PACIS 2023 Proceedings

Pacific Asia Conference on Information Systems (PACIS)

7-8-2023

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Recommended Citation

Ellenrieder, Sara; Mehler, Maren; and Turan Akdag, Merve, "Design for Acceptance and Intuitive Interaction: Teaming Autonomous Aerial Systems with Non-experts" (2023). *PACIS 2023 Proceedings*. 55.
https://aisel.aisnet.org/pacis2023/55

Design for Acceptance and Intuitive Interaction: Teaming Autonomous Aerial Systems with Non-experts

Completed Research Paper

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Abstract

In recent years, rapid developments in artificial intelligence (AI) and robotics have enabled transportation systems such as delivery drones to strive for ever-higher levels of autonomy and improve infrastructure in many industries. Consequently, the significance of interaction between autonomous systems and humans with little or no experience is steadily rising. While acceptance of delivery drones remains low among the general public, a solution for intuitive interaction with autonomous drones to retrieve packages is urgently needed so that non-experts can also benefit from the technology. We apply a design science research approach and develop a mobile application as a solution instantiation for both challenges. We conduct one expert and one non-expert design cycle to integrate necessary domain knowledge and ensure acceptance of the artifact by potential non-expert users. The results show that teaming of non-experts with complex autonomous systems requires rethinking common design requirements, such as ensuring transparency of AI-based decisions.

Keywords: Human-Autonomy Teaming, Design Science Research, Autonomous Drones, App Design

Introduction

Rapid advances in the field of robotics and artificial intelligence (AI) boosted the development of autonomous transportation systems in recent years. In particular drones, also known as unmanned aerial systems (UAS) or unmanned aerial vehicles (UAVs), offer a promising solution for low-emission, autonomous transportation of various goods and multiple successful test flights have already been conducted to deliver several medications, vaccines or even defibrillators to people in need (Krey, 2018; Scott & Scott, 2017). For example, during test flights in Sweden in December 2021, a drone successfully transported an automated external defibrillator (AED) to a 71-year-old who suffered an out-of-hospital cardiac arrest. A bystander quickly administered cardiopulmonary resuscitation using the AED before emergency medical services arrived, saving the patient's life. (Hicks, 2022) Besides applications in healthcare, drone service providers and manufacturers strive to offer existing services in other industries today and food or general parcel deliveries have been tested by global players such as Amazon PrimeAir (Amazon, 2016) and Google Wing (Levin, 2016) as well as entrepreneurial startups (Giones & Brem, 2017;

Heunemann, 2022). In addition to expanding application areas, the increasing autonomy of transportation systems such as delivery drones enables scalability and may also allow inexperienced individuals to use these technologies to their own advantage in the future (Hicks, 2022; Moshref-Javadi & Winkenbach, 2021; Pasztor & Ferek, 2021).

However, even if delivery drone systems are operated autonomously to allow for large scale operations that provide value to the general public, humans still need to interact with these systems to retrieve parcels and take advantage of the benefits that a modern drone delivery network can offer. In this case, the human does not control the drone and many decision-making powers are transferred to the drone system. Nevertheless, interaction is still required and effective teaming between the human and the autonomous system is thus critical to success (McNeese et al., 2019; McNeese et al., 2021). In many growing application areas of delivery drones, this will lead to untrained humans with little or no knowledge of AI, robotics or autonomous systems to interact and team up with autonomous drones with increasing frequency in the upcoming years. Besides being non-experts, studies show that people oftentimes oppose the use of drones in general and acceptance of this technology remains a major societal challenge today (Eißfeldt et al., 2020; Eißfeldt & End, 2020; Rice et al., 2018). The research field of human-autonomy teaming, which has grown in recent years as machines have become more capable, is already investigating how attributes such as situational awareness (Demir et al., 2017; Endsley, 2018) or trust (McNeese et al., 2019; McNeese et al., 2021) influence effective teaming between humans and autonomous systems. Nonetheless, research in the field of human-autonomy teaming (McNeese et al., 2021) and human-drone collaboration (Dolata & Aleya, 2022) calls for further work and we aim to take a step forward by providing guidance on how to implement this special form of interaction in real-world use cases and, in particular, to consider the role of non-experts in this context to enable scalability and foster acceptance in the future. Hence, we aim to answer the following research question: *In the context of autonomous delivery drones, how should a mobile application be designed to promote the acceptance and use of autonomous delivery services and to enable non-experts to interact intuitively in such human-autonomy teams?*

We apply a design science research (DSR) approach to develop a mobile application that enables non-expert users to interact with autonomous drone systems in order to safely retrieve a delivery and thus have access to modern service offerings. While intuitive interaction design is a focus of the design project, we specifically aim to increase acceptance of autonomous delivery drone technology among non-experts. We follow the approach of Kuechler & Vaishnavi (2008) and perform two design cycles, an expert and a non-expert design cycle to derive design requirements (DRs) and principles (DPs) that are structured along the unified theory of acceptance and use of technology (UTAUT) model (Venkatesh et al., 2003) and instantiate a solution in form of a mobile app prototype afterwards. The implementation of our artifact in the form of an app allows to provide access to autonomous transport systems to a wide range of end users and in particular to non-experts (Pitt et al., 2011). Within the first expert design cycle, semi-structured interviews are performed with experts that work at different drone manufacturers as well as delivery drone pilots to incorporate the necessary domain knowledge. Based on the interview results, DRs and DPs are instantiated in a click prototype and evaluated in expert focus groups. After analyzing the results of the expert design cycle, a non-expert design cycle explores how non-expert users of different ages and experience evaluate the instantiated solution to derive a final design that incorporates domain knowledge and satisfies the needs of end users while fostering acceptance of autonomous delivery drones. Overall, we focus on fully autonomous drones with vertical take-off and landing (VTOL) capabilities because they offer great flexibility in adjusting their trajectory and have been successfully deployed in real-world delivery flights with non-experts in the past (e.g., Hicks, 2022). Focusing on fully autonomous drones allows us to explore the interaction between non-experts and autonomous systems without risking interference of other human intermediators such as human pilots.

Theoretical Background

The following section reviews existing research in human-autonomy teaming and shows how our study aims to extend this relatively young area of research. In addition, the UTAUT model, which is used as the kernel theory in our DSR approach, is outlined.

