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An assessment of the acceptance and aesthetics of UAVs and helicopters through an experiment and a survey

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ABSTRACT

Public attitude toward Unmanned Aerial Vehicles (UAVs) has been extensively researched, frequently using surveys or experimental settings involving sound/noise. In this study, we present an experiment using visual stimuli, exploring not only the acceptance of UAVs as such but also of their interactions with different environments. The stimuli were pictures of quadcopters, either white or orange, with medical or commercial markings. For comparison, pictures of helicopters with the same four variations and a goose were also used. These pictures were superimposed over three types of backgrounds: urban, industrial, and rural.

Twenty-four student participants took part in this study, each responding to 81 stimuli with Likert scale ratings for the acceptance and beauty of the stimuli after responding to objects that were used as a manipulation check. Reaction times for all responses were recorded. Afterward, participants completed a survey designed to identify the reasons for their judgments regarding acceptance.

Our results deliver a complex view of the acceptance of UAVs. For example, the usage of the UAV had the largest impact on acceptance, with medical usage having the highest acceptance rating. Commercial usage was more accepted in industrial areas, and UAVs were more accepted than helicopters.

The survey showed a heterogeneous variety and relevance of reasons for the acceptance ratings. On average, usefulness, traffic relief, reduction of privacy, and acceptance by society were indicated as the most relevant factors affecting the acceptance ratings.

In general, our study suggests that the less considered visual factors of drones (salience in our study) can be expected to influence the acceptance of UAVs in addition to the noise factor. Most importantly, the physical characteristics of UAVs alone are insufficient to predict their acceptance. The purposes for which UAVs are used (that might be visually recognizable) and the environment in which they are operated play an important role in shaping public attitudes towards this new technology.

1. Introduction

Transition of mobility in cities from the ground to the air is a major objective of governments, industries, and scientists. There are plans to integrate so-called Unmanned Aerial Vehicles (UAVs) over the next ten to 20 years into larger Unmanned Aerial Systems (UAS) or Urban Air Mobility (UAM). Different stakeholders hope for several benefits, while others fear negative impacts on the quality of life, safety issues, and loss of jobs. We discuss these acceptance factors in this paper.

Methodological research on the acceptance of UAVs differs from the research on commonly used technologies insofar as UAVs have hardly been implemented or have not been implemented at all. Therefore, actual experiences, at least with complex UASs, cannot yet be collected [1]. Experience with similar systems, like helicopters, differs not only concerning technical characteristics such as noise; in addition, in contrast to most helicopter usage, plans for applications of UAVs go beyond public safety missions and monitoring tasks. The industry is attempting also to determine how UAVs could be implemented on a larger scale, for example, to transport wares or people for commercial purposes. Society's acceptance of UAVs is often mentioned as a crucial aspect in this discussion. A common approach to modeling acceptance in UAV research builds on the knowledge, attitudes, and practices (KAP) surrounding the use of a particular technology [e.g., 2–4]. KAP influences the perceived costs, fears, and benefits which could lead to

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acceptance or rejection of the technology [4]. In addition to individual attitudes, societal beliefs about a technology can influence acceptance. Thus, in the theory of planned behavior (TPB), normative beliefs are modeled as determinants of subjective norms [5], with individuals evaluating whether (peer) groups would approve of the behavior. The subjective norms, in turn, are relevant for acceptance. The technology acceptance model (TAM; e.g. Refs. [6,7]) integrates different variables that influence attitudes towards technology indirectly, such as through perceived ease of use, and directly, such as through perceived usefulness (see Section 1.5.1.3). The TAM maintains that directly or indirectly (via attitudes towards the technology), behavioral intentions to use or reject the technology and subsequently actual use or rejection of the technology follow. For the present research, we investigated various variables (technological, psychological, and others) that have been shown to influence the perception of UAVs and implemented these as independent or control variables in an experiment or a survey. Appendix A provides an overview of the experimental and survey variables.

1.1. Technical considerations

In a recent article, Hassanalian and Abdelkefi [8] review various classifications that have been used for UAVs. Most are based on the UAVs' weight and range; for example, the weight classifications in one study ranged from ≤200 g to >600 g ([9], cited in Ref. [8]) and in another from ≤ 5 kg to > 2000 kg ([10], cited in Ref. [8]). In Hassanalian and Abdelkefi's summary of the classifications by size and weight, UAVs range from 2 m to 61 m wingspans (smaller than 2 m referred to as micro-UAVs) and from 5 kg to 150,000 kg. Further possibilities for technical classification of UAVs represent the type and number of rotors, and the type of takeoff and landing (horizontal takeoff and landing, HTOL, or vertical takeoff and landing, VTOL). These technical aspects of UAVs may influence their acceptance due to different noise emissions or the visual field they cover. Additionally, Hassanalian and Abdelkefi describe future technical challenges for the rotors and the power supply. For example, the energy range and cost reduction of operations might be particularly relevant when deciding to operate a UAV for a specific purpose, and the former might also be relevant when considering the environmental impact.

Hassanalian and Abdelkefi's psychological literature review indicates that aspects such as the degree of visual control by a pilot (remote, visual) or the degree of autonomy of UAVs' flight can also be used to categorize UAVs. The authors [8] also observe that UAVs can be categorized by the purpose of their usage, which could include search and rescue missions, environmental protection, mail, and delivery. These considerations are also crucial in psychological acceptance research and will be addressed in section 1.3.1.

1.2. Perception and aesthetic evaluation of UAVs

The senses with which we perceive the environment can be divided into far and near senses, which is relevant for UAVs, as information from the far senses will have the largest impact on the perception of the residents of a city. The auditory system uses sound waves as incoming information, while the visual system uses light waves. Perceived sound provides essential information about our surroundings, can harm individuals, and prolonged exposure to noise can lead to psychological harm such as stress and related illnesses [11; see also 12, 13]. Hearing is likely the most discussed and researched sense in the context of UASs, as UAVs produce noise that can amplify with increasing use.

There have been preliminary findings on various aspects of UAV auditory perception. Some findings can be adapted from other studies on noise and stress. However, some areas require a more differentiated consideration—for example, the noise profile of UAVs differs from that of other means of transport [11,14]. There is a consensus that the noise impact of UAVs should be reduced as much as possible through technological advances or regulatory intervention. If the noise emission decreases, the visual impact of UAVs will be brought into greater focus, as discussed next.

Humans can use visual information to draw conclusions based on UAVs' visually recognizable features such as distance, size, coloring, shape, movement direction, and sometimes, usage. The visual system is the primary source of information for a majority of people. However, evidence on the visual perception of UAVs is sparse. In urban areas, we receive relevant visual information regarding which we must decide if and how to respond—for example, whether we need to dodge an approaching bus. The importance of the visual system can be seen in an experiment by Chang and Li [15]. They demonstrated that the probability of detecting a small UAV (DJI Phantom 4, 490 mm) was higher for visual than auditory perception. Of course, this requires the UAV to be in one's field of vision. Nevertheless, Chang and Li's experiment demonstrated that in some situations, UAVs will first be detected visually. The difference between auditory and visual detection could increase as technological innovations or regulations reduce noise emission [e.g., 16]. Thus, in the long term, visual perception of UAVs and their societal effect will likely become—and most importantly, will likely remain—relevant.

Salient sources such as UAVs attract significant attention. Salience can be perception- or value-based. In value-based salience, a source attracts attention if, for example, it corresponds to an individual's goals or action tendencies. This may happen if the semantic content of a source is valued as particularly interesting—for example, when one sees one's name [e.g., 17; for a review of value-based attention, see 18]. In perceptual salience, the source is distinguished from the background by characteristics such as brightness or color [19,20]. UAVs are expected to be perceived as salient objects, both visually and auditorily, especially during the trial and introductory phases, because most people are not used to the sight or sound of UAVs [21].

Following perception, the processed information is evaluated. Participants in some studies have already expressed a fear that the frequent operation of UAVs could lead them to accumulate in the sky in an unappealing way [21,22]. This topic has been studied and discussed in other disciplines (such as advertising) under the term "visual pollution," "visual smog," or "shadowing." Chang et al. [23] also reported that darker UAVs were perceived as more threatening than lighter ones. To further investigate the impact of various physical characteristics of UAVs on their acceptance would thus be necessary. Rather than simply evaluating the threats posed by UAVs, however, we are interested in another, more positive, cognitive evaluation: aesthetic judgments about the beauty of UAVs (henceforth referred to as the *beauty rating*, as we have previously used ratings to evaluate the sensory experience of beauty, and "beauty" is the term most often associated with aesthetics [e.g., 24]). Marković [26] notes that various definitions of aesthetic experiences view aesthetic situations and objects as fundamentally different from everyday ones. It is necessary to distinguish aesthetic experiences from the pragmatic meaning of situations or objects to experience the holistic aesthetic. Jacobsen [27] described the process of aesthetic processing as a sensation-based evaluation of an entity in terms of the dimension of beauty. Thus, UAVs might not be considered solely as a means of transportation but might also become aesthetic objects, with the dimension of beauty serving as an evaluation criterion.

Even if the implementation of new technologies focuses on usefulness and user-friendliness, factors such as aesthetic and emotional qualities can also influence the preference for and evaluation of technical systems [28]. Since, as mentioned earlier, the visual perception of UAVs will probably not be eliminated, even by advancing technology, it is essential to consider the effects of the visual perception of UAVs. Especially in their interactions with the physical areas in which they operate, as explained in Section 1.3.2, since different scenery is likely to differ in terms of aesthetics. In addition, recent design studies presented by parcel and delivery services often use highly salient colors resembling rescue helicopters [29]. We, therefore, considered such schemes in our experiments, from which two possible conclusions might be drawn. On the one hand, as positive attitudes towards the medical usage of UAVs have been demonstrated in the literature (see Section 1.3.1), it is conceivable that positive attitudes towards rescue helicopters may transfer, at least briefly, to delivery UAVs that have the same color. On the other hand, it is also possible that a highly salient color might intensify an already negative visual perception of UAVs, which could reduce their acceptance. For example, Kellermann and Fischer [21] showed that UAVs were described as tending to be visually ugly.

Next, we discuss other external factors that might influence the perception and acceptance of UAVs, along with perceived/expected benefits and risks that we considered in our experiment or survey.

1.3. External factors influencing the acceptance of UAVs

In the literature, many external factors that could influence the perception and acceptance of UAVs have been investigated. We first address the factors we experimentally manipulated in the present study, namely, the usage of UAVs and the area of their operation; the salience of these factors was discussed in Section 1.2. Then we discuss other influencing factors that we assessed in a survey following the experiment, where we assessed the extent to which participants considered each of these factors when deciding how acceptable they judged each scene to be. We also explain other relevant factors shown in the literature to affect the acceptance of UAVs, which we therefore kept constant.

1.3.1. Usage

Potential usages of UAVs that serve society have consistently been found to be described as more accepted by participants than, for example, commercial or hobby usages. The usages that fall under the term “societal” and “commercial” differed between studies. Societal usages included, for example, medical usages (medical supply, SAR), governmental usages, or monitoring tasks such as fires, infrastructure, or traffic. Typical commercial usages were parcel or passenger transport, but some studies investigated far more specific usages. A second factor for acceptance of UAVs that connects to their usage might be the expected distance to people in areas where the UAVs would operate and thus affect these people (see also Section 1.3.2). Examples are agricultural UAVs that might operate over a field or UAVs that only operate on a company premises, in contrast to parcel drones, which are expected to fly over people and their property.

