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Public reactions to drone use in residential and public areas

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INTRODUCTION

The public will play a vital role in shaping the future of the drone sector. The sector's fate is tied to factors such as the capacity to serve the public and convince it that drones can benefit society, the ability to ensure that drones are used in a safe and considerate manner, and the readiness and effectiveness of the sector to address public concerns, such as safety and privacy. This report addresses public reactions to drones in residential and public settings and the concerns they raised. We present the results of two studies conducted as part of a collaborative project between the University of Southern Denmark (SDU), Aalborg University (AAU) and the Danish Transport, Construction and Housing Authority. The report builds upon and supplements the research conducted in the initial phase of the project (Bajde et al. 2017).

The research questions were formulated as follows:

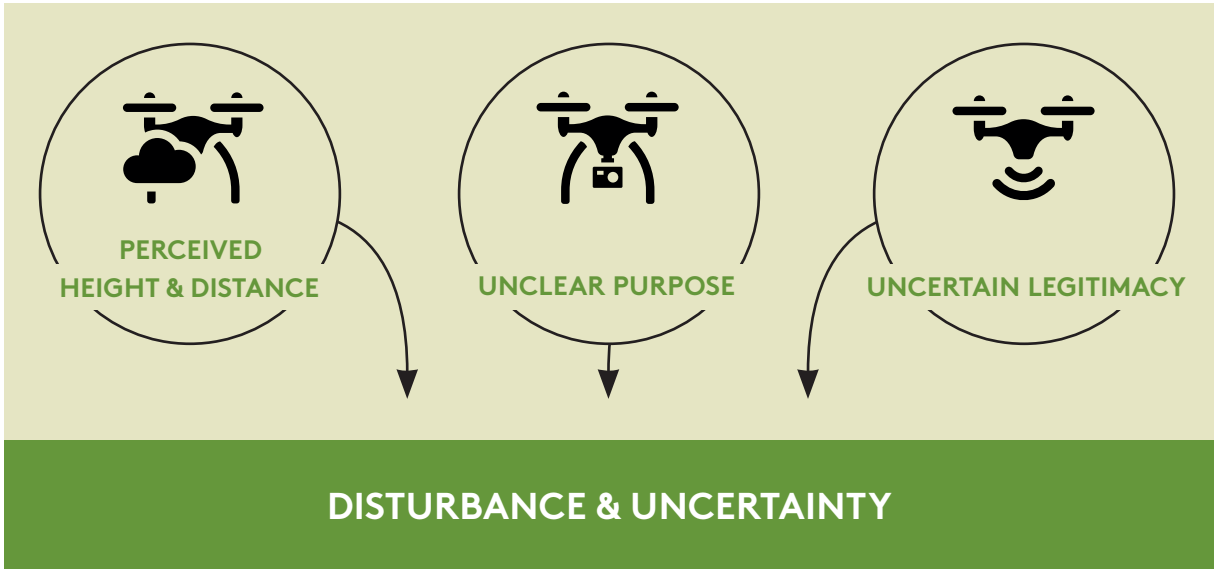
- How do people respond to the presence of drones in public areas? How are these responses impacted by the altitude at which the drone is flying and other factors, such as the size of the drone and the nature of its use?
- How do people respond to the presence of drones in the vicinity of their homes? How are these responses impacted by the altitude at which the drone is flying and other factors, such as the size of the drone and the nature of its use?
- Does the presence of drones provoke privacy concerns? If so, what kind of privacy concerns and under what conditions?

We pose these questions to provide insights for policy makers and businesses who are interested in designing regulations and drone solutions that are attentive to public concerns. The report provides an overview of the work process and the main results of two studies, conducted by two independent research teams. The first study looks at reactions to drones in public areas, while the second study investigates reactions to drones in people's private home settings.

SUMMARY OF MAIN RESULTS

Our study of reactions to the presence of drones in public settings shows a dependency on the perceived purpose and legitimacy of the drone, which is mediated by the perceived distance and duration of the drone's presence. A drone that flies by sufficiently far away and has a clear and legitimate purpose does not cause people to interrupt their activities, and is not seen as problematic. However, a drone that lingers in public areas, comes too close to bystanders is disruptive or intrusive if its purpose and legitimacy is unclear. People might infer that they are being filmed or followed, or feel unsafe or bothered. When seeing a drone, bystanders therefore try to ascertain its purpose and legitimacy by either trying to interpret its flight pattern, lights, or design; or by looking for a pilot to hold accountable.