Interaction for Human – Autonomy Teaming

The field of human-machine interaction has grown considerably in recent years, leading to the emergence of multiple sub-fields. Today, research on human-machine interaction also covers the fields of human-machine teaming as well as human-autonomy teaming. In general, this research stream explores interactions between a human and a machine working in interdependent roles to achieve a common goal. (McNeese et al., 2021, 2018) However, in the case of human-autonomy teaming, the machine has the ability and authority to make decisions independently and is not supervised in those decisions by the human (Demir et al., 2017; Endsley, 2018; McNeese et al., 2018). The latter area of research has received less attention in the past because limited machine capabilities did not allow for the required level of autonomy. However, autonomous machines will be increasingly used in the coming years and research in the area of human-autonomy teaming will increase in practical relevance (Bradshaw et al., 2004; McNeese et al., 2019). McNeese et al. (2021) argue that we need to rethink human-machine interaction if humans and machines do not interact as supervisors and subordinates anymore. The authors state that we are currently at an *inflection point*, which is why we need to transfer concepts from the field of human-machine interaction and insights from teams that have exclusive human members into the field of human-autonomy teaming. They conducted an experiment to analyze the role of trust in human-autonomous teams, and also studied the context of remotely piloted aircraft operating in the role of autonomous team members. Here, the aircraft interacts with, but is not controlled by, the human team member. (McNeese et al., 2021) A study by (Yuan Zhang & Jessie Yang, 2017) showed that uncertainty in human-autonomy teams will lead to a higher perceived workload and those teams will, in general, be able to perform fewer tasks at the same time. Modeling team interactions and incorporating human cognition into the design of the autonomous agent are crucial aspects to be considered for effective human-autonomy teaming in dynamic environments (Gutzwiller et al., 2018; Klein et al., 2004; Parasuraman et al., 2000). While some studies exist that explore the impact of characteristics such as trust (McNeese et al., 2019; McNeese et al., 2021) or situational awareness (Demir et al., 2017; Endsley, 2018) on human-autonomy teaming and thus already allow researchers to draw new insights from empirical work, research calls for additional work (McNeese et al., 2021). Rapid developments in the field of autonomous systems reinforce the need for research to also address the implementation of such human-autonomy teams. Furthermore, the higher level of autonomy should especially enable non-experts to use such systems in the future.

Designing Human-Drone Collaboration

As for autonomous systems, delivery drones have already shown great potential to improve logistic networks in various industries today (e.g., Mao et al., 2019; Scott & Scott, 2017). However, many use cases require non-experts to interact with these autonomous systems in the future, and the general public remains opposed to the use of drones as a means of transportation (Eißfeldt et al., 2020; Eißfeldt & End, 2020; Rice et al., 2018). Intuitive interaction for non-experts that further promotes acceptance of this technology is urgently needed to make the benefits of delivery drones accessible to the general public (Ellenrieder et al., 2023). In addition, interacting with a drone as an autonomous agent provides special challenges due to the physical embodiment of the agent in an autonomously controlled, flying object (e.g., McNeese et al., 2019; McNeese et al., 2021). While the IS community is primarily concerned with the advantages and disadvantages of various drone applications, there is a lack of approaches to designing human-drone collaboration (Dolata & Aleya, 2022). To address this shortcoming, Dolata & Aleya (2022) propose a taxonomy of dimensions and characteristics that are relevant for designing human-drone collaboration. However, they do not provide requirements for the design of artifacts in this field. We preselect outdoor delivery flights in the proposed context dimension, untrained operator's skillset in the social dimension, single drone flights that interact with one human in the mutual interactions dimension and lastly fully autonomous drones with light to heavy payload in the technical component dimension. (Dolata & Aleya, 2022) Other characteristics such as unidirectional or bidirectional communication between drone and human will be defined in the design cycles. The taxonomy outlines that social and organizational aspects must be considered for the design of human-drone collaboration instead of solely focusing on technical requirements. While Dolata & Aleya (2022) already argue that the operator's skillset (expert vs non-expert) is a relevant social dimension for the design of human-drone collaboration (Alex & Vijaychandra, 2016; Allen & Mazumder, 2020; Dolata & Aleya, 2022), they do not mention the influence of the operator's acceptance of the technology or the operator's environment. However, existing research primarily targets the use of drones for emergency operations which is associated with higher levels of acceptance (Aydin, 2019). In the context of our paper, we aim to bridge the gap between non-experts and autonomous drones by providing clear design requirements that combine domain knowledge from experts with user requirements from non-experts and promote acceptance of the technology.

Unified Theory of Acceptance and Use of Technology

The UTAUT model was derived in 2003 by Venkatesh et al. (2003) and is useful for understanding which factors affect acceptance of a technology and thus influence the likelihood of success for that technology. In addition, the model can be used to derive strategies for targeting potential users who are less inclined to adopt the new technology (Venkatesh et al., 2003, 2016). Performance expectancy, effort expectancy, social influence and facilitating conditions are the four core determinants of intention and usage that are considered in the UTAUT model, as pictured in Figure 1 (Venkatesh et al., 2003). In general, the performance expectancy of users can be defined as the extent to which a person believes that using the system will help them improve their job performance. In addition to performance expectancy, effort expectancy also has a significant influence at the beginning of use, but it decreases over time. Effort expectancy is defined as the degree of ease that is associated with using the technology or system. In addition, social influence affects the intention to use a new technology and is defined as the extent to which an individual perceives that significant others believe that he or she should use the new technology. Social influence is also found to be significant in the beginning when experience is still low. Lastly, facilitating conditions are defined as the extent to which a person believes that resources such as organizational and technical infrastructure are in place to support the use of the system. (Brown & Venkatesh, 2005; Venkatesh et al., 2003, 2012)

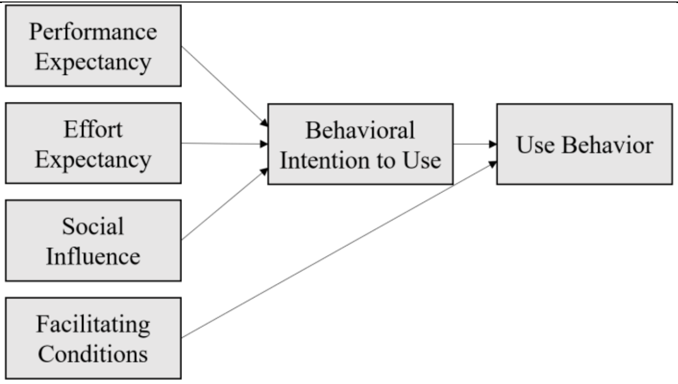
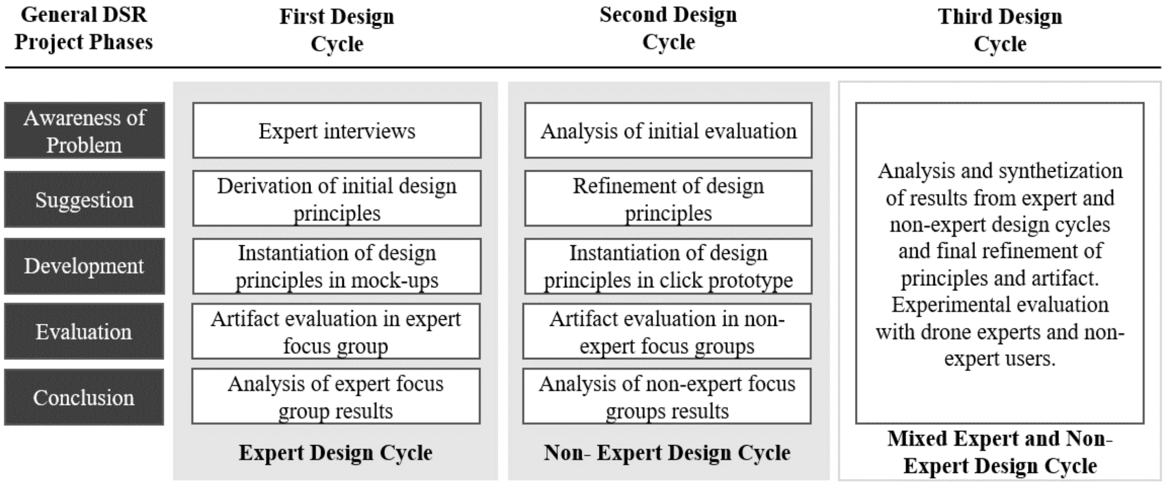