The usage or purpose of UAV flights could be one of the strongest influencing factors for UAV acceptance, along with their noise. Kellermann and Fischer [21] held focus group discussions in three German cities in 2019 about parcel and personal UAVs that led to the conclusion that medical UAVs were more acceptable than commercial parcel UAVs. Other surveys have further broken down the usage of UAVs. Murray [30] conducted a country-wide telephone survey in the US in 2012 with 1709 participants that assessed various possible usages of UAVs by the military or the government. The main usages that were most accepted were search and rescue missions (80%), followed by tracking criminals (67%) and controlling illegal immigration (64%). The least acceptable usage was for speeding tickets (23%). This survey demonstrated an early tendency to accept UAVs for usage in public safety, especially in search and rescue missions. Klauser and Pedrozo [31] conducted a survey in Switzerland in 2015 that assessed acceptance for four usages, based on 604 returned questionnaires. The results showed that the usage of UAVs for scientific research was classified most favorably (81%, 10% indifferent), followed by police mandates (63%, 13% indifferent), aerial photography (49%, 15% indifferent), and, far behind, postal delivery (18%, 15% indifferent). Aydin [2] compiled a detailed listing of 40 current or possible future UAV usages for a 2017 online survey, which included 153 participants (16 participants who had never heard of UAVs were excluded). In addition to surveying the participants’ awareness of the (potential) applications (ranging from 13% for disease spread detection to 98% for military applications), the participants’ attitudes regarding the specific benefits were also queried. The results showed, for example, an average acceptance between 4.5 and 5 (out of 5; 1 = *strongly oppose* to 5 = *strongly* support) for most public-serving usages, and a somewhat lower average acceptance, between 4 and 4.5, for a variety of usages, primarily monitoring usages (e.g., construction, railway, or environmental monitoring) but also such usages as military applications, agricultural applications, drug traffic control, and home security alarms. Passenger transportation and UAV racing had the least acceptance (on average 3, *neutral*, to 3.5). Summarizing in four categories of UAVs, Aydin found the lowest average acceptance for hobby UAVs (3.89), somewhat higher for commercial usages (3.99), about 0.6 higher for scientific (4.6) and public safety usages (4.65). Eiβfeldt et al. [3] provided data on the acceptance of civil UAVs in Germany in 2018 based on 832 interviews, with the last part of the survey addressing the acceptance of different UAV usages, and they found the highest acceptance for the usages summarized by Klauser and Pedrozo [31] under “public safety.” The usage of UAVs for hobbies was, on average, more rejected than in other studies, as was the usage for advertising purposes. The somewhat more negative overall evaluation could be partially explained by omitting of a neutral category, which required deciding in one direction [3]. Tan et al. [4] conducted a survey in Singapore in 2019 with 1050 participants, and the acceptance rate for the various usages of UAVs was consistently higher than 60%. Again, the usages for public safety (for example, medical, search and rescue, and research) were accepted by almost the entire sample. However, the acceptance rate was also high for government users and maintenance and monitoring tasks by commercial and industrial users. Speeding and parking tickets by the government were less accepted usages (between 62% and 66%; but still twice as high as in Murray’s [30] US survey). Commercial and industrial usages, transportation for people, and photography by public users were accepted by about two-thirds of the sample. To place these results in a cross-cultural context, the authors described Singapore as a “highly urbanized city state where its population is extensively exposed to mass media and emerging technologies” [4, p. 4]. In summary, various studies have shown that usage significantly influences UAV acceptance. The following section discusses another important external variable: the area where the UAV will be operated.

1.3.2. Area of operation

Studies on the area where a UAV will be operated have frequently distinguished between urban, rural, and industrial areas, and sometimes also between commercial and privately owned properties. The acceptance patterns by area of operation were similar across the studies, as participants began to accept UAVs the most in industrial areas and had more reservations about UAVs in rural and urban areas. Flights over their own property were seen as problematic for security and safety reasons (see section 1.5.2.1). As mentioned earlier, Klauser and Pedrozo’s [31] survey in Switzerland demonstrated differences in the acceptance of different usages. Specifically, the acceptance rates (indicated as “favorable”) were 31%, 43%, and 15% for hobby UAV usage and 21%, 33%, and 21% for commercial UAV usage in private, rural, and urban areas, respectively. The “indifferent” responses fell between 12% and 16%, thus, the unfavorable percentages fell between 43% and 72%. UAV acceptance (designated as “favorable”) was thus highest in rural areas (although less so for commercial UAVs than for hobby UAVs). Commercial UAVs were equally less accepted in private and urban areas (21%). Tan et al. [4] also investigated the acceptance of UAVs in Singapore depending on the area of operation: industrial, recreational, commercial, or residential. To do this, they inserted a small UAV into two photos of each area of operation. The average acceptance (on a Likert scale with 1 = *strongly disagree* and 6 = *strongly agree*) differed significantly for the four areas, with the highest acceptance for industrial areas (*mean* = 4.58), followed by recreational areas (*mean* = 4.40), commercial areas (*mean* = 4.58), and finally, residential areas (*mean* = 3.87). Eiβfeldt et al. [3] also evaluated a question about the acceptance of UAVs in city centers, residential areas, commercial areas, and industrial areas as a function of the participants’ residency (small vs. large cities). Participants living in large cities were more accepting of the usage of UAVs in city centers' residential and commercial areas than participants living in small cities. Eiβfeldt et al. found no difference between residents of large and small cities for the consistently highest acceptance of industrial areas. The authors attributed the pattern for UAVs operating in industrial areas to their possible lower impact on people.

1.4. Demographic factors influencing the acceptance of UAVs

The perception of UAVs was found to depend on various demographic characteristics, such as age, gender, socioeconomic background, or culture [1,3,4,11,32]. To summarize, these authors found, on average, tendencies for younger people to view UAVs more positively than older people and for men to have more positive attitudes towards UAVs than women. Tan et al.'s [4] study also highlight cultural differences, as the attitudes regarding UAVs in Singapore (highly urban and technologized) were more positive than those found by previous studies in Western countries.

1.5. Perceived/expected benefits and risks of UAVs

Various surveys have been conducted to determine the public's hoped-for benefits and fears about risks in their perception of UAVs.

1.5.1. Perceived/expected benefits in the context of UAVs

1.5.1.1. Traffic relief. Full roads mean lots of traffic jams. In several studies, many participants hoped this would be overcome via UAV usage. In Kellermann and Fischer's [21] focus groups, the hope was expressed that traffic relief could result from UAV usage, but there were also concerns that this could only happen through an enormous number of UAVs. The concern of the focus groups resembles expert assessments, discussed in Kellermann et al.'s [33] literature review, that, for example, current parcel transportation accounts for only a small share of the road traffic volume. Therefore, parcel UAVs would not necessarily lead to a substantial reduction in road traffic. For example, Doole et al. [34] calculated that in 2035, 174,521 drone flights per hour would be needed in Paris to cover 70% of parcel deliveries. This percentage was based on an assumption of parcels suitable for drone transport. A potential increase in the demand for transportation using parcel drones could exceed the available capabilities, resulting in continued high volumes of ground-based traffic [33]. Therefore, UAVs' actual potential for reducing road traffic could be lower than society might hope. If this expectation is compared with the reality when UAV usage is implemented, this factor could lose its positive valence for the acceptance of UAVs.

1.5.1.2. Time savings. Potential time savings through the usage of UAVs compared to ground transportation is one of the most frequently mentioned benefits of UAVs. In their overview article, Straubinger, Rothfeld, Shamiyeh, Büchter, Kaiser, and Plötner [35] highlight potential time savings as a relevant factor for the usage of Urban Air Mobility (UAM). Kellermann and Fischer's [21] focus groups also discussed this factor and assessed it as important. However, doubts have also been expressed regarding whether air taxis in an urban context would achieve worthwhile time savings. Al Haddad et al. [1] also found in their study, which included 221 participants mainly from Germany or other European countries, that the time-saving factor ranked high among the participants regarding the essential factors for UAV acceptance. Model calculations produced different results regarding when UAV usage would be profitable in terms of time savings [33]. It depends on many factors, from UAS organization to the comparison of means of transportation or the terrain. Thus, for the positive influence of UAV time savings on their acceptance, the same conclusion applies as in the case of traffic relief: the potential positive influence must withstand comparison with reality.

1.5.1.3. Usefulness. As explained in section 1.3.1, usages that serve society have always been more accepted than, for example, commercial ones. Perceived usefulness is a key factor in the TAM [e.g., 6, 7] and is influenced by various other variables. Behavior (use/rejection) follows the behavioral intention, which depends on the perceived usefulness. Kellermann and Fischer's [21] focus groups discussed the usefulness of UAVs as a relevant factor for their acceptance. The focus groups quickly reached a consensus on the usefulness of medical UAVs and then turned to a longer discussion about parcel delivery, focusing on the possible benefits of (temporally and spatially) flexible parcel delivery. Ultimately, perceived usefulness is an evaluation of various pro and con arguments, which depends on many factors. However, the quick consensus in the group hints at how strongly the usefulness of medical UAVs might already be envisioned (see section 4.3 for a discussion of the connection between processing time and attitude strength).

1.5.2. Anticipated risks in the context of UAVs

1.5.2.1. Safety and security. Kellermann et al.'s [33] systematic literature review emphasizes the volume of literature that revolves around concerns regarding the security of UAVs. Based on definitions that are formulated in the context of engineering [36], we summarize definitions of safety and security for our purposes. *Safety* covers all aspects of a technical system that must function correctly for its safe operation. *Security* aims to secure the safety of the system against, for example, hacker attacks and, more generally, crime and misuse [36]. Kellermann and Fischer's [21] focus groups discussed both of these aspects of UAVs, and related concerns about accidents (safety) and manipulation possibilities (security) were expressed by the participants.

In Eiβfeldt et al.'s [3] survey, concerns were raised about safety aspects of UAVs, such as transportation safety and damage and injuries, as well as security aspects, such as security against crime and misuse, and all of these were identified as potential threats by at least 70% of the sample. Similarly, in Al Haddad et al.'s [1] survey, most participants indicated that safety was most relevant to them, and thus safety emerged as the most important influencing factor for acceptance.

1.5.2.2. Effect on privacy. Some studies summarize UAV privacy issues under safety and security. Other studies, including ours, include privacy as a separate factor. Klauser and Pedrozo's [31] survey found that the participants had privacy concerns about UAVs ranging from 26% for hobby UAVs to 36% for police UAVs and 28% and 26%, respectively, for military and commercial UAVs. Interestingly, the number of scientific publications on this topic increased from 2016–2018 compared to 2015 [33]. Lidynia et al.'s [37] 2017 survey in Germany ($N = 228$) added to the discussion about privacy that even active UAV users would not accept foreign UAVs flying over their homes for fear of having their privacy violated. The surveys conducted by Behme and Planing [32] ($N = 11$) and Al Haddad et al. [1] in 2019 also demonstrated that data and privacy protection were an issue.

1.5.3. Topics discussed as both a benefit and a risk

1.5.3.1. Job situation. The introduction of complex and large-scale UASs may have a far-reaching impact on the logistics of the work world. The research investigating how people imagine UAVs might affect jobs tends to revolve around potential job losses. Nevertheless, it should also be mentioned that working with UAVs on company premises—or for example, in disaster control or rescue services—can also be researched as *UAVs in the context of the job situation* with favorable views. However, we do not consider all occupational contexts in which UAVs may have a psychological impact, as not all of these are relevant to our study.

Kraus et al. [22] highlighted the fear of job loss as one of the social fears regarding UAVs in a document analysis covering the years 2016–2020. Similarly, Aydin et al. [2] reported serious concerns about potential job losses. Kellermann and Fischer's [21] focus groups also discussed such fears. In contrast to other studies, however, a few participants in their focus groups reported that they could imagine new jobs being created because of UAV usage. Nevertheless, a problem was suspected in this connection, namely, that these jobs would require higher skill levels than were held by those who were replaced by UAVs and that the newly created jobs would therefore not be filled by those who were replaced by UAVs. This shift in job requirements might have a negative effect on the perception of UAVs. Al Haddad et al.'s [1] survey showed a link between concerns about possible job losses and lower acceptance of UAM. In sum, the job factor is relevant to the consideration of UASs in a social context for several reasons, which include both hopes and concerns, although the fear of job losses is presently more prominent in the literature.

