not contribute to the creation of human trust in the drone, can result in uncomfortable, undesired, and sometimes dangerous situations. Interaction capabilities are indeed primordial to solving trust issues right from the start, where a bystander can understand the drone's goal. So, to make a sustainable mobility chain possible, social acceptability and trust in automated vehicles will be key. For the acceptance of delivery drones, the so-called Service Robot Acceptance Model (sRAM) [45] identifies social-emotional elements as one core component for user acceptance of service robots. The social-emotional elements of this model need to match with the needs of the bystanders to positively influence the attitude towards the automated delivery vehicle. Yet, interfaces and communication paradigms are still lacking.

Our study involved two participatory design workshops and functional prototype testing, with a particular focus on building trust and acceptance towards autonomous delivery drones. We began with co-design workshops, inviting participants to ideate and create autonomous drones that could communicate with bystanders and explain their purpose. By gathering input from the public, we gained valuable insights into their expectations and needs. Using this feedback, we designed physical prototypes that incorporated novel design propositions aimed at improving trust and acceptance. We then evaluated the effectiveness of these designs in a Wizard-of-Oz experiment, exploring factors such as drone appearance, interactions with bystanders, and types of shared information. Our findings contribute to a deeper understanding of the social interactions between autonomous healthcare delivery drones and the public. We identified several key design needs and factors that contribute to public acceptance, including the use of familiar colors and iconography, and the importance of context in shaping attitudes.

Overall, our work highlights the potential for future socially acceptable delivery drones, paving the way for a cooperative integration of autonomous drones and people on our streets. By building trust and improving communication between drones and the public, we can unlock the full potential of this exciting technology.

## 2 BACKGROUND

The discussion about the economic and ecological advantages of last mile delivery has been in the works for the last decade [20]. With the increasing fidelity of automated vehicles with low speed, like delivery robots, and the high flexibility and low weight of drones, individual delivery of goods and services by automated electric vehicles is now within reach [10, 25]. We are already witnessing food deliveries [9], but also delivery of well-needed items such as medication, blood, and even organs [15, 23]. Autonomous drones can also provide remote healthcare [17] including providing information [1] and detecting symptoms, such as by taking people's temperature or heart rate [18]. They have the added value of being able to reach medically vulnerable populations, who would potentially have been put at risk by a health worker [13]. Reducing traffic by using better coordination of last mile logistics with micro-hubs, joint with delivery drones that are optimally routed, saving transportation and human resources, can contribute to a cost-effective, efficient, and at the same time sustainable delivery of goods and services to end-users [5]. However, to make delivery drones successful in shared spaces, the social aspects need to be implemented in addition to the technical functions [22, 27]. Indeed, current implementations of delivery robots in human spaces without communication strategies lead to safety and privacy concerns [4, 6, 12], misunderstandings [21], and sometimes to violence [24, 26]. Bystanders are more likely to accept automated (a.k.a. autonomous) vehicles in their spaces when they understand the importance of its goal. As such, goal sharing being an important contributor to their acceptance, we posit that the success of these technologies will depend on their ability to effectively communicate their goal to bystanders. We propose to design interaction strategies for goal sharing which contribute to a social acceptance of automated drones for delivering medical goods and healthcare. The usage of drones for healthcare services present clear benefits to society [5], as well as a vision for a sustainable future [11] where people can get timely access to medical services and deliveries, not only in times of a global pandemic. Our main is the feedback and information that these drones should present when interacting with bystanders.

## 3 CO-DESIGN WORKSHOPS

We organized a series of co-design sessions to better understand bystanders' perspectives on autonomous healthcare delivery drones and to elicit concrete and intuitive ideas for communicating autonomous delivery drones' purpose and intentions. Co-design [2] allows diverse stakeholders to participate effectively in the design process and can be a powerful tool for designing communications with bystanders, e.g., status indicators [14]. We chose generic bystanders as workshop participants to avoid the risk of legacy bias seasoned designers might have. We hoped to gain a fresh view of the topic by including inexperienced participants. Research on human-drone interaction has previously applied co-design techniques to address similar design challenges, e.g., to co-design novel applications for drones with stakeholders in the sub-Saharan region [28].

### 3.1 Participants

A total of N=12 participants took part in our co-design workshops. Participants were recruited from the general population through online advertising and word-of-mouth.

### 3.2 Method & Procedure

We ran two workshops. The first workshop was run with a focus on general healthcare drones. At this stage, the range of available healthcare-related applications was deliberately kept open and included delivery but also scenarios focused on medical check-ups or search & rescue. This allowed us to ensure that drones for the delivery of basic healthcare goods (e.g., medication) were indeed the most relevant focus based on public perception. Building on our results from the first workshop, we ran a second workshop, where we aimed for concrete proposals for interactions between bystanders and autonomous delivery drones. We considered that, for practicality, interactions and signifiers (e.g., iconography) would need to align with the form factors of current, commercially available, or close-to-marked delivery drones or robots. Thus, we decided on slightly more confined tasks within the co-design activities and focused on key characteristics identified in the first workshop.