Figure 1. The UTAUT Model with its Four Direct Determinants of User Acceptance and Usage Behavior (Venkatesh et al., 2003)

The relationship between these four independent variables and the dependent variables of behavioral intention and usage are moderated by gender, age, experience and voluntariness of use (Venkatesh et al., 2003, 2016). Venkatesh et al. (2003) showed, for example, that the effect of performance expectancy is stronger for men and younger workers while social influence has a stronger effect on women, older workers and those with less experience. The unified theory of acceptance and use of technology will serve as a kernel theory in our DSR approach. The UTAUT model has proven to be particularly useful compared to other technology acceptance models because it directly incorporates social influences, which are currently considered one of the biggest challenges facing the drone industry (e.g., Eißfeldt et al., 2020; Tan et al., 2021). In addition, we decided to use UTAUT instead of the extended UTAUT2 model (Venkatesh et al., 2012) since constructs such as price value and experience and habit of the UTAUT2 model are not feasible for our use case. Non-experts do not hold prior drone experience or regularly interact with fully autonomous systems and the current tradeoff of perceived benefits of drones and costs cannot be compared as costs are expected to decrease significantly in the future as the autonomy level increases and economies of scale can be realized through mass production of autonomous drones in the future.

Design Science Research Approach

We apply a design science research approach by Kuechler & Vaishnavi (2008) to develop a mobile application that enables non-experts to interact with autonomous drone systems in human-autonomy teams while fostering acceptance of this technology. We contribute to the growing science of design for IT artifacts by deriving DRs and DPs for human-autonomous drone teams as well as creating and evaluating the instantiated solution in multiple design cycles in this study. The general design cycle as defined by Kuechler & Vaishnavi (2008) comprises five distinct phases, namely *awareness of the problem, suggestion, development, evaluation* and *conclusion*. We perform two design cycles (as outlined in Figure 2), an expert design cycle and a non-expert design cycle to ensure the instantiated solution is built on domain knowledge and fosters acceptance by end users. Thus, we performed 10 semi-structured expert interviews within the *awareness of the problem* phase from which we derived initial DRs and overarching action-oriented DPs during the *suggestion* phase of the first design cycle. We formulated a semi-structured interview guideline according to Sarker et al. (2013) which addressed all independent variables of the UTAUT model and allowed interviewees to freely share their experiences and ideas. At the beginning of each interview, we outlined the use case of delivering parcels with autonomous VTOLs to the general public, most of whom can be defined as non-experts in drone technology. Afterwards, we collected interviewee-related information such as their current position and prior experience in the drone industry. We then asked experts to share their opinions and insights on why drone acceptance remains low and what risks the general public typically sees with test flights before discussing how experts envision a solution approach in the form of a mobile application that would allow non-experts to interact with these systems.



General DSR Project Phases	First Design Cycle	Second Design Cycle	Third Design Cycle
Awareness of Problem	Expert interviews	Analysis of initial evaluation	Analysis and synthetization of results from expert and non-expert design cycles and final refinement of principles and artifact. Experimental evaluation with drone experts and non-expert users.
Suggestion	Derivation of initial design principles	Refinement of design principles	
Development	Instantiation of design principles in mock-ups	Instantiation of design principles in click prototype	
Evaluation	Artifact evaluation in expert focus group	Artifact evaluation in non-expert focus groups	
Conclusion	Analysis of expert focus group results	Analysis of non-expert focus groups results	
	Expert Design Cycle	**Non- Expert Design Cycle**	**Mixed Expert and Non-Expert Design Cycle**

Figure 2. DSR Project Structure (cf. Kuechler & Vaishnavi, 2008) Including Expert, Non-expert and Mixed Design Cycles. This Study Focuses on the Cycles Highlighted in Grey

Experts work in different areas within the drone industry and provide in-depth knowledge on safety-related aspects of drone deliveries as well as current AI-based capabilities of (partially) autonomous drone systems. We followed a theoretical sampling approach and initially invited drone pilots (E1 - E3) to our interviews to gain insights from today's users who already interact with drones. Drone pilots, who still control some processes manually today, are already preparing for their new role in the coming years, in which they will primarily monitor a fleet of autonomous drones and intervene only in exceptional situations. Thus, they enriched this study with real-world experiences with the challenges of human-autonomy teaming. However, drone pilots mentioned that interfaces to guide interaction between drones and end users are usually designed for pilots and the design of interfaces for non-experts is still a research and development (R&D) topic in many companies. Thus, we invited experts (E4 - E8) from R&D and product development departments of different drone manufacturers in the second round. Our focus on autonomous delivery drones is associated with special risks since drones are required to carry payload and transfer parcels from the drone to the non-expert. A payload specialist (E9) was thus invited for an interview once we identified these risks. Lastly, we invited a drone program manager (E10) who gained prior experience in R&D as well as drone customer service and operations management to ensure all relevant information was being obtained. The program manager confirmed the derived DRs and no additional DRs were identified during the last interview. Although the civilian delivery drone industry is relatively young, seven out of ten respondents, already had five or more years of experience in this industry. Interviews were conducted from April to August 2022 via online meetings and recorded following mutual agreement. Interviews lasted 58 minutes on average and were subsequently transcribed.

Case	**Work Title/ Area of Expertise**	**Years of Experience**
E1	Drone Pilot	6 years
E2	Drone Pilot	5 years
E3	Drone Pilot	3 years
E4	R&D, Drone Manufacturer	5 years
E5	Product Development, Drone Manufacturer	2 years
E6	Product Development, Supplier Drone Technology	9 years
E7	Product Development, Supplier Drone Technology	5 years
E8	Product Development, Drone Manufacturer	11 years
E9	Payload Specialist	4 years
E10	Program Manager, Drone Manufacturer	12 years

Table 1. Roles of Expert Interview Participants

We performed a content analysis according to Weber (1990) for the evaluation of the qualitative data gained and conducted two coding cycles that comprised descriptive and pattern coding (Saldana, 2021). Following the *suggestion* phase, we developed mock-ups of a suggested solution instantiation using the wireframing tool Balsamiq which considered all derived DRs and DPs during the *development* phase (Balsamiq, 2022). All experts listed in Table 1 were invited to a focus group study that lasted 78 minutes to evaluate the prototypical implementation of the DRs and DPs. Following an analysis of the focus group study results, a second design cycle to involve potential non-expert users was conducted and initial DPs were refined before a clickable prototype was developed using Figma (Figma, 2022). For *evaluation* of the non-expert design cycle, we conducted a combined exploratory and confirmatory focus group study which is outlined in detail in the evaluation section (Tremblay et al., 2010). Overall, experts that participated in the first design cycle did not participate in the second design cycle. Our focus group studies aim at obtaining in-depth understanding of how a selected group of individuals evaluates the artifact (O'Nyumba et al., 2018) in terms of promoting acceptance and intention to use the technology. The approach allows us to refine our design principles iteratively before obtaining a statistically representative sample of a broader population in the final and still outstanding mixed-expert and non-expert design cycle. The three non-expert focus groups, which were conducted in October 2022, lasted for 66 minutes on average to ensure all DRs, DPs and instantiated prototype features were evaluated in detail. Audio recordings of all sessions were transcribed afterwards. We applied a mixed content analysis in accordance with Morgan and Scannell(1998) to obtain both qualitative and quantitative information in our focus group studies. We allowed for a maximum of eight participants for non-expert groups because they may require a different amount of explanations which becomes difficult to manage in larger groups or leads to the formation of subgroups that have independent discussions (Krueger, 2014). Following the expert and non-expert design cycle, results were discussed and summarized during the *conclusion* phase and we prepared the outstanding final design cycle for which more information is provided in the outlook on future research.