1.5.3.2. Environment. A highly complex factor related to the acceptance of UAVs is their possible impact on the environment. For example, although UAVs could impact wildlife through noise or accidents, this is little discussed, and the assessments are complex, also due to the thin data available about UAVs in the context of the environment [21]. There is a hope that emission-free operating UAVs might perform better compared to other forms of transportation [21]. However, the calculations differ as a function of the assumptions and comparisons made for such a scenario. For example, a passenger UAV could be environmentally superior to a helicopter in terms of noise and its carbon footprint. However, single shipments using parcel UAVs could be significantly inferior to even diesel-powered trucks with respect to environmental concerns, especially if the trucks' parcel routes can serve many customers [38]. Thus, uncertain energy efficiency is a concern when assessing the environmental impact of UAVs [e.g., 39–41]. Kellerman and Fischer's [21] focus groups held a similar discussion, with participants indicating that they would only want to use UAVs if they were environmentally friendly. However, the participants disagreed on whether UAVs would be environmentally friendly. This evaluation could influence future acceptance or usage of UAVs, possibly in part due to different levels of information (KAP) and even more so because of the general discord in the discussion of this topic.

In summary, the perception of the impact of UAVs on the environment cannot yet be accurately assessed, and it depends strongly on the point of view. An assessment of UAV's environmental friendliness entails a certain degree of freedom, which could be even more significant in the case of the environmental friendliness perceived by persons who lack a broader amount of information about them, which could, in turn, impact their acceptance and user behavior [e.g., 21].

1.5.3.3. Fair use for all. The research on fairness or perceived fairness in mobility is also voluminous and cannot be discussed in great detail in this study. In a recent article, Hauptvogel et al. [42] discuss the fairness or social justice in aircraft noise. The basic concepts are transferable to the UAM context. Consideration of fairness in the context of aircraft noise is particularly relevant since noise can lead to various health restrictions (see also Section 1.2), and a feeling of injustice resulting from the noise can lead to actions against, for instance, construction projects. Hauptvogel et al. discuss different forms of fairness (distributive fairness, procedural fairness, informational fairness, and interactional fairness) that can be improved by different proposed solutions, including, for example, fair noise distribution, improvement of the cost-benefit ratio, regulation, and varying stakeholder participation opportunities, as well as transparent and comprehensible information provision. Parallels between vertiports and airports as well as flight routes could be identified, and experiences with possible solutions might be transferred to UAM stakeholder processes. As UAVs have a distinct noise profile compared to aircraft (see Section 1.2), more detailed research on the impact of the noise profile and evaluation of the advantages and disadvantages are needed.

In the research on the perception of UAM, fairness is also frequently mentioned by participants. However, in this context, no systematic differentiation has yet been made between the types of fairness. Klauser and Pedrozo [31] mention the fear that the price for using UAM would be high and that, consequently, not everyone would be able to use such a service (a fear of exclusivity). Behme and Planing [32] and Straubinger et al. [25] reported the price as a barrier to the fair use of UAVs by everyone. Vascik and Hansman's [43] literature survey classifies perceived fairness as a factor that is expected to have a moderate effect on public action.

1.5.4. Autonomy

Hassanalian and Abdelkefi [8] indicate that UAV autonomy is discussed in UAV acceptance research. Unlike commercial UAVs, there was a clear preference for hobby UAVs to be operated by sight (e.g. Ref. [31], found 89% in favor of that regulation). For commercial UAVs, the picture is different. In a survey of an American convenience sample ($N = 877$; 2014 and 2015), PytlikZillig et al. [44] examined (among other things) acceptance as a function of autonomy, which was differentiated into fully autonomous, partially autonomous, and no autonomous control. They found no correlation between the degree of autonomy and the acceptance of UAVs, even when the purpose of the usage was included in the model, and the different degrees of autonomy showed no significant difference (only a trend). In the Fraunhofer Institute's [45] survey during an exhibition of a passenger UAV (an air cab) at a Berlin train station in May 2019 ($N = 320$), 35% indicated that they would favor pilot control, 26% autonomous control, and 35% had no operation preference. In Behme and Planing's [32] qualitative interviews on air cabs, one participant mentioned a lower price as a hoped-for benefit of not having a pilot. Autonomous air cabs were described as rather safe, especially in a context where they were licensed by German authorities. One participant also saw possible programming or technical errors as less likely than possible human errors by a pilot (safety). On the other hand, concerns were expressed regarding sabotage possibilities (security) for autonomously operated UAVs compared to operation by a pilot. These few findings might indicate that society would not refuse to accept UAVs because of their remote or autonomous control, although preferences for the level of autonomy differed.

1.6. Methodological considerations

In this study, we aimed to investigate the acceptance of UAVs depending on the area in which they operate, their usage, and their salience. Since previous surveys mainly referred to theoretical scenarios and our sample could not have experience with established UASs, we incorporated comparative measurements in our survey design. For the comparisons, we included a helicopter, as these are currently used for public purposes, and a native bird species as a natural reference. Both helicopters and birds are found in the airspaces of metropolitan regions. UAVs have parallels to helicopters in terms of flight characteristics and possible usages. For this reason, helicopters represent the best possible example of established technological objects in the urban airspace, allowing a comparison of acceptance between a novel and an established technology. In contrast to airplanes, helicopters have a lower service ceiling, can complete hovering flights, fly slowly, and thus remain in the viewer's field of vision for longer periods. The research on the perception of helicopters used for medical purposes is inconsistent [46], mainly because they are often criticized for their high noise levels [47]. Search and rescue (SAR) missions are still commonly performed by helicopters due to their hovering capability. With the increasing availability of UAVs, it is conceivable that UAVs will also be used for this purpose in the future [48]. The comparison of UAVs and birds is also reasonable due to the high occurrence of birds in metropolitan airspaces. In addition, some bird species are similar in size to UAVs. The distance to a viewed object also affects the coverage of the perceptual field, so the actual size of an object is just one aspect of the size perception of an object.

However, it was not obvious how to implement a comparison of UAVs and birds because the acceptability of different bird species in different environments can vary greatly, and participants' attitudes towards them should confound the experimental design as little as possible. For example, 21% of the respondents from the French city of Rennes in a study by Clergeau et al. [49] reported disliking the European starling, while as many as 71% of the participants from the adjacent suburbs made the same statement. Clergeau et al. found similar large differences for other bird species in different areas, which should be considered. Thus, birds in the airspace are not perceived uniformly since birds can evoke different emotions linked to complex factors such as the type of bird, the place of the viewing, and personal experiences with the birds. However, it can be argued that the advantages of birds as a comparative object outweigh the disadvantages. The alternative—merely presenting a scene with an open sky—would result in more severe limitations on interpreting the results in terms of perception than the noted limitations of using birds for comparison to other objects. Therefore, we decided that a comparison to a natural object in the airspace (a bird) would be more appropriate for this study than a comparison of the acceptability of UAVs to the acceptability of an open sky. Nevertheless, to have a baseline, henceforth natural comparison condition, for the scenes independent of the technological flying object, it was critical that the objects in the airspace would be perceptually comparable. Therefore, we selected a rather large, perceptually less salient native bird species, which would be less likely to evoke negative affect than, for example, seagulls, ravens, or pigeons: the graylag goose. Although it is impossible to make a general statement about the acceptability of geese, there is minor evidence that graylag geese are not perceived negatively by individuals [50,51], which supported our decision. In addition, the neutral coloration of their plumage does not enhance their saliency.

In summary, in the experimental part of this study, we systematically manipulated four factors that our literature review has resulted to be relevant for UAV's acceptance: area of operation (industrial, rural, urban), object (goose, helicopter, UAV), and, for the UAV and helicopter, usage (commercial, medical) and salience (white, orange). In line with previous evidence outlined above, we expected the highest acceptance rates in industrial areas and the lowest in urban (due to proximity to humans). The geese were expected to be more accepted compared to the technical objects. Large effects were expected for the factor Usage as prior evidence showed a strong preference for medical UAVs over commercial ones. Salience was the factor least reported in the literature, nevertheless, suggesting fear of visual pollution. In line with the evidence, we discussed different effects in section 1.2. Several interaction effects could be hypothesized derived from the literature. We expected, for example, that the high acceptance of medical objects is less affected by the other factors than commercial objects. Further interactions between the factors in our design were not proposed. The manipulation allowed us to compare the effects of these factors on acceptability.

The visual factors will probably persist in the perception of UAS, regardless of potential noise reduction. As discussed in Section 1.2.2, there are societal concerns about visual clutter/visual pollution that technological advances cannot reduce. An early consideration of the visual factors prior to widespread UAS implementation, therefore, seems relevant. To this end, in addition to asking the participants about acceptability, we asked participants a question about the beauty of the scene with the specific object. It also seemed necessary to conduct a manipulation check since it would have been possible for the participants to provide a rating without recognizing the icon indicating the usage of the technological objects (as no correct or false answer can be made in a rating task). For this purpose, we inserted a discrimination task for each scene before asking for the ratings. In this task, participants had to indicate whether a commercial object, a medical object, or a goose was depicted in the scene. The manipulation check ensured that in the subsequent rating tasks, the participants were aware of the usage of the depicted technological objects. Finally, we measured the reaction times for the acceptance and beauty ratings, as these can provide additional information about the strength of a judgment, which may be relevant for later acceptance [52].

2. Method

2.1. Participants

Twenty-four students majoring in psychology at the Helmut Schmidt University/University of the Federal Armed Forces Hamburg participated in a single-session experiment as part of their graduation requirements. The mean age was 24.58 years (range = 23–29), and 15 identified as male and 9 as female, with none identifying as diverse. Their mean residency in Hamburg was 60.37 months (range = 24–312 months). All participants gave their informed consent.

2.1.1. Experimental design

The experimental factors were an incompletely crossed design with the factors Area of operation[1] (industrial, rural, urban) and Object (goose, helicopter, UAV), and for the helicopter and UAV, two additional factors: Usage (medical, commercial) and visual Salience (orange, white). There were two additional control factors for the flying object: Position (upper left, upper middle, and upper right) and a between-participants factor Direction of flight (towards the left or the right); see also Section 2.1.3.2. The dependent variables were the three responses given for each stimulus. The first response was given by pressing one of three keys to identify whether the flying object was medical, commercial, or a goose, which produced a reaction time and a correct/incorrect answer. The next two responses were given by pressing one of seven keys based on a Likert scale to indicate judgments about acceptance and beauty. The order of these was balanced across participants, and in addition to the Likert values, reaction times were also recorded. For an overview of the full experimental design, see Appendix A.

2.1.2. Apparatus

The experiment was conducted on a standard PC running Windows 7 and was implemented using MATLAB R2016a and Psychtoolbox-3.0. The experiment took place in one of six identical, ventilated, sound-attenuated booths (height = 205 cm, width = 120 cm, depth = 180 cm) with the lights turned on, which are installed in a larger room. Immediately afterward, participants filled out a pencil-and-paper survey (see Section 2.3).

2.1.3. Stimuli

2.1.3.1. Objects. The goose was taken from the license-free website Pixabay. A license for the helicopter [53] and the UAV [54] was purchased from iStock by Getty Images. The medical and commercial icons were designed by the graphic designer at the authors' university, who also created the final nine objects and did further editing tasks for the scenes. To increase saliency differences, we used a light grey color against the cloudy background. The high saliency orange color chosen is similar to the city's rescue helicopters.