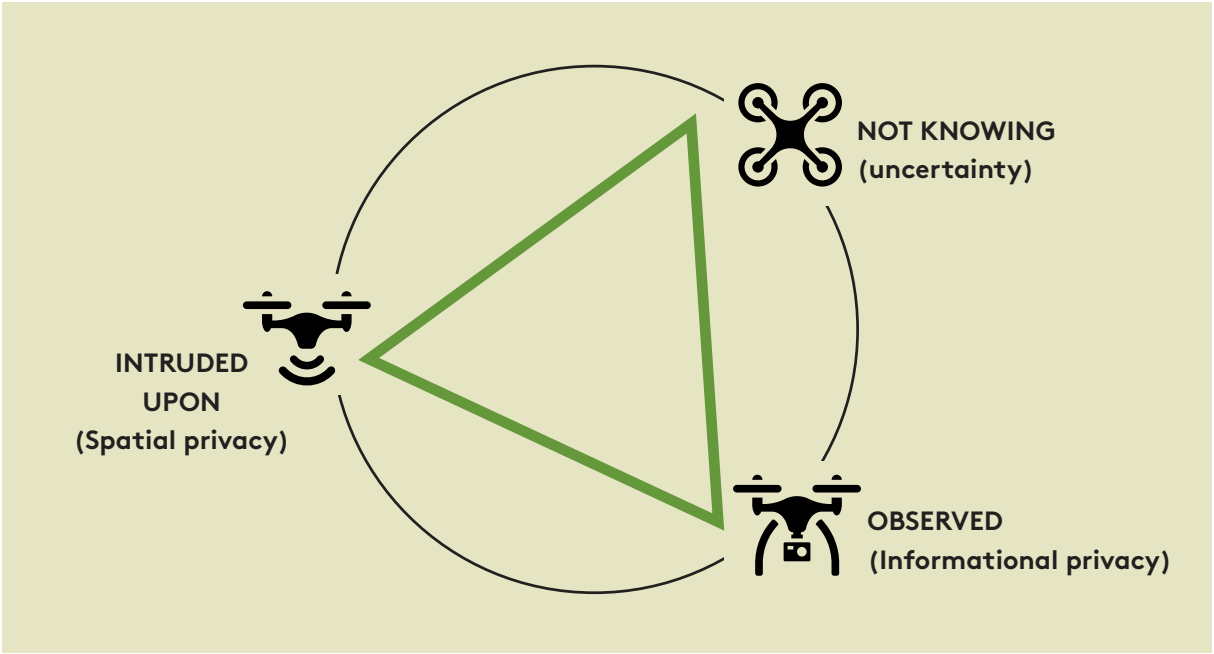
Figure 1: Determinants of reactions to drones in public settings



Crucially, by observing a drone from the ground, it is hard for members of the public to discern how high a drone is flying, what it is doing, and who is responsible for it. Uncertainty and disturbance occur if purpose and legitimacy of drones are not easily identifiable. Current drone designs offer little indication of the responsible entity (e.g. public authorities, commercial or private users), the mission or direction of the flight (e.g. bystanders cannot tell the meaning of red and blue lights on the drone), and whether or not current regulations are being followed (e.g. even if bystanders know the permitted flight level, they cannot estimate the altitude that a drone is flying at).
We conclude in particular that low-flying drones often interrupt social activities, and that current designs and regulations make it difficult to assess purpose and legitimacy, causing uncertainty and disturbance.

Our study of reactions to drones in residential settings shows that public concerns regarding privacy cannot be reduced to the problem of unauthorised capture of personal information or images (i.e., violation of *informational privacy*). Instead, privacy concerns are better seen through the prism of the ***privacy triangle*** comprising three dimensions: informational privacy, spatial privacy and uncertainty. Our data stresses the importance of spatial privacy, which refers to the protection of one's private space from uninvited intrusions and threats. In the case of drones, violations of spatial privacy relate to feeling threatened, or intruded upon by the noise and physical presence of the drone in private space. Problems of spatial privacy become particularly acute when large drones overfly private gardens or houses at lower altitudes (e.g., 25 metres). Our study shows that the noise and visual design of the drone play an important role in shaping the public's experiences of intrusion, thus providing insight into how drone designers and regulators can mitigate problems related to spatial privacy.

Figure 2: Privacy triangle



Informational privacy and spatial privacy are significantly impacted by the third element of the privacy tringle, uncertainty – the public's inability to understand what is going on in the vicinity of their home. We find that the inability to obtain information, such as information about who is operating a drone and for what purpose it is being flown over their house, significantly diminishes people's sense of privacy in both public and private residential settings. This problem can be mitigated by creating identification systems for drones that could be used by citizens to access real-time information about specific cases of drone use, as well as by improved communication with the public about the costs and benefits of drone use.