Results

The following section describes the results collected and synthesized in all phases of the design cycles. For the derivation of the DRs and DPs, the focus is on the inductively obtained results from the expert interviews. Subsequently, the final prototype is presented, which already integrates the feedback from the expert evaluation, before the results of the non-expert focus group evaluation are outlined.

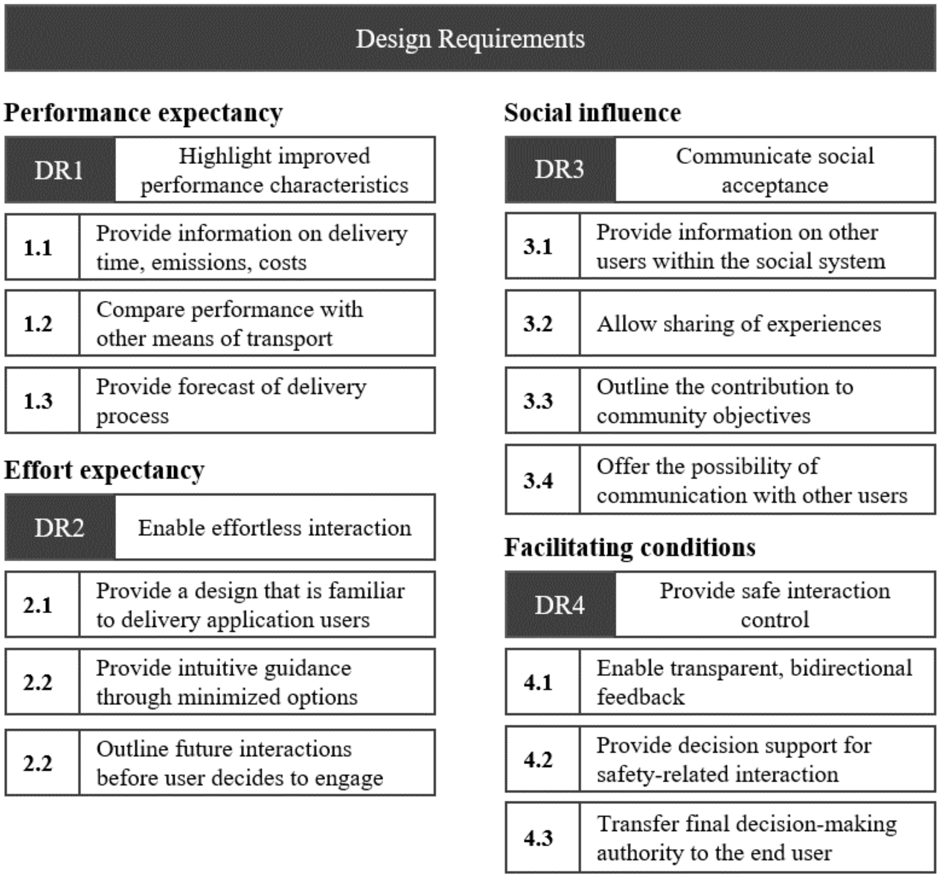
Awareness of the Problem

As stated in the introduction and background section of this study, current information systems (IS) research examines what challenges arise and need to be addressed in the area of human-autonomy teaming (e.g., Gutzwiller et al., 2018; Parasuraman et al., 2000). Autonomous aircraft, which can be a physical embodiment of an autonomous agent, recently received attention from this research stream (McNeese et al., 2021). To advance this research, we address the specific design of human interaction with autonomous delivery drones. In doing so, we consider two specific aspects that we identified in expert interviews as key challenges for practical applications in the coming years, namely: the interaction of non-experts with complex, autonomous drone systems and the low acceptance of this technology among non-experts (E1,3,4,5,8,9,10). In terms of the relevance of the topic, one interviewee stated: *"What we've seen in rapid technology development is quite impressive. But in the past, when we conducted test flights, only trained people interacted with our drones to, for example, retrieve a package. That's definitely going to change now as we look to grow our drone fleet in many different areas and the drone has more and more capabilities"* (E2). Many use cases of drone delivery services require non-experts to interact with drone systems even though they do not control actions of the drone such as its movement in airspace (E3,4,6,8,9). Thus, interaction should work without much effort and should not require any prior knowledge (E5,7,9). While this poses a great challenge, an interviewee also argued that *"bringing drones closer to the general public may finally help us to foster acceptance"* (E7). Raising awareness of the benefits of drone technology in modern urban areas and areas with poor infrastructure is a key task that providers of these services have addressed in previous pilot projects (E2,3,10). Delivery flights directly to customers now offer the possibility of*"first-hand experience"* (E4) and it will be particularly important at the outset to create a convenient experience for the end user here (E1,5). Several interviewees argued that deriving and following design suggestions from drone experts will be key due to the complexity of the systems and the associated safety risk if used incorrectly (E1,2,6,9). Bringing together the requirements of experts and non-experts for the interaction of autonomous drone systems and translating them into a common design proposal represents a core challenge that we address in this study. One interviewee even stated: *"Systems in aviation have actually always been operated by experts. However, with increasing autonomy, people will have to interact with more and more systems themselves in the future, and it will be our goal to find solutions in close cooperation between experts and people without prior knowledge"* (E10).

Suggestion

To ensure our artifact fosters acceptance of autonomous delivery drones among non-expert users, we structure the derivation of design requirements along the four independent variables of our kernel theory the UTAUT model, namely performance expectancy, effort expectancy, social influence, and facilitating conditions (Venkatesh et al., 2003). Figure 3 provides an overview of all derived design requirements. All sub-requirements were derived based on challenges or solution approaches that were explicitly mentioned by the experts and could be identified during the coding process.

Performance expectancy is defined as the extent to which a person believes that using the system will enhance their job performance. It has the highest impact on the intention to use a technology as shown by Venkatesh et al. (2003). Multiple interviewees argued that acceptance for delivery drones remains low, primarily because the general public is unaware of the benefits drones can offer in terms of delivery times and emissions (E1,2,4,10). *"We need to get to the point where we are really transparent about the positive impact that this technology could have. People need to be able to critically question what the advantages or disadvantages of delivery by a drone are – especially if it's not manually controlled"* (E8). Apart from the performance characteristics of this autonomous means of transport, non-experts are usually not familiar with the process that will be followed during delivery and what interaction is required (E2,3). An interviewee further stated: *"Users must understand that it is not just autonomous drone features that they* *can rely on. It is also their active participation in the interaction that influences the overall performance."* (E1). We therefore propose **(DR1) Highlight improved performance characteristics:** Interacting with the app should increase performance expectancy and reassure users that the capabilities of autonomous drones will improve delivery performance. Sub-requirements include **(DR1.1)** providing information on delivery time, emissions, and costs, **(DR1.2)** a performance comparison with all applicable other modes, and **(DR1.3)** providing a forecast of the delivery process to the end user, including upcoming interactions.