2.1.3.2. Scenes. The flying objects were a goose, a UAV (orange or

[1] The *commercial* areas (shopping streets), used in Tan et al. [4] as a factor level of Area, are mostly integrated into residential or bureau areas in Hamburg. These areas would be visible in the photographs used as stimuli and thus lead to a mixed factor level. Therefore, we only choose three factor levels.

white, with either medical or commercial icons; see Appendix C and D), and a helicopter (in the same four versions), for a total of nine flying objects. The backgrounds were photographs of the three different areas (industrial, rural, and urban), each subdivided into three sub-areas for a total of nine sub-areas. For each sub-area, we had three different versions, which differed not only on the specific background shown, but also the position on which the objects were superimposed. Thus, the total amount of available stimuli was 9 objects x 9 subareas x 3 versions = 243 stimuli. For a full crossed design, the nine sub-areas combined with the nine superimposed flying objects result in 81 stimuli. We had to devise a way to choose which particular version of a stimulus would be shown to each participant, with the constraints that each participant would judge the same number of objects in each of the three possible positions, and each specific background would be judged by the same number of participants.

The three versions can be classified following the object's position as upper left [L], upper middle [M], and upper right [R]. The versions were selected in a cyclical fashion, e.g., for a given participant, the stimuli could be selected in the order L-R-M-L-R-M and so on. There are six possible orders, and these were balanced over the participants. Once selected, the presentation order of the 81 stimuli was randomly permuted. Two versions of each of the flying objects, one flying to the right and one to the left, were produced, but we do not count the two versions as different objects because we balanced them between the participants.

We selected the photographs for the nine sub-areas from different settings in Hamburg. The criteria were that each photograph should clearly indicate only one area and that the photographs should be perceptually or contextually similar. The industrial park photographs included typical small buildings with no special charisma. The office blocks portrayed taller buildings (four to eleven floors, with the distance to the object used to maintain our proportions) with a neater look in an area of Hamburg that was primarily populated with office buildings. The apartment buildings had three to six flats. The container port area depicted three motives with cranes (blue and red) and a big container ship. Photos for the third sub-area, *prominent/touristic buildings*, were chosen to represent a more urban part of the city. We used the Elbphilharmonie (opera house), the Higher Regional Court with its Neo-Classicism style, and the Planetarium to sample three different styles of buildings in Hamburg. Except for an urban park with a few anonymized people in the background, no people or animals other than the flying geese were pictured in any of the scenes. The selected scene compositions (see Appendix A) struck a compromise between the natural realities of a city (without skyscrapers) and the largest standardization possible while picturing different but realistic scenes. Following the selection of the image composition, unsuitable salient objects were removed or adjusted to the scene by our graphic designer. For example, a red bin in a park, a white goose on a lake, a speed limit sign in front of an apartment building, and a street sign in a one-family building scene were removed, and the saturation of the orange color of one house was reduced to a less salient shade, and a shadow on the ground was adapted to the surroundings because the sky was cloudy. The sizes and visual angles of the objects and the icons in the scene are shown in Appendix C, and example stimuli are shown in Appendix D.

2.2. Survey

The factors included in the survey were derived from the literature review, based on the decision and selection process described in the introduction (Section 1). The chosen factors were: Acceptance by society, Expected job situation, Impact on the environment, Fair use for all, Reduction of privacy, Safety (German *Sicherheit*), Traffic relief, Time savings, and Usefulness. As the usage was manipulated in our experiment, we asked in the survey whether the participants had considered the object's usefulness in their acceptance rating. As discussed in Section 1.5.2.1, safety and security are distinct. However, we decided to use the German word *Sicherheit*, which includes both aspects of safety and security, in our survey since we were not primarily interested in investigating which concerns were more significant. As the reduction of privacy needs different solutions than safety concerns, we addressed this separately. The 5-point Likert scale used on the survey ranged from *very low* to *neutral* to *very high*. The question was always, "How much did you consider the factor … of/by the objects in the scene in your acceptance rating?". The factors were usefulness, safety, impact on privacy, traffic relief, time savings, fair use for all, possible acceptance by society, impact on the environment, and job situation (listed in this order). For concerns regarding jobs, we asked whether the job situation was considered in the acceptance rating for the object. Job losses were not explicitly mentioned in order to avoid suggesting a direction of association (only negative or only positive). As environmental issues are complex, the participants were only generally asked whether they had considered the effects on the environment in their assessment of the object's acceptance. Because fairness has been shown to concern participants in studies of UAM, we asked whether potential fair use for all was considered in the acceptance rating without a more differentiated consideration of the three subcategories of fairness due to the increasing scope. Additionally, because the normative beliefs modeled in TPB [5] influence subjective norms, we asked whether participants considered societal acceptance of the scenario in their assessment of acceptance.

Since the experiment was tested on a young, small, and homogeneous sample, who might mainly be familiar with hobby UAVs on a small scale, the participants' experience (practice) was not assessed. Mainly because of the small scale of the study, such modeling did not seem appropriate. Knowledge about UAVs was kept constant at a low level by adding basic information about the depicted UAV and helicopter (e.g., size, autonomy, energy supply; see Appendix A and E) in the instruction to control for the factor knowledge about UAVs or helicopters. Since an experimental manipulation of the autonomy (remote or autonomous) would have made the design too extensive, we decided, based on the KAP model, to provide this factor as knowledge and therefore kept it constant, as autonomy has been shown to influence acceptance. The UAV was described as "remotely monitored in a control center."

2.3. Procedure

Participants worked through the written instructions on the screen and were able to ask questions. They were instructed to respond quickly and correctly for the initial decision task, and with the last screen only, to take their time they need to evaluate the rating tasks. In the rating tasks, the instruction was to assess the object in the scene (for either acceptability or beauty). The survey began with a practice block with 18 trials. Each trial started with the cue "medizinisch/kommerziell" ("medical/commercial"; 1000 ms) for the decision task, followed by the picture, which was shown until the participant's response for medical (left central response key, "f"), commercial (right central response key, "j"), or goose (space key) was made. In cases where there was an incorrect response, the correct response key was shown on-screen for 800 ms. Otherwise, the reaction time was displayed for 800 ms. Afterward, the same picture was presented again. Beneath the picture, the question for the rating task was presented in upper case letters (*AKZEPTANZ*, "acceptance"; *SCHÖNHEIT*, "beauty") centered beneath the picture, followed on the next line by the poles *INAKZEPTABEL* ("unacceptable"), *AKZEPTABEL* ("acceptable") or *HÄSSLICH* ("ugly"), *SCHÖN* ("beautiful"), separated by spaces so that they were presented to the left and the right beneath the question. After a response to the first question was given, the other question was presented with the picture, and following the rating for that question, the subsequent trial started. The order of the practice trials was kept constant.

After the 18 practice trials were completed, the participants were provided with a basic definition of UAVs and helicopters (see Section 2.2 and Appendix E). A sheet with the key-assignments was placed between the keyboard (RT = 1 ms) and the monitor for the entire experiment (Appendix E, screen 5), and the response keys were marked with matching colors and symbols. Participants saw each object twice in the practice block, distributed over the areas for which additional photographs of the areas were used.

Participants were able to ask questions and then worked through the 81 experimental trials with the door closed and the same procedure as the practice trials, only with randomized order of the stimuli. After the participants completed the ratings on the computer, they opened the booth door and were given the survey. It took between three and 10 min to complete the experiment, and an overall session took between 15 and 25 min.

3. Results

The analysis was conducted using SPSS 27 [55], and the graphs were constructed using R Studio Version 1.4.1103 [56]. We conducted 3 × 3 ANOVAs with repeated measures of the factors Area of operation (industrial, rural, urban) and Object (goose, helicopter, UAV) for the natural comparison of technical objects with the goose. To estimate the modulating effect of the features of the technical object, we conducted 3 × 2 × 2 × 2 ANOVAs with repeated measures of the factors Area of operation (industrial, rural, urban), Object (helicopter, UAV), Usage (medical, commercial), and Salience (orange, white). The results for the reaction times (RTs) and error rates (ERs) for the discrimination task, as well as the ratings and RTs for the rating tasks (acceptance and beauty), are reported in the following subsections, based on the same factor levels. We report partial eta squared ($\eta p2$) for effect sizes. A small effect is taken to have values between 0.01 and 0.06, medium between 0.06 and 0.14 and large >0.14 [57].

3.1. Discrimination task

We did not eliminate high RTs and solely aggregated all RTs by condition to include all the correct decisions.

We conducted a 3 × 3 ANOVA with repeated measures of the factors Area of operation and Object on the mean RTs of the discrimination task which showed a significant main effect for Area of operation ($F(2, 46) = 3.72$, $MSE = 0.05$, $p = .032$, $\eta p2 = 0.14$) and for Object with Greenhouse-Geisser corrected values ($F(1.40, 32.20) = 44.50$, $MSE = 0.19$, $p < .001$, $\eta p2 = 0.66$). The decision task was on average fastest for the rural scenes (1213 ms), followed by the industrial scenes (1277 ms) and the urban scenes (1314 ms). The decision task was, on average, fastest in the case of a goose (939 ms) and similar for UAVs (1417 ms) and helicopters (1447 ms). No other significant results or trends were found.

We conducted a 3 × 2 × 2 × 2 ANOVA with repeated measures of the factors Area of operation, Object, Usage, and Salience on the mean reaction times for the discrimination task, which resulted in a Greenhouse-Geisser corrected significant main effect for Area of operation ($F(1.4, 32.22) = 4.56$, $MSE = 0.38$, $p = .029$, $\eta p2 = 0.17$); the discrimination task was fastest for the rural scenes (1353 ms) followed by the industrial scenes (1433 ms) and the urban scenes (1511 ms). A trend was found for Usage ($F(1,23) = 3.8$, $p = .064$, $\eta p2 = 0.14$), with commercial objects identified marginally faster than medical objects (1373 ms and 1491 ms, respectively). No further significant results or trends were found. Fig. 1 shows the results as a function of the four factors.

3.1.1. Error rates for the decision task

The sum of the errors made by each participant in the discrimination task lay between 0 and 3 (*mean* = 1.04). Ten participants answered without any errors.

We conducted a 3 × 3 ANOVA with repeated measures of the factors Area of operation and Object on the error rates of the discrimination task, which showed a significant Huynh-Field corrected main effect for Object ($F(1.64, 37.70) = 5.29$, $MSE = 0.001$, $p = .014$, $\eta p2 = 0.19$), 0% ER for trials involving a goose and 5% for UAVs and helicopters. No other significant results or trends were found.

The analogous 3 × 2 × 2 × 2 ANOVA for the error rates showed no significant results or trends. Fig. 2 shows the results as a function of the four factors.