We organized each workshop as a series of co-design activities that were inspired by several established design methods. The first workshop (N=6) used *focus groups*. This group discussion method is well suited for gaining an initial exploration of a new topic, in combination with co-design activities inspired by *dialogue-labs* [16], a co-design technique supporting structured ideation that has previously been successfully applied to designing drones [28]. *Dialogue-labs* allows to rapidly generate various ideas, scenarios, or concepts related to one main theme. The focus group discussion was centered around (1) ways in which drones can be used for healthcare applications, (2) their characteristics, (3) the information needs of bystanders, and (4) potential bystander concerns. It lasted approx. 60 min, after which the participants voted on their three favourite application scenarios (Figure 1. Then each of the selected applications was then assigned to a station with different sets of craft materials (e.g., Legos, clay, paper, or cardboard). Then, participants cycled the three applications in pairs, creating a low-fi prototype of a healthcare drone appearance at each station (each approx. 15 Min). They were encouraged to consider the drone's form (look and feel), interaction modalities for communicating with bystanders, as well as further capabilities of the drone (e.g., sociability). Lastly, ideas were shared and discussed.

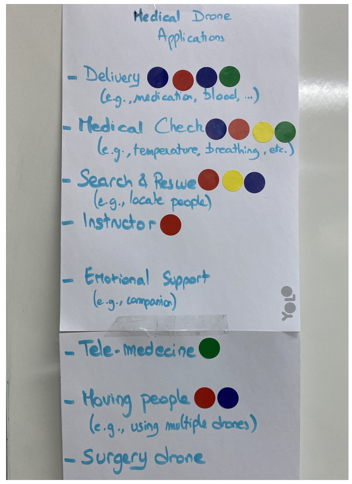


Fig. 1. Participant's votes for favorite medical drone's applications.

The second workshop (N=6) made use of *scenarios*, a widely-used UX design method that has been successfully applied to similar design challenges [7, 30] that are discussed and elaborated on using a hands-on sketching activity. First, the participants discussed a set of four different scenarios demonstrating different types of encounters between a bystander and an autonomous drone in a public space. Scenarios were presented as storyboards (Figure 2), and participants were asked to imagine themselves in the place of the bystander. The guided discussion focused around (1) their perception of the depicted situation, e.g., how they might feel, (2) their actions in response to the depicted situation, e.g., whether they would approach, and (3) their expectations towards the robot in the depicted situation, e.g., how it should provide information to bystanders. The set of four scenarios was discussed in two iterative rounds, where more detail was added to the story in the second round. E.g., the autonomous drone was identified as medical delivery service for an old woman unable to leave the house. In the second part, we asked participants to elaborate on how they expected the autonomous drone to (implicitly or explicitly) communicate based on a participatory design activity hands-on sketching exercise [8, 29]. We provided them with A4 paper with printed silhouettes of the respective drone (drone or robot) from a variety of viewpoints (side, front, top, bottom, side-top). Again, they were asked to focus on its appearance (e.g., how can it be visualized that the drone's purpose is medical delivery), *interactions* (e.g., should the drone communicate multimodally?), and *information* (e.g., what types of information does the drone share with bystanders?). Lastly, participants shared and discussed their ideas with the rest of the group.

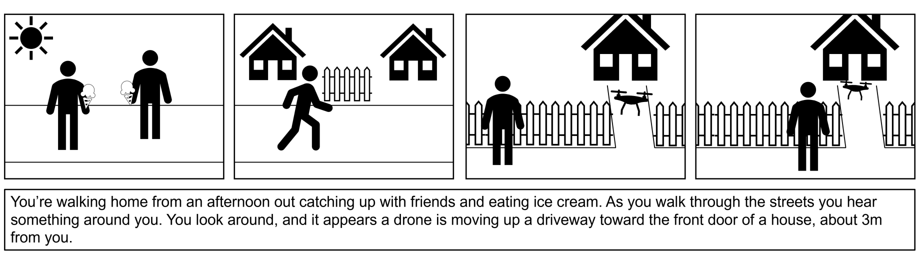


Fig. 2. Example for a scenario from the second workshop we ran - seeing a drone on a random street.

### 3.3 Data Analysis & Results

Workshops were audio-recorded and transcribed. We analyzed the transcripts along with the artifacts and sketches created during the co-design activities qualitatively, using Thematic Analysis (TA) [3] as a loose guideline. We opted for this approach as we were interested in identifying patterns of themes across verbal statements and created artifacts. After familiarization with the data, two researchers inductively developed codes based on the transcripts – first individually, then, the analysis was continued jointly, codes were iterated, merged, and integrated. Conflicts and discrepancies were discussed to achieve agreement. After developing an initial set of themes, we returned to the artifacts and sketches from the co-design activities with an eye to how the themes manifested themselves in the designs.