Design Requirements

Performance expectancy

DR1	Highlight improved performance characteristics
1.1	Provide information on delivery time, emissions, costs
1.2	Compare performance with other means of transport
1.3	Provide forecast of delivery process

Effort expectancy

DR2	Enable effortless interaction
2.1	Provide a design that is familiar to delivery application users
2.2	Provide intuitive guidance through minimized options
2.2	Outline future interactions before user decides to engage

Social influence

DR3	Communicate social acceptance
3.1	Provide information on other users within the social system
3.2	Allow sharing of experiences
3.3	Outline the contribution to community objectives
3.4	Offer the possibility of communication with other users

Facilitating conditions

DR4	Provide safe interaction control
4.1	Enable transparent, bidirectional feedback
4.2	Provide decision support for safety-related interaction
4.3	Transfer final decision-making authority to the end user

Figure 3. Design Requirements Derived from Expert Interviews

Effort expectancy is defined by the ease of use of the system. The determinant was found to be especially significant during the first temporal use (Venkatesh et al., 2003). Multiple interviewees argued that effort expectancy will be one of the key challenges in teaming up non-experts with autonomous systems (E3,5,6,7). In addition, one interviewee argued: *"There are so many preconceptions about how complicated it is to control an autonomous system because the systems are so complex now. But non-experts won't control our drone systems. Rather, they will only interact with the system in certain situations."* (E10). To ensure intuitive use, the possibilities for the end user to shape the interaction with the autonomous system should be limited (E1,6,8,10). The non-expert user must be prepared for every interaction and, if possible, feel reminded of already familiar environments and tasks (E4,6,8). Drone pilots and others who interact with drones in the aviation industry must undergo a knowledge assessment to obtain the required licenses. While in the case of autonomous drones, no special skills are required, a self-assessment is still beneficial to strengthen the user's confidence that no skills are required that they do not possess (E1,2). We therefore propose (**DR2) Enable effortless interaction:** The app should enable intuitive interaction with autonomous drones to reduce complexity and maximize perceived ease of use.

Respective sub-requirements ensure that **(DR2.1)** the design of the artifact reminds the user of familiar delivery applications, **(DR2.2)** user options for shaping the interaction are minimized, and **(DR2.3)** emerging interactions are communicated to the user early on.

Social influence is defined as the extent to which the user perceives that significant others believe that he or she should use the new system. User behavior is thus influenced by the user's belief in how a technology may enhance his or her status in his or her social system (Venkatesh et al., 2003). An interviewee described the current situation as follows: *"If you have, say, an electric car. You would probably be proud and talk about it with neighbors and friends. However, drone technology is known to be used by the military, and people are often biased toward civilian applications as well, especially in urban areas. In our pilot test flights, we realized that sharing experiences between communities had the most positive effect. In fact, people were even excited after learning about the positive experiences and improved infrastructure of similar communities."* (E1). First and foremost, respondents mentioned that an app needs to connect users with each other to convey that the technology is already being used by a variety of similar users, especially non-experts. This can reduce the fear of rejection by the social environment and has already been experienced as beneficial during real test flights (E1,2,3,9,10). In addition to encouragement from the social environment, it is important to convey to the user the contribution they can make to society by choosing a low-emission mode of transport. Highlighting the contribution to emissions targets can further encourage users to share their experiences with others (E4,10). We therefore propose (**DR3) Communicate social acceptance:** The app should communicate to the user that the use of autonomous drones is gaining social acceptance and supports societal goals such as achieving the SDGs. Corresponding sub-requirements define **(DR3.1)** to provide information about other users within the app user's social system and **(DR3.2)** to enable experience sharing among users. In addition, **(DR3.3)** the artifact should clearly demonstrate how users can contribute to emission goals or other social goals by using the new technology.

Facilitating conditions are defined as the extent to which a person believes that an organizational and technical infrastructure is in place to support the use of the technology. If facilitating conditions are supporting the use of a technology, the user would have a positive perception of behavioral control (Venkatesh et al., 2003). While this could also involve available resources or compatibility issues, facilitating conditions for human-autonomy interaction are rather understood in the context of behavioral control to address questions such as: How much control should the human have and how much autonomy should the drone have? In the interviews, the experts argued that the facilitating conditions should first be determined by experts to ensure safety (E1,2,4,5,6,8). However, they also mentioned that input from non-experts will be crucial to ensure that users feel comfortable and can interact with the technology without being overwhelmed (E2,5,8,10). A drone pilot further stated: *"As a drone pilot, I already feel comfortable letting the system make certain decisions on its own. However, I would like to receive information about why the system reacts in a certain way. We should also provide easy-to-understand feedback to people who have no prior knowledge. [...] And even if I'm monitoring multiple drones at once, I always want to be able to abort a mission. This decision should remain possible for every user in every planned interaction."* (E2). In addition, the experts made it clear that the app must offer the possibility of requesting help from experts (E6,7). It is difficult to define in advance all the situations that may occur in the real world during the interaction between a non-expert and the autonomous drone system. In all safety-critical interactions such as the acceptance of a dropped package, the user should therefore be provided with decision support and the opportunity to provide feedback (E1,8,9,10). Thus, we propose **(DR4) Provide safe interaction control:** The app should allow the user to access the necessary infrastructure to safely control the interaction with the autonomous delivery system. The sub-requirements specify **(DR4.1)** that bidirectional feedback should be possible that is transparent but understandable to users. In addition, **(DR4.2)** decision support should be provided for all safety-related interactions, **(DR4.3)** with the final decision-making authority to enter or exit an interaction remaining with the human.

Deriving Design Principles

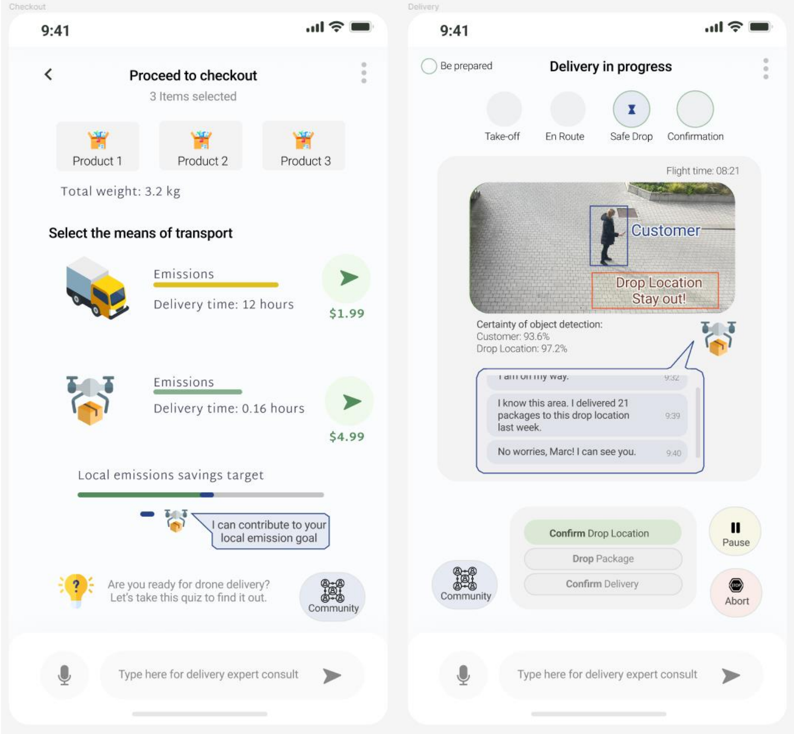
Before the development of a solution instantiation, we derive design principles in accordance with (Gregor et al., 2020) which provide the basis for all features that are integrated into our artifact. To promote informed decisions about the use of the emerging technology, non-expert users should understand what autonomous delivery drones can offer in terms of performance metrics such as delivery times or emissions, and what impact this will have on the social environment of users (see **DR1** and **DR3**). We thus define