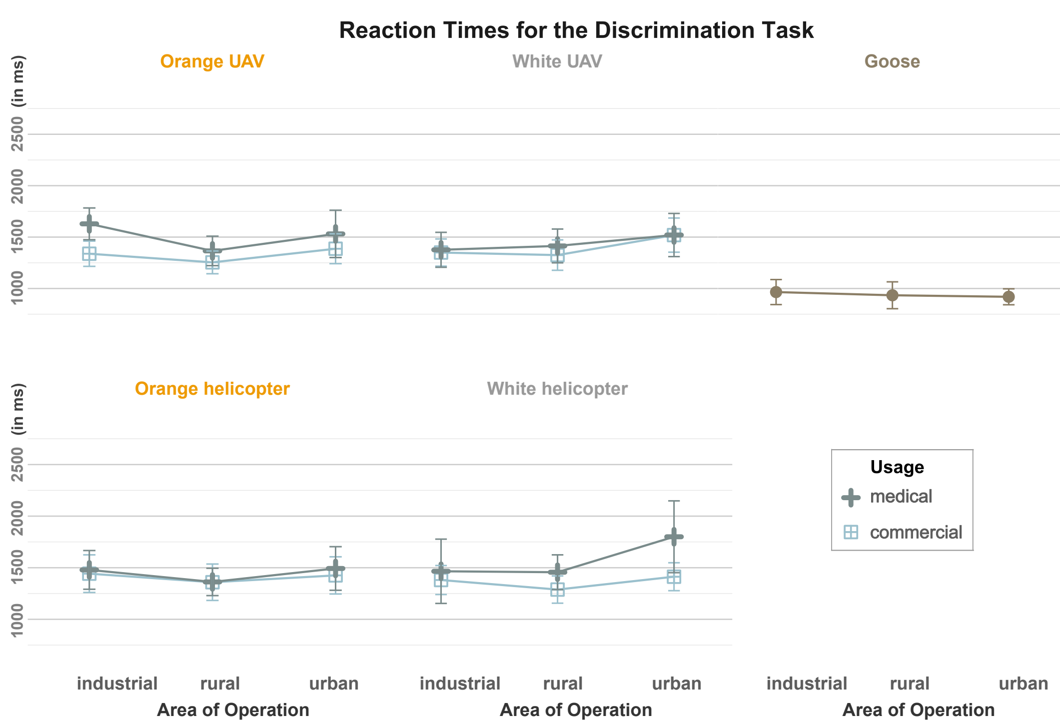

Fig. 1. Mean reaction times for the discrimination task as a function of Area of Operation (industrial, rural, urban), Object (goose, helicopter, UAV), Usage (medical, commercial), and Salience (orange, white). Error bars indicate 2.5 within-confidence intervals. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

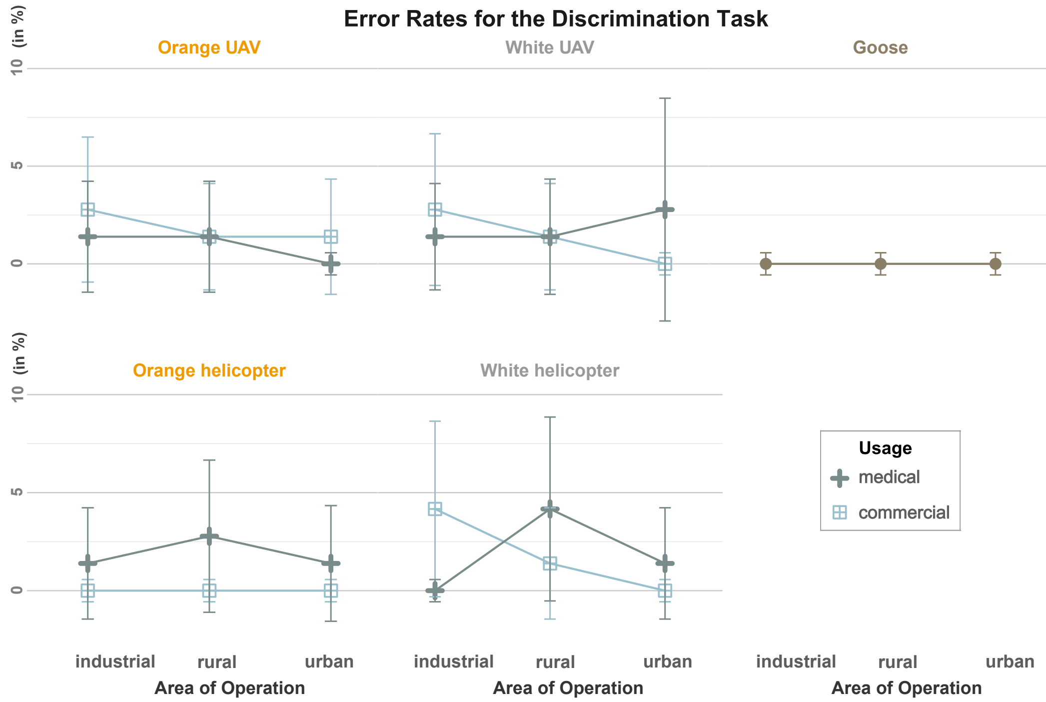

Fig. 2. Error rates for the discrimination task as a function of Area of operation (industrial, rural, urban), Object (goose, helicopter, UAV), Usage (medical, commercial), and Salience (orange, white). Error bars indicate 2.5 within-confidence intervals. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

3.2. Acceptance ratings

The mean ratings for the three scenes were aggregated per participant. Trials with incorrect answers on the decision task were not excluded for two reasons: First, they were scarce (only 0–3 errors per participant; *mean* = 1.04), and second, incorrect responses were reported to the participants, so that they were alerted to their incorrect evaluations of the usage (geese were always reported correctly). The scale for the ratings ranged from *very unacceptable* (−3) to *neutral* (0) to *very acceptable* (3).

A 3 × 3 ANOVA for the mean acceptance rating with repeated measures was conducted on the factors Area of operation and Object and resulted in a significant main effect of Area of operation (F (2, 46) = 12.11, MSE = 0.27, p < .001, $\eta p2$ = 0.35), Object (F (2, 46) = 17.4, MSE = 1.56, p < .001, $\eta p2$ = 0.43) and an interaction effect of Area of operation and Object with Greenhouse-Geisser corrected values (F (2.64, 60.78) = 10.40, MSE = 0.39, p < .001, $\eta p2$ = 0.31). The acceptance as a function of Area of operation was on average highest for the industrial scenes (1.917), followed by acceptance in the rural (1.591) and urban scenes (1.519). The acceptance of the goose was on average higher (2.338) than acceptance of the UAV (1.564) and helicopter (1.125). The interaction effect of the landscape and object resulted in a smaller difference between the mean ratings for the goose and the technological objects in industrial scenes (goose = 2.181, helicopter = 1.622, UAV = 1.948), compared to rural scenes (goose = 2.583, UAV = 1.260, helicopter = 0.931) and finally, a tripartite pattern in urban scenes where geese were, on average, accepted the most (2.25), but UAVs were accepted more (1.483) than helicopters (0.823).

We were primarily interested in comparing the acceptance of commercial and medical usage. Thus, we separately conducted two 3 × 2 × 2 ANOVAs for commercial and medical usage with repeated measures of the factors Area of operation, Object, and Salience for commercial and medical usage. The ANOVA for medical usage yielded no significant effects, with only a trend for Area of operation (F (2, 46) = 3.07, MSE = 0.24, p = .056, $\eta p2$ = 0.12), as the acceptance tended on average to be higher for industrial scenes (2.77) compared to rural and urban scenes (2.61 and 2.63, respectively). See Fig. 3.

A 3 × 2 × 2 ANOVA conducted for the acceptance ratings of the commercial usage with repeated measures of the factors Area of operation, Object, and Salience resulted in a significant main effect for Area of operation with Huynh-Field correction (F (1.68, 38.64) = 21.06, MSE = 2.49, p < .001, $\eta p2$ = 0.48), Object (F (1, 23) = 9.16, MSE = 6.78, p = .006, $\eta p2$ = 0.29), and Salience (F (1, 23) = 5.88, MSE = 0.30, p = .024, $\eta p2$ = 0.20), as well as an interaction effect for Area of operation and Object (F (2, 46) = 3.37, MSE = 0.67, p = .043, $\eta p2$ = 0.13). The acceptance of commercial objects was highest for the industrial scenes (0.80), followed by the urban (−0.32) and rural scenes (−0.42). UAVs were more accepted than helicopters (0.49 and −0.44, respectively). Finally, salience reached significance in the model with high effect size, as the white objects were, on average, slightly more accepted (0.1) than the orange ones (−0.06). The interaction effect of Area of operation and Object displayed a smaller difference between the mean acceptance ratings for helicopters and UAVs in industrial scenes (0.45 and 1.15, respectively; Δ = 0.7) and rural (−0.82 and −0.01, respectively; Δ = 0.81) compared to urban scenes (−0.96 and 0.32, respectively; Δ = 1.28). See Fig. 3.

3.2.1. Reaction times for the acceptance ratings

The mean rating times were aggregated per participant.

A 3 × 3 ANOVA of the mean reaction times for the acceptance ratings with repeated measures of the factors Area of operation and Object resulted in a significant main effect with Greenhouse-Geisser correction for Object (F (1.48, 33.99) = 18.74, MSE = 0.77, p < .001, $\eta p2$ = 0.45), as the acceptance rating was fastest for the goose (1112 ms) and slower for the helicopter (1747 ms) and the UAV (1805 ms). No further significant results or trends were found.

A 3 × 2 × 2 × 2 ANOVA with repeated measures of the factors Area of operation, Object, Usage, and Salience was conducted for the RTs for the technological objects' acceptance ratings. This resulted only in a main effect of Usage (F (1, 23) = 26.54, MSE = 2.51, p < .001, $\eta p2$ = 0.54), as the acceptance rating for medical objects was on average faster than the rating for commercial objects (1436 ms and 2116 ms,

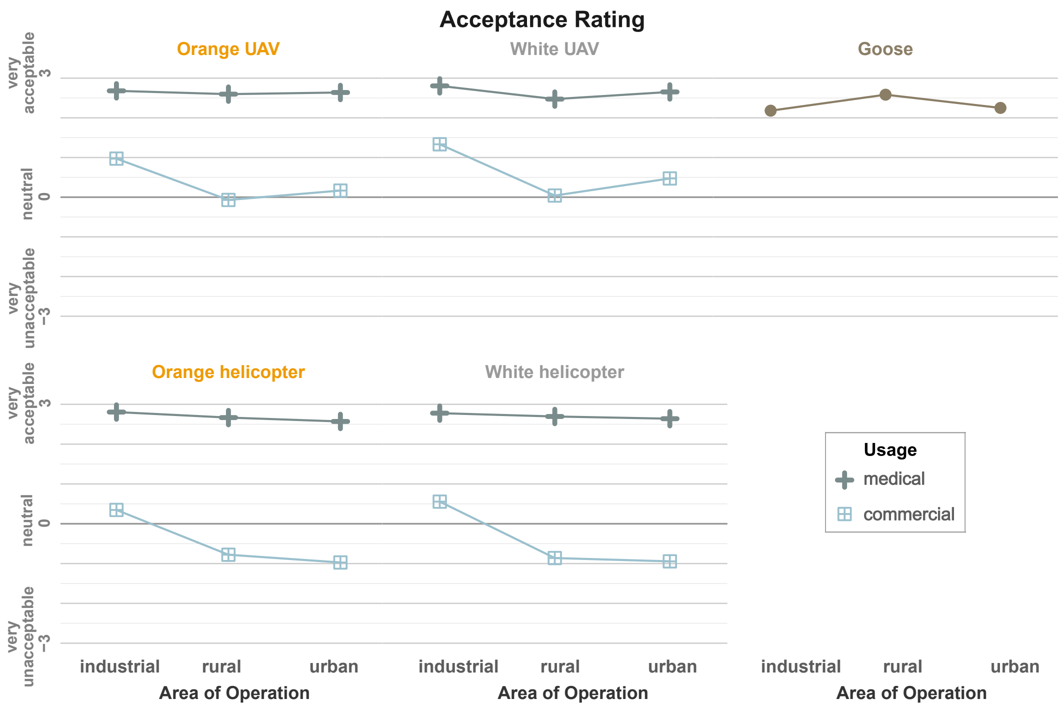

Fig. 3. Mean acceptance rating as a function of Area of operation (industrial, rural, urban), Object (goose, helicopter, UAV), Usage (medical, commercial), and Salience (orange, white). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

respectively). No further significant results or trends were found. See Fig. 4.

3.3. Beauty ratings

The data exclusion criteria were the same as for "Acceptance," and the ratings ranged from *very ugly* (−3) to *neutral* (0) to *very beautiful* (3).