*3.3.1 Workshops Results.* We present key insights with regard to the focal areas of our co-design, namely *Appearance*, *shared information*, and *interactions*.

*Appearance: Indicating Purpose and Ownership.* Participants expressed a need to know the delivery drone's purpose, who controls it, and who owns it. They elaborated that they perceived it as vital that the association of the autonomous drone with healthcare services is made clear. Re-using colors and symbols that are known from similar medical services (e.g., ambulances or pharmacies) for design elements that would be visible or accessible to bystanders address this information need. For instance, 10/15 of the produced drone designs, made use of the red cross symbol. Participants further suggested similar, pharmacology-related symbols (e.g., the Rod of Aesculapius), as well as known color schemes.

Moreover, anticipating bystanders perceiving the drone as a threat, several participants suggested adding a friendly look or even included a face to convey the drone's benign intentions. In contrast, participants in the second workshop (where we limited them to the form factors of commercial drones or ground robots), pivoted towards alternative means of information sharing. Such as QR code to retrieve information or contact information atop the drone. These important findings highlight the importance of design to convey the drone's role and intent. They further describe possible mental models to support their acceptance by bystanders.

*Shared Information: Ensuring Recipient Safety, Privacy, and Preventing Stigma.* Participants unanimously agreed that indicators of delivery purpose shall not extend towards personal, potentially stigmatizing, information, such as the recipient or the type of medication being delivered. Throughout all stages, participants limited information shared with them about the drone's purpose and details about its operator. Yet, the level of detail at which their designs detailed the drone's purpose differ: some participants, for instance, found it important to indicate what the drone is delivering (e.g., a blood donation), while others voiced concerns that this type of information may lead to malicious or criminal activities (e.g., intercepting an organ delivery). Participants further suggested protecting the drone against theft, such as by using a code to access the goods being delivered. In cases where the delivery drone needed help from a bystander, it should (for instance) only ask for the house number but not share any additional information: *"If it's urgent, then it should give more details. [...], if it isn't for saving lives, then just the destination address"*. It is enough to solely understand the goal of the healthcare delivery vehicle.

*Shared Information: Bystander Privacy.* We found that drones were associated with privacy risks. These concerns were shared by all participants in the workshops, who also noted concerns about the privacy of their neighbors. Participants noted that they would feel more at ease, and less worried about privacy risks, if the delivery drone was clearly marked as "medical" or "healthcare", i.e., goal sharing could help to mitigate privacy concerns as described in the previous subsection.

*Interactions: Implicit and Explicit Communication.* Reflecting on encounters in public spaces, none of our participants believed that they would have approached the autonomous delivery drone to obtain more information about it. In cases where the drone is flying by at some distance, participants stated that they would feel at ease, and might not even pay (much) attention. We note that, during our workshops, the drone's motion that can be used as another form of implicit communication was not elaborated on, possibly as our participants worked with sketches, low-fi prototypes, and image-based scenarios. When the drone was clearly labeled as "medical", participants saw a potential need in helping it and thus communicate, especially in emergencies (e.g., pointing it to the right house). Participants suggested a range of *explicit* interactions between the drone and a bystander. Several interaction modalities were suggested, including text messages displayed on a screen attached to the drone, touch input on the screen, or voice input and output. Participants also suggested gestures for input and pointed to accessibility needs and the risk of communicating the drone's goals not inclusively. Besides using text or speech for communication (both input and output), participants suggested using a mobile application or scanning a QR code to open a web page, call a telephone number, or access a user manual.

*Interactions: Willingness to help.* We found our participants to disagree on whether the autonomous delivery drone should proactively share its goals (beyond its design elements), or whether the drone initiating an interaction might be perceived as irritating (we explored both options in our later experiments). Overall, sharing the drone's medical purpose and conveying urgency could promote interactions with the drone. Participants equipped their drones with a means to signal the urgency of the delivery, e.g., sirens, sounds or voice messages ('emergency help needed'), changing or red lights. They also suggested pinging the smartphones of nearby bystanders in case the drone might encounter an obstacle or need help from bystanders. They furthermore pointed out, that they believed that knowledge about the urgency of the delivery would affect their willingness to help the drone.

## 4 CONCLUSION

Autonomous delivery drones may soon become a normality in our daily lives. Our research explored how bystanders react to such autonomous technologies coming their way. In this work, we presented two workshops on the design of an aerial drone in the context of autonomous medication delivery. Our research results are based on the drone's appearance, as well as the required information and interaction with bystanders. One key finding is that understanding an autonomous drone's goal and intent is important to accepting co-existence in public spaces. If an autonomous drone wants to successfully complete its task, i.e., deliver medicine, it will inevitably need help from bystanders at some point. As bystanders are more likely to provide assistance to it if its intentions are clear to them, goal sharing and an overall benevolent appearance are important. Our results identify design needs and factors for the acceptability of autonomous delivery drones. With this work, we contribute to a better understanding of a cooperative integration of autonomous delivery drones and people on our streets.

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