DP1: *For an intuitive mobile application to inform and encourage, the user should be able to evaluate the emissions-related environmental impact of the autonomous transportation system and compare the system's performance with other transportation modalities to assess whether the user's performance expectations are being met.* The user's effort to perform a given task in cooperation with the autonomous drone system depends on the provided guidance and preparation, which must be explicitly designed for non-experts (see **DR2** and **DR4**). We therefore derive **DP2:** *For an intuitive mobile application to guide the user throughout the interactive process, the user should be able to inform and prepare for all upcoming decision-making activities to avoid frustration and overwhelm.* While respondents frequently mentioned that a non-expert will not control the delivery drone system, the ability to actively shape the interaction between the human and autonomous system will become a key characteristic (see **DR1, DR2,** and **DR4**). Thus, we propose **DP3:** *For an intuitive mobile application to support and enable active engagement of the user, the application should mediate feedback between the autonomous system and end user and provide decision support to the user for initiating or aborting interactive processes*. Even though users do not supervise the autonomous system, the experts see ensuring situational awareness as highly relevant to user-friendliness and safety (see **DR2** and **DR4**). We propose **DP4:** *For an intuitive mobile application to ensure situational awareness of the user for safe collection of deliveries, the user should be able to access the current and upcoming operational status of the autonomous drone system in a transparent manner without having to navigate through menus.* Finally, according to experts, user acceptance is strongly influenced by the social acceptance of the technology by the general public. In addition to the exchange between the user and other users from his/her social environment, the offer of support by trained, human experts can also promote acceptance (see **DR3** and **DR4**). We therefore derive **DP5:** *For an intuitive mobile application to promote usage and relationship building, users in the same neighborhood should be able to connect, share experiences and provide external human support for human-autonomy interaction.*

Development

In the first step, we derived design features (DFs) based on the defined requirements and principles and used Balsamiq to build a sketched artifact in form of a mobile application (Balsamiq, 2022). Following an expert evaluation, we then developed the clickable prototype in Figma as pictured in Figure 4 (Figma, 2022). This version of the artifact allows us to vividly present how the interaction between users and the autonomous delivery drone system is designed within our non-expert design cycle. The artifact primarily aims to allow non-experts to test DFs on their own smartphone and get a realistic sense of the interaction possibilities and challenges. Two scenarios are selected to provide some insights into the suggested solution instantiation. The first scenario requires the user to accept the technology and directly interact with it following this decision in the second scenario. The left screenshot of the click prototype in Figure 4 shows a scenario that occurs before the user selects the desired mode of transport for a delivery (DF2).

The performance features are shown below a familiar shopping cart display (DF1). As a gamification element, the user is also offered a small quiz (DF3, DF11) to playfully test and extend his or her drone knowledge and find out what knowledge and skills are required. To give the feeling of two-way communication in all scenarios, the user can write with a human drone expert in the chat (DF10) and receives regular updates from a small drone icon (DF5). In the figure on the right, which shows a scenario shortly before the drone drops the goods, these interaction options are also available. In addition, the user is shown the entire delivery process to prepare him or her for the interaction at an early stage (DF4). To increase situational awareness, an AI-assisted bird's-eye view allows the user to understand what the autonomous system can detect (DF7). Experts explained that even for pure interaction, it will be crucial to understand that the drone detects e.g. objects and with what degree of certainty. Detected objects such as a feasible drop location and the human itself are marked by a 2D-bounding box and a certainty for object detection is provided below. In the interaction panel at the bottom of the right screenshot (DF6), the user can only pause or permanently cancel the interaction. Further design options are only made available in the appropriate interaction phase and are grayed out beforehand to prepare the user in advance for future interactions. Finally, the user can access the community platform within this panel to get support from their social circle or share experiences (DF9).



Are you ready for drone delivery? Let's take this quiz to find it out.

Certainty of object detection:
Customer: 93.6%
Drop Location: 97.2%

I am on my way. 9:32

I know this area. I delivered 21 packages to this drop location last week. 9:39

No worries, Marc! I can see you. 9:40

Design Features

- **DF1**: Performance comparison
  - **1.1** Delivery characteristics
  - **1.2** Regional goal achievement
- **DF2:** Means of transport selection
- **DF3:** Capability self-assessment
- **DF4:** Operational phases forecast
- **DF5**: Proactive drone messenger
- **DF6**: Interaction control panel
- **DF7**: AI-enhanced bird view
- **DF8**: Navigation
- **DF9**: Community platform
  - **9.1** Regional flight history
  - **9.2** Milestone overview
  - **9.3** Community FAQs
  - **9.4** Community messenger
- **DF10:** Expert support
- **DF11:** Gamification

Figure 4: Instantiated Solution for Teaming Non-experts with Autonomous Drone Delivery Systems and Respective Design Features (Icons Made by Freepik, Pixel Perfect and Satawatdesign from Flaticon, 2022)

Evaluation and Discussion of Results

The instantiation of derived DPs in the form of the clickable prototype was evaluated through three focus groups that were conducted in October 2022 with potential non-expert users (Tremblay et al., 2010). Participants with extensive experience with drones, such as using drones for filming, were excluded from the focus groups to ensure evaluation by non-experts. In addition, participants had to be at least 18 years old. During the exploratory phase, we gathered insights into the participants' attitudes toward delivery drones and the use of autonomous systems as well as their knowledge base. After a brief introduction about delivery drones and the collection of personal data, we presented a video of a drone delivery and showed how our artifact would shape the interactive process using an Apple iPhone12. Non-experts could then click independently through the functions of our prototype. We aimed to understand how non-experts evaluate and interact with our artifact in terms of performance and effort expectancy, as well as social influence and facilitating conditions. Finally, we gained insights into how non-experts evaluate derived DPs and interaction with the prototype in order to assess whether the artifact promotes acceptance and use of the emerging technology. Our sample with N = 22 participants (50% male, 50% female) represents the group of potential users ranging between 19 and 81 years. All participants owned a smartphone and reported familiarity with delivery apps. Overall, participants indicated a low level of experience with drone technology (on a 7-point Likert scale) as shown in Table 2.