A 3 × 3 ANOVA conducted for the beauty ratings with repeated measures of the factors Area of operation and Object resulted in a significant Greenhouse-Geisser corrected main effect of Object (*F* (1.43, 32.78) = 64.39, *MSE* = 2.07, $p < .001$, $\eta p2 = 0.74$) and a Greenhouse-Geisser corrected interaction effect of Area of operation and Object (*F*

Fig. 4. Mean reaction times for the acceptance ratings as a function of Area of operation (industrial, rural, urban), Object (goose, helicopter, UAV), Usage (medical, commercial), and Salience (orange, white). Error bars indicate 2.5 within-confidence intervals. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

(1.84, 42.27) = 18.51, *MSE* = 0.78, $p < .001$, $\eta p2 = 0.45$). The scenes with a goose were on average rated as more beautiful (1.657) than scenes with a helicopter (−0.314) or a UAV (−0.35). The interaction effect resulted from a higher difference in mean beauty ratings between the goose and the technological objects in the rural scenes (goose = 2.319, helicopter = −0.271, UAV = -. 594) and the urban scenes (goose = 1.611, helicopter = −0.635, UAV = -. 531), which differed by about two units, and the difference in mean beauty ratings for the industrial scenes (goose = 1.042, helicopter = −0.035, UAV = 0.076) which differed by about one unit. For the factor Area of operation, only a Huynh-Field corrected trend can be reported (*F* (1.65, 38.03) = 3.04, *MSE* = 0.83, $p = .07$, $\eta p2 = 0.12$), as the mean beauty ratings tended to be higher for the urban scenes (0.148), compared to the industrial (0.361) and rural scenes (0.485).

To estimate the effects of the modulation of the features of the technological object on beauty ratings, a 3 × 2 × 2 × 2 ANOVA with repeated measures of the factors Area of operation, Object, Usage, and Salience was run on the mean beauty ratings.

The Huynh-Field corrected main effect for Area of operation (*F* (1.63, 37.54) = 7.15, *MSE* = 3.26, $p = .004$, $\eta p2 = 0.24$), Usage (*F* (1, 23) = 50.06, *MSE* = 2.24, $p < .001$, $\eta p2 = 0.69$), and Salience (*F* (1, 23) = 8.99, *MSE* = 6.90, $p = .006$, $\eta p2 = 0.28$) as well as interaction effects for Area of operation and Object (F (2, 46) = 6.99, *MSE* = 0.42, $p = .002$, $\eta p2 = 0.23$), Area of Operation and Usage (*F* (2, 46) = 8.16, *MSE* = 0.42, $p = .001$, $\eta p2 = 0.26$), and Object and Usage (*F* (1, 23) = 8.86, *MSE* = 0.76, $p = .007$, $\eta p2 = 0.28$) reached significance. The scenes with technological objects were on average rated more beautiful for industrial scenes (0.02, *neutral*) compared to rural (−0.43) and urban scenes (−0.58). An, on average, higher beauty rating was found for medical (0.11) compared to commercial usage (−0.77). Finally, on average, scenes with white objects (−0.003) were rated as more beautiful than scenes with orange objects (−0.66). The interaction effect of Area of operation and Object was due to a higher and numerically reversed difference between the mean beauty ratings for UAVs and helicopters in rural scenes (−0.59 and −0.27, respectively; Δ = 0.32) compared to their ratings in industrial (0.08 and −0.04; Δ = 0.12) and urban scenes (−0.63 and −0.53; Δ = 0.1). The interaction effect of Area of operation and Usage showed a smaller difference between the mean beauty ratings for commercial and medical usage in industrial scenes (−0.27 and 0.31, respectively; Δ = 0.58) compared to rural (−0.96 and 0.09; Δ = 1.05) and urban scenes (−1.1 and −0.07; Δ = 1.03).

Finally, the interaction of Object and Usage was due to a more pronounced difference between mean beauty ratings for helicopters with commercial and medical usage (−0.86 and 0.24, respectively; Δ = 1.1) compared to the ratings for UAVs (−0.68, and −0.02; Δ = 0.66). The interaction effect of Object and Salience showed a trend (F (1, 23) = 3.56, *MSE* = 0.47, $p = .072$, $\eta p2 = 0.13$), as the difference between the mean beauty ratings for orange and white UAVs tended to be higher (−0.73 and 0.03, respectively; Δ = 0.76) than the difference for helicopters (−0.59 and −0.04; Δ = 0.55). No other effects reached the level of significance or a trend. Fig. 5 shows the results for the beauty ratings as a function of all four factors.

3.3.1. Reaction times for the beauty ratings

The data exclusion criteria were the same as for "Acceptance." A 3 × 3 ANOVA was conducted on the beauty ratings mean RTs with repeated measures of the factors Area of operation and Object. It resulted in a significant main effect of Area of operation (*F* (2, 46) = 3.59, *MSE* = 0.23, $p = .04$, $\eta p2 = 0.14$) and a Greenhouse-Geisser corrected main effect of Object (*F* (1.12, 25.72) = 11.04, *MSE* = 1.34, $p = .002$, $\eta p2 = 0.32$). The reaction time for the beauty rating was, on average, faster for the rural scenes (1477 ms) than the industrial (1628 ms) and urban scenes (1687 ms). The beauty rating time was, on average, faster for scenes with a goose (1211 ms) than those with a helicopter (1738 ms) or a UAV (1843 ms). No other effects reached the level of significance or a trend.

A 3 × 2 × 2 × 2 ANOVA of the mean reaction times for the beauty ratings with repeated measures of the factors Area of operation, Object, Usage, and Salience yielded neither a significant main effect nor an interaction effect. There were three trends. First, there was a trend for Object (*F* (1, 23) = 4.24, $p = .051$, $\eta p2 = 0.16$), as the rating time for UAVs tended to be slower than for helicopters (1843 ms and 1738 ms, respectively), and the beauty ratings for the factor Salience (*F* (1, 23) = 3.2, $p = .09$, $\eta p2 = 0.12$) hinted that the rating of orange objects tended

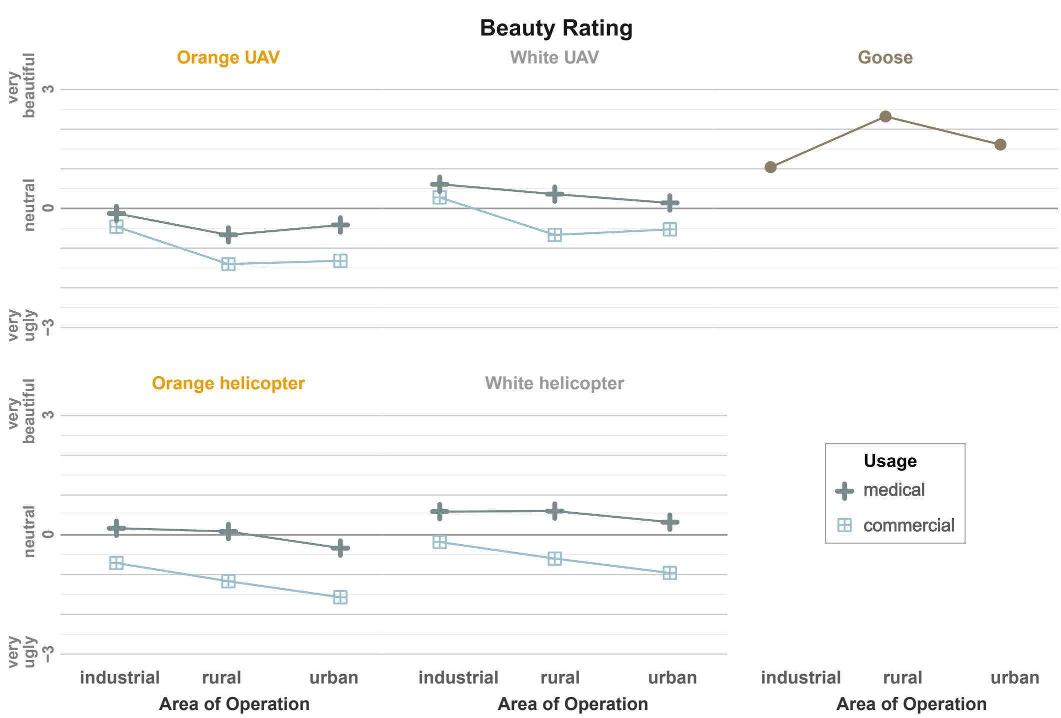

Fig. 5. Mean beauty ratings as a function of Area of operation (industrial, rural, urban), Object (goose, helicopter, UAV), Usage (medical, commercial), and Salience (orange, white). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

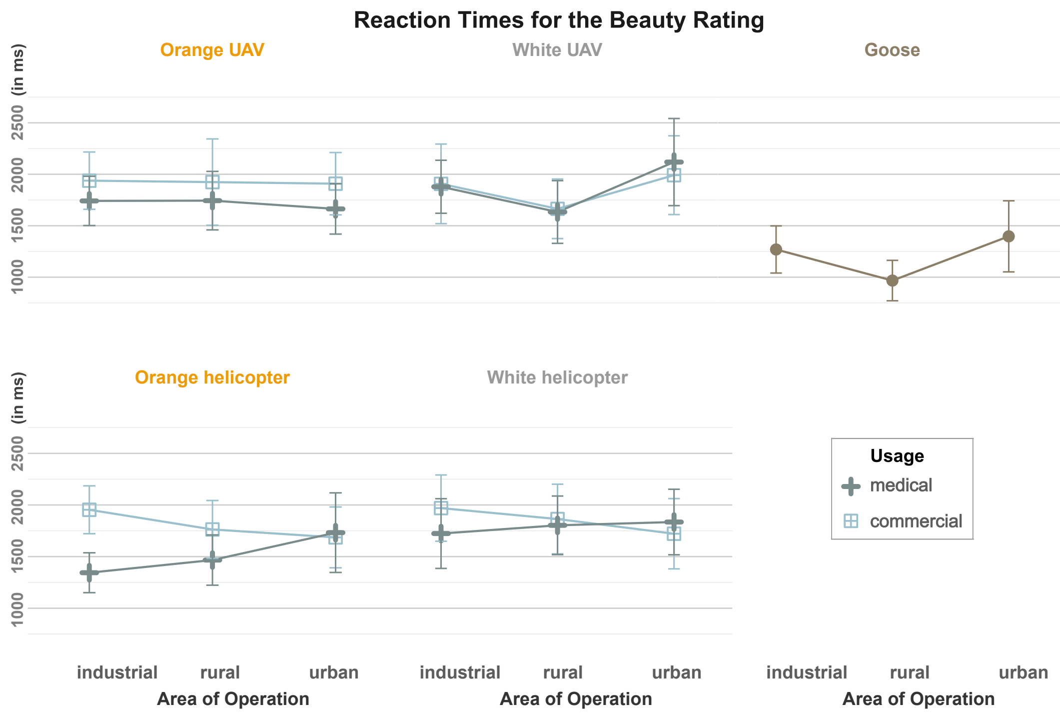

Fig. 6. Mean reaction times for the beauty ratings as a function of Area of operation (industrial, rural, urban), Object (goose, helicopter, UAV), Usage (medical, commercial), and Salience (orange, white). Error bars indicate 2.5 within-confidence intervals. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

on average to be faster than the rating of white objects (1739 ms and 1842 ms, respectively). A trend for the interaction of Usage and Salience (F (1, 23) = 3.06, p = .09, $\eta p2$ = 0.12) was due to a tendency toward a smaller difference in the mean beauty rating reaction times for commercial usage between orange and white (1862 ms and 1853 ms, respectively; Δ = 9 ms) than the difference between these saliencies for medical usage (1615 ms and 1832 ms, Δ = 217 ms). Fig. 6 shows the results for the mean reaction times for the beauty ratings as a function of all four factors.

3.4. Survey

The participants' statements regarding how strongly they took a factor into account when evaluating the acceptability of the scene with the UAV were descriptively analyzed. The averaged results across the 24 participants are presented in Fig. 7. We also plotted each participant's values separately for each factor in Fig. 8. For visualization, we used Tol's [58] color-blind-friendly scale for qualitative data. The scale for the ratings ranged from *very low (−2)* to *neutral* (0) to *very strong* (2).

The on average strongest factors for the acceptance rating were Usefulness (MW = 1.58, SD = 0.88) followed by Acceptance of society (MW = 0.88, SD = 0.85), with a mean between rather strong and strong and around strong, respectively. The factors Reduction of privacy (MW = 0.33, SD = 1.24) and Time Savings (MW = 0.25, SD = 1.36) was rated on average between neutral and rather strong, with a somewhat higher SD than the first factors. The factor Environment (MW = 0.04, SD = 1.4) was rated on average around neutral, but with a high SD, and Expected job situation (MW = −0.38, SD = 1.5) was rated, on average, between neutral and rather low but with a similar high SD. Finally, the factor Safety was rated, on average, between neutral and rather lower SD (MW = −0.46, SD = 0.98). This pattern was slightly more pronounced for the factors Fairness (MW = −0.58, SD = 1.1) and Traffic Relief (MW = −0.58, SD = 1.2). In Fig. 7, the boxplots indicate the median and percentiles for each factor, whereas Fig. 8 displays the results for each factor as a function of participant.

4. Discussion

In this study, we systematically varied the visual aspects of UAVs with the surroundings and objects of comparison, which drew a differentiated picture of the interactions between different factors of interest regarding attitudes towards UAVs. We investigated the effects of the color (contributing to salience) and usage of UAVs on their perceived beauty and acceptance in various scenes and compared these to a familiar technological object (a helicopter) and a naturally occurring goose as a natural comparison condition. Since this pilot study surveyed 24 psychology students, we can only discuss the results our methods yielded rather than describe public opinion or even the opinion of people between the ages of 20 and 30. Nevertheless, effects repeatedly reported in the literature were observed in the present study, as well. Data collected about the reaction times for the rating tasks, primarily implemented as a manipulation check, provided information about the temporal duration of the decision-making that yields additional information about the participants' assessments. In this section, we report and discuss only the major findings.

4.1. Discrimination task

The result patterns were not surprising, as the detection of geese was faster and with fewer errors than the detection of the usages of the technological objects (indicated by a small icon). As the object recognition times were faster for rural scenes than for industrial scenes and longest for urban scenes, future studies might consider the possible visual clutter of the scenes (regarding the effects of visual search, e.g. Ref. [59], or semantic congruency/priming, e.g. Refs. [60–62]). Congruency effects between the factors Usage and Salience (color) were not found to hold. Because orange (and sometimes yellow or red) is a typical color for medical usage (congruent), recognition of our congruent objects could have been faster and more precise than recognition of incongruent objects (e.g., the white medical object).

For our purposes, the main goal of the discrimination task was to implement a manipulation check of the most difficult-to-recognize

Fig. 7. Boxplot based on the survey of the extent to which the factors were considered in the acceptance rating. Line = 50 percentile; box = interquartile range; whiskers = largest value within 1.5 times the interquartile range above the 75 percentiles; dot = outside value.

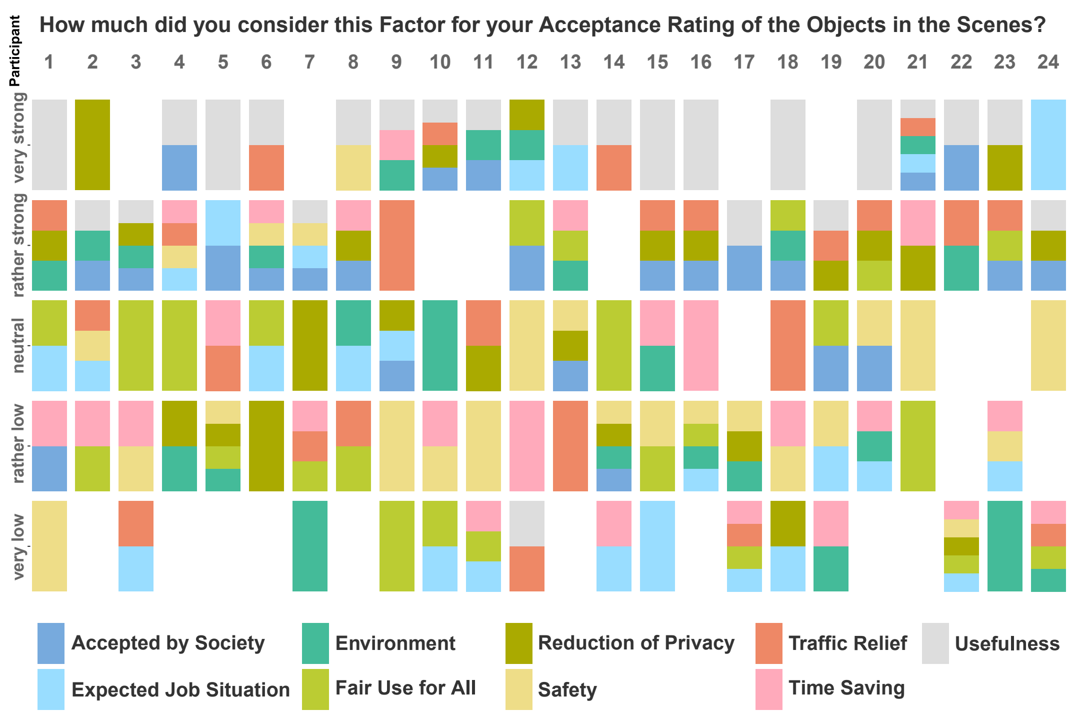

Fig. 8. Descriptive analysis of the survey as a function of the factors influencing the acceptability rating for each participant.

feature of our design, the usage indicated by a small icon (a 0.5 cm icon on an object in a 34 × 22.3 cm photograph). Participants' decreasing compliance with the instruction to correctly assess the usage of the object (and just rate the scene's acceptability and beauty without knowledge of the object's usage) could have resulted in a failure of our experimental manipulation of the object's usage. However, as the error rate was low, and in the few cases where errors occurred, the correct usage was reported to the participants, we can assume that they knew the correct usage in the rating tasks that directly followed.

4.2. Beauty ratings

Our natural comparison condition between the technological objects and the geese demonstrated that scenes with the goose were rated, on average, as more beautiful than those with the technological objects. We found a difference in the beauty ratings for the technological objects as a function of the area of operation: The ratings were on average higher (roughly *neutral*) for industrial scenes and, on average, tended towards *rather ugly* for rural and urban scenes—the opposite of the beauty ratings for scenes with the goose, which decreased for industrial scenes (on average *rather beautiful*) compared to rural and urban scenes. Using this natural comparison, we could rule out the possibility that the beauty ratings were driven only by the level of beauty of the scenes themselves (e.g., a generally higher beauty rating for industrial scenes).

The rating of the technological objects showed, on average, a higher beauty rating for stimuli in which the icon indicated medical usage rather than commercial usage (about one unit higher, *neutral* vs. *rather ugly*). An attitude-based explanation might be that a positive association with medical purposes could have led to a higher beauty rating (the reverse Halo effect, i.e., being good equals looking good, e.g. Ref. [63]). Also, beautiful objects have been shown to be rated more useable (the Halo effect, e.g. Ref. [64]). In our experiment, the beauty ratings could have been biased by the properties of the icons. The icons shared a high impact factor for beauty, namely symmetry (e.g. Ref. [65]), although the red cross icon was axisymmetric on four axes, the commercial icon was only axisymmetric on one axis. However, it may also be that the effect mirrored the pattern of the acceptance ratings. Further studies on the perception of beauty as a function of an object's usage should therefore take these potential confounders into account. Nevertheless, to provide a less artificial setting, we decided to use the standard icons to achieve higher external validity.

The difference between the mean beauty ratings for the commercial and medical objects was moderated by the area of operation, as the rating difference between the usages decreased for industrial scenes. This difference could hint that the beauty rating as a function of usage was not solely driven by the icon properties and that the usage is less critical for beauty ratings in an industrial setting than in an urban or rural setting. The difference in the mean beauty ratings for commercial and medical objects was also more pronounced for helicopters ($\Delta = 1.1$ units) than for UAVs ($\Delta = 0.7$ units). Besides the icon features, the icon itself had to be placed differently on the technological objects, and the relative proportions were thus not the same. In addition, the helicopter had a larger surface than the UAV. The final effect for the scenes with the technological objects was a higher beauty rating on average for white objects than for orange objects (about a half unit). The preference for the low salience condition is consistent with our hypothesis that the high salience disrupted either the scene or the known effect that white technological objects are evaluated as more beautiful than objects of other colors [66]. The difference between orange and white objects was marginally more pronounced for UAVs than for helicopters.

The differing reaction times for beauty ratings as a function of the area of operation are negligible for the technological objects, as they were only significant in the analysis including the goose. Overall, the beauty rating for the goose was, on average, given faster than for the technological objects (500 and 600 ms faster).

It should be noted that we cannot evaluate how the goose impacted the beauty rating of the scene itself (increasing or decreasing the perceived beauty). As noted earlier, we discussed two options when choosing the natural comparison condition. Both options (with and without an object in the sky) would have resulted in limitations for our interpretations. When investigating the perception of UAVs in several environments, a suitable comparison yields information on whether UAVs are perceived as less beautiful or even more beautiful than existing technical or natural objects.

4.3. Acceptance

We hypothesized that medical usage of the technological objects should be accepted irrespective of other factors, in line with the literature showing high acceptance for medical usage [e.g., 2–4, 21, 44]. Therefore, we analyzed the data separately for medical and commercial usage. The analysis of the mean acceptance ratings for the medical objects did not yield a significant influence on the area of operation (only a trend for higher acceptance in industrial areas) or the salience of the technological object, as it was high ("very acceptable") in every sub condition (see Fig. 3). This ceiling effect demonstrated our subpopulation's strong positive attitude towards the usage of UAVs and helicopters for medical purposes. Equally important, the rating was given much faster for medical objects (1436 ms) than for commercial objects (2116 ms). In the literature, such a pattern is commonly interpreted as showing that an attitude is more accessible in memory or has a more pronounced strength. Additionally, the behavior predicted by attitudes is often invalid, and the gap between attitudes and behavior might be closed by the accessibility or strength of the attitude [e.g., 52. Further information is essential as, in the end, behaviors towards or against UAVs and not the attitude alone will be crucial in their implementation. With this in mind, we next discuss the results of the acceptance ratings for the commercial objects, which took much longer than for the medical objects.

The commercial objects' acceptance ratings were, on average, higher in industrial than rural and urban areas. As a function of the factor Object, UAVs were, on average, one unit more accepted than helicopters, and this difference was more pronounced for urban areas than other areas. Thus, the preference for commercial UAVs over commercial helicopters was strongest in the urban areas. The natural comparison condition with the goose demonstrated that the acceptance of scenes with a goose was significantly higher than the acceptance of the same scenes with technological objects. For example, the difference between the objects' acceptance ratings was smaller in industrial scenes, where the goose acceptance decreased while the acceptance of technological objects increased, especially compared to the rural areas. This comparison supported the hypothesis that the higher acceptance of technological objects in industrial scenes was not solely driven by an overall higher acceptance rating for industrial scenes.

The salience of the technological objects impacted their acceptance with a high effect size (lower acceptance for more salient objects), while the difference between the mean acceptance ratings for the white and orange objects only differed by 0.16 units. Even though this is little, it could hint at an experimental replication of a concern found in the qualitative studies of the past years, namely, that UAVs could produce unappealing—"ugly" in the focus groups of Kellermann and Fischer [21]—visual clutter, as well as in Kraus et al. [22]. Our result hints that this could impact the acceptance of UAVs without explicitly asking for color preferences. This effect would be significant to recognize because the visual impact, unlike the sound level, cannot be entirely eliminated and may therefore be a topic of discussion in the long run, even though the safety of operating different objects in the urban air space may require that UAVs have a certain amount of salience and thus require regulations in favor of a higher saliency of UAVs. This point illustrates the interdisciplinarity that is needed for the successful implementation of UASs.