After a brief introduction to the use of delivery drones as a means of transportation, the majority of participants in all focus groups expressed concerns, such as privacy risks and the risk of accidents. Several participants stated that they would feel watched if drones flew over private property. In addition, concerns arose regarding noise pollution. However, during the simulated delivery, participants also expressed excitement and quickly engaged with the artifact themselves. When we asked participants what they liked most about the app, they all mentioned its intuitive use: *"I don't really have an idea how such drones work,* *but this is like ordering something on Amazon." (P3G2), "it is easy to use" (P6G1), "I feel like I always know what to do next" (P3G3).* Effort expectancy was assessed to be low overall and several participants mentioned that the self-assessment was very helpful before beginning the delivery process. In addition, the majority of the participants see the bird-eye view in which the drone camera footage is shared as generally beneficial to *"understand what the drone can see and is doing" (P4G2).* Nevertheless, when we asked participants to tell us about what they disliked most about the app, they mainly complained about the features that aim to increase the transparency of AI-based decisions and display e.g., with which certainty the drone currently detects objects: *"This is just confusing. The drone says it detects me with 93 something percent certainty. What does this mean now? Can it see me now or not? [...] And then there is also nothing I can do about it. I would prefer the system to only tell me things it is sure about." (P6G3).* While participants mentioned that they need more information to understand this data, it also became clear that sharing this information in such a human-autonomy team is not very helpful because non-experts cannot interpret this information and act on it by, for example, taking control of the drone system. In addition, such statements clearly show why it is crucial to involve both experts and non-experts to design any collaboration between complex, autonomous systems and non-experts. During the first design cycle, experts have repeatedly emphasized that it is important to be able to evaluate the reliability of a system. Even if the user no longer actively controls the system, this would be helpful for creating trust. This view is influenced by the experts' previous experience of system-human interaction, which is strongly characterized by human control over the system. However, evaluation by non-experts in the second design cycle shows that known design principles for human-autonomy teaming need to be revised.

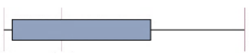
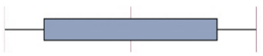
	Group 1 (G1)		**Group 2 (G2)**		**Group 3 (G3)**	
# of Participants (P)	8		8		6	
Age	 25 36 81		 22 29.5 53		 19 25.5 32	
Gender (m/f)	62.5% / 37.5%		37.5% / 62.5%		50.0% / 50.0%	
Prior Drone Experience	Mean: 1.2	SD: 0.43	Mean: 1.5	SD: 0.50	Mean: 1.8	SD: 0.69

Table 2: Non-expert Focus Group Study Sample

The proactive drone messenger, symbolized by a small drone icon sending messages, was rated as encouraging and helpful in providing needed information at the right time. However, non-experts pointed out that they need to be fully focused as soon as direct interaction with the drone system becomes necessary. The number of short messages received via the drone messenger should be kept to a minimum in these situations. All participants mentioned that they need a performance comparison to make an informed decision about the optimal means of transport. Since they considered different benefits such as faster delivery times or lower emissions to be more important, the comparison of performance characteristics should therefore also be individualized and adapted to the goals of the users. In addition, participants wished the app communicated more clearly that their presence was expected during delivery, as they cannot predict what interaction will be required before they need to make the decision for or against drone delivery. While only a minority of the participants indicated they saw *"no need to share something like this with their social network" (P5G2),* many participants said they were concerned about disturbing their neighbors with delivery drones and it would be good to know if this technology was already being used in their region. In addition, participants indicated that they would share their experiences with the drone app with family and friends, resulting in a positive overall assessment of the community platform features.

Many participants argued that intention to use increased following the interaction with the prototype. Participants stated that gaining more knowledge on drones and to be able to better assess effort and performance expectancy were primary reasons. This finding is supported by other studies which showed a positive correlation between public drone knowledge and acceptance of the emerging technology (Aydin, 2019; H. Eißfeldt et al., 2020). Relationships in the UTAUT model are moderated by gender, age, experience, and voluntariness of use (Venkatesh et al., 2003). While we only consider voluntary use by non-experienced users, we observed and gathered qualitative insights into the impact of gender and age. Older participants indicated that they were hesitant to use the new technology primarily because they expected *"a lot of effort" (P3G2)* during the delivery process and were unsure if the app would support them sufficiently to complete their tasks. Lower familiarity with delivery apps was also cited as an influencing factor. Younger study participants, on the other hand, reported that they enjoy testing out new technologies and have little fear of being overwhelmed. While a majority of female participants expressed concern about whether their social environment would support the use of delivery drones, this statement was only made by one male, older study participant. Apart from perceptions of social influence, no other gender differences were found.

While our study focuses on delivery drones, we derived general design principles for non-experts to interact with any autonomous transportation system and discussed these principles in our focus group studies following the demonstration of the artifact. **DP1**, which aims to inform the user on the system's performance and environmental impact and encourage use, was overall found to be *"very important" (P1G1), "crucial for such new technologies that I haven't tested out before" (P4G1),* the *"primary reason I would decide to use it" (P2G3)*. However, participants disagreed on whether they primarily wanted persuasive arguments or preferred neutral information that required individual interpretation. **DP2**, which aims to guide the user in all interaction and decision-making activities and enable intuitive use, was evaluated to make users feel *"comfortable" (P4G3)* and like they *"have done it before" (P5G1*). However, non-experts strongly argued that intuitiveness depends on their level of knowledge and insights that might be helpful to a drone pilot were found to be confusing such as displaying the certainty in object detection tasks. **DP3** and **DP5**, which state that the app should be equipped with functions for communication and relationship building, can provide autonomous systems *"with a human component" (P1G3)*. Overall, the communicative form of interaction was perceived by the study participants as very easy and pleasant. However, individual participants stated that they would not contact expert support early on because they *"did not want to ask stupid questions" (P5G1)*. While experts described this service as particularly safety-critical, the support could also be labeled as ordinary customer service to lower this inhibition threshold. Regarding **DP4**, which aims to increase situational awareness, participants emphasized that they were primarily focused on the current interaction and therefore the bird's eye view was particularly helpful. Overall, **DP4** was rated as *"absolutely necessary" (P2G3)*. Some participants further argued that the app should dynamically adapt to situations to improve situational awareness and one participant said: *"I tried this app for the first time. When I interact with the drone, I want to know what's going on at that second. I can't check all the other things at that moment, like the upcoming process stages" (P5G3)*. In addition to these insights into the lively discussion about the suitability of derived DPs, Table 3 highlights other identified design aspects that found wide acceptance during the focus group study. In addition, opportunities for further improvement of the artifact are shown which will be addressed during the upcoming third design cycle.