Further possible factors affecting the acceptance of UAVs in areas where UAVs have little or no (direct) impact on humans (or only an impact on employees), such as industrial or company areas, should be investigated in the future. In addition, factors influencing the acceptance of UAVs in urban areas should be investigated in more detail, as well as the possible effects of the operators of commercial drones (e.g., different industries). In conclusion, our study supports that it is essential to include the area of operation and the usage when investigating or discussing attitudes towards UAVs, primarily commercial ones. In addition, factors such as the salience or visual clutter that UAVs create should be considered at an early stage of UAV implementation.

4.4. Survey

We collected factors for use in our survey that have been demonstrated to impact UAVs' acceptance. We assessed the extent to which they were relevant to our participants in their (overall) acceptance ratings for the experimental scenes with the objects. The intention of our descriptive analysis was to show the distribution of the acceptance factors derived from the literature, and the differences between the participants of our, in many aspects, homogenous sample.

The factor rated as having the highest relevance on average for the acceptability rating was usefulness. The relevance of usefulness for acceptance is in line with the TAM [e.g., 6, 7]. Only one participant indicated that this factor was unimportant for the rating. Since the usage was an experimental manipulation and a task on its own, the relevance of this factor may have been reinforced by design. Closely following the importance of the factor usefulness for the acceptability rating was acceptance by society. The high importance could mainly indicate normative beliefs that, according to TPB [5], influence behavior. This factor could also have different relevance and different valence in different populations—particularly if, for example, the attitude of a direct peer group differs from the society's attitude. Reduced privacy and time savings were also considered between neutral and rather strong on average. The environmental impact was considered neutral but with a high standard deviation, indicating a large variance of its importance in our sample. The expected effect on jobs was, on average, considered somewhat less than neutral and with a high standard deviation. As we did not want to give the factors environment and expected job situation a valence (see sections 1.5.3.1 and 1.5.3.2), the associations with the job situation and environment should be investigated in more detail in the future, as the high standard deviation could either hint at diversity in the attitudes and/or meaning of the terms. The hoped-for benefits of traffic relief, safety issues, and fair use for all were indicated on average to have been rated at a rather low level. Contrary to prior evidence, the factor traffic relief was rated on average rather low for the acceptance of UAVs. The singular UAV in the images might have been perceived as insufficient for traffic relief. It will also be intriguing to see the differences in perceptions of distributive fairness, procedural fairness, informational fairness, and interactional fairness that might be found in the context of UAM. As our survey asked about the overall acceptance ratings, future studies could assess the motivational factors in a more differentiated manner. For example, in our study, positive associations with receiving critical medical supplies more quickly could have canceled out the negative associations of job losses owing to the usage of commercial UAVs.

In addition to the averaged results, the relevance of the individual motivations for the acceptance ratings broken down by respondent (Fig. 8) is particularly significant. In this sense, our survey successfully illustrates how diverse the criteria for the acceptance ratings already were in this small and demographically homogeneous sample. The diversity could be even more pronounced in a larger or more diverse sample leading to different acceptance levels. In larger surveys, the information provided by the participants could also be used to investigate acceptance ratings according to, for example, different motivation profiles. However, significantly more participants would be needed to model the data, for example, following the TAM. Future studies could also query the factors for usage alone or for the area of operation since it could be assumed that certain factors are weighted differently in these cases.

5. Conclusion

The main methodological conclusion of our study is the rich comparison possibilities that our design offers. It also supports our hypothesis that the concerns regarding visual pollution from UAVs [e.g., 21, 22] could become an issue independent of noise emission and should be considered early on. Thus, the results concerning the acceptance and beauty perception of UAVs can be used to better frame discussions of possible barriers to implementation because there is a consensus in the literature that we will see some effects of the perception of UAVs only when UAVs are introduced. We believe that for discussions prior to their implementation, it is even more important to know not only how they are perceived for particular usages or in certain areas but also whether they are perceived as better or worse than existing (technological) alternatives. The natural comparison condition with the goose enabled other insights into the acceptance and perception of the beauty of technological objects, especially in industrial areas compared to the other two areas. The industrial scenes were not generally perceived as more beautiful or acceptable than the other scenes because the industrial scenes with a goose were perceived as uglier than the urban scenes with the goose and somewhat less accepted than the goose in the rural areas. Thus, the higher acceptance of technological objects in industrial areas was probably due to the objects themselves. For many discussions, it is not only relevant whether a person has a certain acceptance level for a UAV for a specific purpose but also whether the person would be more or less accepting of a UAV than of the solution that presently serves the same purpose. Furthermore, we were able to show that the salience of a UAV affects its beauty and acceptance ratings. Salience might be even more critical when not one, but several objects are presented. Whether there are stronger effects of the UAVs' color on their acceptance could be replicated with a simpler design in which other factors do not overshadow the effect. Commercial objects are particularly suitable for this purpose, since the high acceptance of medical objects was independent of all other factors. We could not determine the extent to which the lower acceptance of technological objects in rural and urban areas was confounded by associations with noise pollution. Nevertheless, the effects on the visual perception of beauty hint that the visual perception of UAVs should not be ignored, especially since the fear of visual pollution has already been documented in the literature. In addition, usage, which has repeatedly been shown to influence the acceptance of UAVs, might be perceived visually as well. Although the levels of acceptance and the beauty ratings cannot be generalized due to our small and homogeneous sample, our main results are in line with previously conducted qualitative studies. The high acceptance of medical objects was not influenced by the area of operation, salience, or object type. Thus, for future studies, medical objects could be implemented as a baseline rather than manipulated by independent variables. Although more critical people might also dislike medical drones, this is the option with the largest prospect of acceptance, besides UAVs operating at a spatial distance from people. The assessment of the importance of our nine factors in the participant's acceptance ratings highlighted, on one hand, the key factors contributing to those ratings and, on the other hand, the diversity of individual priorities—particularly since our sample was so homogeneous. Different patterns of the factor's relevance could be expected between distinct groups of people.

Our results connect to the previous evidence regarding UAV acceptance and emphasize the relevance of a differentiated discussion of the acceptance of UASs by factors such as the area of operation, usage, salience, or a comparison with the present alternative serving the same purpose. By including the reasons behind acceptance ratings, the influencing factors for acceptance as a function of an individual or a group might be addressed in a more tailored way in implementing UASs by the industry or policymakers.

Disclaimer

All statements within the paper are made by the authors and do not implicate any reference to the University's views.

Ethics

The conducted studies follow the principles of the Declaration of Helsinki.

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Author statement

Svantje T. Kähler: Conceptualization, Methodology, Formal analysis, Investigation, Original draft, Writing – Review & Editing, Visualization, Project administration. Thomas Abben: Conceptualization, Methodology, Investigation. Aquiles Luna-Rodriguez: Conceptualization, Methodology, Software, Writing – Review & Editing. Miriam Tomat: Writing – Review & Editing. Thomas Jacobsen: Conceptualization, Methodology, Resources, Writing – Review & Editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

To our knowledge, there are no possible conflicts of interest.

Data availability

Data will be made available on request.

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Appendix A

Table 1
Experiment and survey design and control by factor influencing perception/attitude/response behavior.

		Construct	Variable/Factor	Levels/Scale/Information
Experiment (Computer)	Independent variables (displayed in stimuli)	Acceptance factors	Area of operation	Industrial, urban, rural
			Usage	Commercial, medical
			Salience	Orange, white
		Comparison to known	Object	Goose, helicopter, UAV
	Dependent variables (response)	Manipulation check for usage (discrimination task)	Reaction time (RT)	Commercial, medical, goose (milliseconds)
			Error rate	Commercial, medical, goose (% of stimulus in category)
		Acceptance	Acceptance rating	Likert scale: −3 (*very unacceptable*), 0 (*neutral*), 3 (*very acceptable*)
			RT for acceptance rating	Milliseconds
		Beauty	Beauty rating	Likert scale: −3 (*very ugly*), 0 (*neutral*), 3 (*very beautiful*)
			RT for beauty rating	Milliseconds
	Control (kept constant) by Instructions	Knowledge	Autonomy	Helicopter: pilot, UAV: unmanned, supervised by a control center
			Take-off & landing	Helicopter & UAV: vertical
			Rotors	Helicopter & UAV: several
			Energy supply	Helicopter: kerosene, UAV: electricity
			Privacy	Helicopter: no information, UAV: several sensors to operate
			Size	Helicopter: 13 m (length) UAV in this paper: 2 m (diameter)
			Payload	Helicopter: 1400 kg, UAV in this paper: 2 kg
			Transported item	Commercial (wares), medical (important: blood, drugs, organs)
	Control in stimuli (kept constant)	Perceptual	Image composition	Similar ratio between sky and scenery Sky: controlled medium grey Picture: similar light & weather conditions Motive: salient objects retouched
			Objects	Similar 3 positions for each sub-area, actual size slightly adjusted to the perceived size, same rotation on z-axis
			Photographed	At height 1.75 m, degree slightly adjusted to the motive height
	Control of other effects in psychological inquiries (balanced between participant)	Sequence effects	Questions (acceptance/beauty)	Order balanced between participants
			Scenes	Randomly presented
		Association with mission status	Flight direction	Copy of all stimuli with object directed left/right, balanced between participants
		Compliance/Stimulus variety	Sub-scenes of similar motives	For details, see Appendix B
		Scene selection		Six sets of 81 stimuli (out of 243). Same amount of each stimulus-type for all 24 participants
Survey (paper-pencil)	Assessment of influencing factors for acceptance rating	Hoped-for benefit	Usefulness	"How much did you consider the factor … of/by the objects in the scene in your acceptance rating?"
			Reduction of traffic	
			Time savings	−2 (*very low*)
		Perceived risk	Safety (*Sicherheit*)	0 (*neutral*)
			Reduction of privacy	2 (*very strong*)
		Discussed potential benefit or risk (but prevailing as risk)	Effects on the environment	
			Fair use for all	
			Job situation	
		Peer evaluation	Acceptance by society	

Appendix B

Table 2
Structure of the sub-levels of the factor Area of operation. Position of the Objects in the Photographs was either upper left, upper middle or upper right.

Area	Sub-Area	Photographs
Urban	One-family houses	3 Photographs
	Apartment buildings	3 Photographs
	Prominent/touristic buildings	3 Photographs
Industrial	Industrial park (only small buildings)	3 Photographs
	Container port	3 Photographs
	Office blocks	3 Photographs
Rural	Parks	3 Photographs
	Rural (grassy areas)	3 Photographs
	Lakes	3 Photographs
		$\Sigma = 27$ Scenes

Appendix C

Table 3
Size (in mm) and visual angle of the icons and objects in the stimulus material. Participants were seated about 50 cm in front of the computer. The size of the objects was adjusted to their relative perceived size compared to other objects.

	horizontal (mm)	horizontal (°)	vertical (mm)	vertical (°)
UAV	65	7.407	25	2.862
helicopter	50	5.711	30	3.434
goose	37	4.232	29	3.319
photograph	340	34.216	223	24.037
icon	5.5	.069	5.5	.069

Appendix D

Fig. 9. Exemplar stimuli for a) urban, b) industrial, and c) rural scenes, as well as d) the medical icon and e) the commercial icon. Nine out of 27 photographs used in the experiment, including one for each sub-area (see Appendix B), are presented. A goose, a helicopter, and a UAV are also shown in each area. Two of the objects (a white commercial UAV and an orange medical helicopter) are not depicted here, as the goose is overrepresented for illustrative purposes. The flight direction in the stimuli (participants only saw one direction) was balanced between participant (see Section 2.1.3.2). The brightness of the stimuli was adjusted to the lighting conditions in the experimental booths.

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