Design Principles	**Identified Design Aspects with High User Acceptance**	**Identified Opportunities for Improvement**
DP1: Inform and encourage use	• Providing neutral information on emissions and performance • Comparison with other transport modalities	• Customization to personal performance goals • Avoiding persuasion to use the technology (e.g., remove drone icon with proactive usage prompt)
DP2: Guide interaction	• Relying on familiar delivery application design • Early communication of upcoming interactive events that require user action	• Minimization of information about system functions that are beyond the user's control • Clear communication of the autonomy level of the drone
DP3: Support active engagement	• Receiving regular messages from the system, even if no interaction is required	• Minimization of system messages in situations that require high cognitive effort

	- Suggest user interactions that are structured in a meaningful way according to the time sequence	
DP4: Ensure situational awareness and safety	- Transparently displaying a summary of the delivery process - Making the perspective of the autonomous system understandable to the user (e.g., bird eye view)	- Identification of situations that may require the system to have final/shared decision-making authority, rather than always relying on the user (e.g., complete failure of the user, detected unauthorized use by minors)
DP5: Promote relationship building	- Sharing their own successes in using technology and learning from others	- Ensuring that only users with sufficient competence offer their support to other users in the community area

Table 3: Results of Focus Group Discussions by Non-experts on Derived Design Principles

Finally, we asked participants if they considered the drone to be a team member. Participants found it *"weird" (P4G3)* to consider an object as a team member. Even though the drone makes many decisions on its own, participants rather viewed it as *"a supporting tool" (P8G2)*. Nevertheless, one participant stated: *"I wouldn't say that the drone was my team partner, but I wouldn't call our delivery guy my team partner either. So, it can also be more due to the task. If I work very well with someone regularly, I develop a team feeling over time. If a drone brought me my daily newspaper every morning, I might develop – yeah - something like a team feeling after a while. For example, my son has such a vacuum cleaner robot and even gives it a name. I find that strange, but here you could perhaps already see the robot as a team partner" (P7G1)*. Although it is not expected to be a viable business model to deliver printed daily newspapers by drones, this statement clearly shows that human-autonomy teams will have to develop over a longer time and also that the developed artifact will fulfil many goals only after a longer period of use.

The qualitative evaluation of the artifact is very feasible to iteratively revise DPs and improve interface design. However, for the final and outstanding third design cycle, our evaluation strategy primarily aims to obtain quantitative data from a larger sample of potential non-expert users and experts to rigorously test the joint value of derived DPs. In addition, we designed an artifact for fully autonomous VTOL drones to deliver parcels. While some DRs and DPs, such as DR1 and DR3, can be applied to the design of artifacts for semi-autonomous drones that interact with non-expert users, DR4 would require adaptation for such use cases. This also applies to all DPs which guide the interaction in human-autonomy teams.

Conclusion, Limitations, and Directions for Future Research

Due to technological advances in the fields of robotics and artificial intelligence, many systems reach for higher and higher levels of autonomy today. Especially delivery drone technology has matured in recent years and a variety of civilian use cases that also foster the creation of sustainable cities have emerged. To enable non-experts with little to no knowledge of autonomous systems such as drones, to also benefit from the emerging technology, we apply a DSR approach to derive a solution instantiation in two consecutive expert and non-expert design cycles. We are responding to the call to expand the growing research field of human-autonomy teaming (McNeese et al., 2021) by addressing implementation in the context of a real-world use case. We develop a mobile application for non-experts to safely and intuitively interact with autonomous delivery drones and promote acceptance and use of the technology, thus addressing our research question. Following the second design cycle, we plan a final mixed design cycle with experts and non-experts to test the app in a real-world experiment.

Our study provides several **theoretical contributions**. First, we present a methodological approach that allows non-experts and experts to be involved in the design process on an equal basis and without mutual interference during the initial derivation of DRs and DPs and initial evaluation. This approach creates a common ground for future research which aim to make complex autonomous systems accessible to the general public. Incorporating domain knowledge and translating it into a design intuitive enough to be understood by non-experts remains a major challenge in many growing research areas, and we provide a foundation on which targeted future research can be built. Second, our study demonstrates an approach that not only places user satisfaction at the center of the design process but also promotes general technology acceptance. Many AI-based technologies are viewed controversially, and drone technology research is just one example that can benefit from this approach. Third, we provide several insights on human-autonomy teaming in the context of non-expert use which goes beyond existing research. We show that the interaction of non-experts with autonomous systems requires an iterative design approach and many existing design requirements need to be reconsidered for human-autonomy teams as already suggested by (McNeese et al., 2021). To provide a concrete example, the transparency features of AI-based autonomous system decisions were found to be rather unhelpful, because users have too little background knowledge of AI, have to trust system decisions, and can no longer control systems. These findings pave the way for transferring and adapting knowledge from the human-machine interaction domain to human-autonomy teaming. Fourth, we contextualize general DPs and develop a solution instantiation for non-experts to interact with autonomous systems. Thus, we contribute by guiding researchers and IS designers on how to design easily understandable artifacts that interface with autonomous systems. Lastly, we outline how UTAUT can be applied as a kernel theory in the DSR approach to develop artifacts for human-AI teaming. Practical insights from experts confirm the impact of all constructs of UTAUT on the intention to use autonomous delivery drones. While UTAUT has been shown to be very suitable, we have also identified factors, such as privacy, that have not yet been adequately addressed by the theory and provide a basis for further research.

This step toward implementing human-autonomy teams in a real-world application also holds several **practical contributions**. First, our solution instantiation vividly demonstrates how broad the application area of delivery drones can be if the autonomy level is sufficient to allow interaction with non-experts and thus the general population. Second, iteratively derived DRs and DPs also clearly show how important it is to involve this new end-user group in the development work of manufacturers and service providers at an early stage. With our study, we also call on the industry to address the challenges in the area of human-autonomy teaming. While the drone industry has already identified this challenge (Ellenrieder et al., 2023), it is expected that this topic will also become more relevant in other industries as autonomy levels increase. Lastly, the civil drone industry can build on the knowledge gained and use our artifact as a basis to develop optimal solutions tailored to different use cases and drone types. In the upcoming third design cycle, drone manufacturers and service providers will have the opportunity to test our artifact to transfer the results into practice.

However, our contributions are also subject to **limitations**. The number of semi-structured expert interviews is limited and results may be biased toward popular fields of application such as deliveries in the healthcare sector. In addition, we focus on the specific use case of parcel delivery by VTOL drones which offer a high degree of flexibility in adapting to human actions and the applicability of our DRs, DPs and the developed artifact cannot be guaranteed for all drone types and application domains. Moreover, it is important to note that qualitative research results were obtained in this study and statistically significant results will have to be added through follow-up studies. Lastly, focus group participants' opinions were obtained after a demonstration of the technology at the prototype stage. Interaction with large delivery drones that appear to move self-directed in the airspace is likely to have an impact on participants' subjective assessment in the real world. Both, the contributions and limitations of this study provide a broad spectrum for **future research**. Besides obtaining statistically significant results, it will be of great relevance to conduct experiments under real conditions and refine design principles in the future. While acceptance of delivery drone technology can be fostered through targeted artifact design, future research and practice will need to take further approaches to ensure that this technology can continue to improve infrastructures and make future cities more sustainable. Delivery drones have evolved rapidly in recent years, and this application domain has provided a great context for our and previous studies investigating human-autonomy teams. We encourage future research to apply the findings to other autonomous and especially semi-autonomous systems. While UTAUT served as a feasible kernel theory to design our artifact for human-autonomy teaming, we see a need for future research to extend this model by also incorporating privacy aspects that arise for all levels of system autonomy. Lastly, drone technology has rapidly improved in recent years and poses many opportunities to improve e.g., infrastructure and access to healthcare services. However, their actual impact on the sustainability of future cities remains controversial, and several delivery drone programs have been discontinued in recent years. Future research should critically discuss sustainability aspects of the technology, and research on the design of human-autonomy interaction should focus precisely on the application areas that have a major impact on sustainability.

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