Finally, we find that the size and purpose of the drone plays an important role in shaping public reactions. The problems of spatial privacy and uncertainty are not as acute when it comes to recreational use of smaller drones. Participants in the study felt that people should have the right to play with drones in their own gardens and on their own property, as long as they do not film, photograph or otherwise observe or monitor neighbours. Reactions to recreational use of small drones in public space, such as public parks and playgrounds, were less univocal, indicating the need for further research and careful consideration of how this aspect of drone use is regulated and communicated to the public.

RESEARCH DESIGN & METHODOLOGY

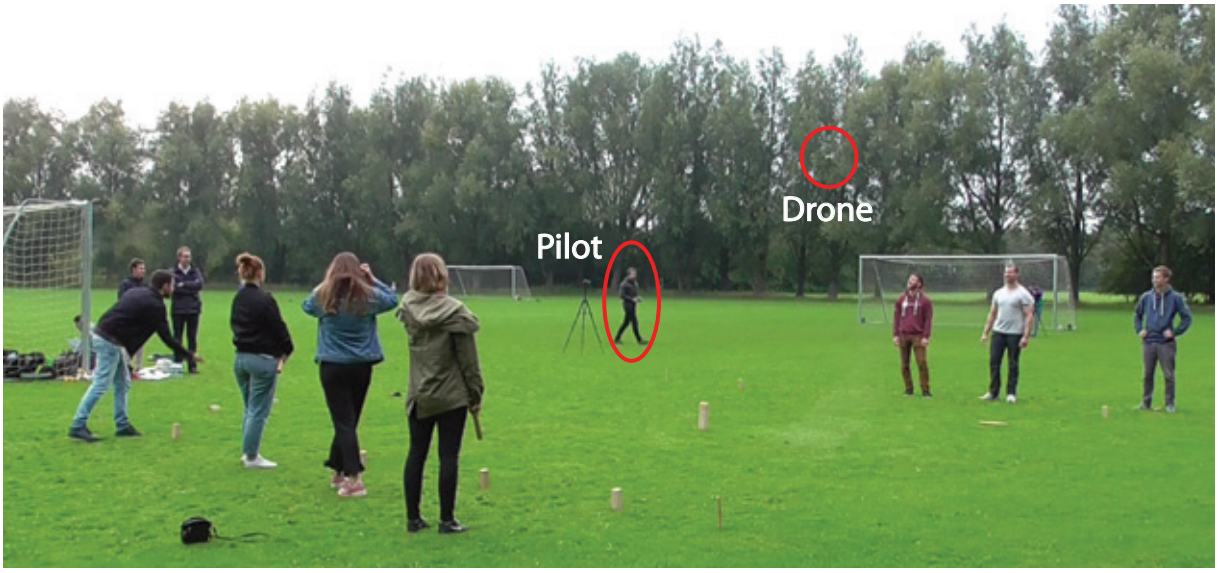
The research project was comprised of two studies, conducted by two independent teams. One team (Bajde, Bruun, Sommer, Nøjgaard, Christensen and Jensen) explored public concerns with drone use in residential areas through interviews with participants exposed to drones in the context of their homes and gardens. Another team (Woermann, Gahrn-Andersen, Kirschner and Bucher) investigated people's reactions to drone use in public areas via field experiments in public settings through video analysis and post-experiment interviews.

STUDY 1: EXPERIMENTS IN PUBLIC SETTINGS

The study design was based on a review of the state-of-the-art of human-drone and human-robot interaction, as well as video analysis of footage capturing naturally occurring encounters with drones available on social media platforms. The results led to a reflexive experimental design: participants were given tasks such as solving an IQ test or playing a game, and then drones were flown unannounced into their vicinity. This forced participants to make sense of the drone and react in ways they deem appropriate. Building on the tradition of ethnomethodological experiments (Garfinkel 1967), studies in human-machine interaction (Suchman 1987), and workplace studies (Hindmarsh et al. 2000), sensemaking and reactions were captured on video from several angles and analysed in conjunction with post-experiment focus group interviews. This allows participants' stated attitude towards drones to be contrasted with their in-situ behaviour.

The experiments were conducted in group and solo settings with either a commercial drone (category 2; DJI Matrice 600) or a toy drone (below 250 g; Silverlit Spy drone II, and Harbok Nano). To understand reactions to different altitudes, the category 1B drone conducted an unannounced fly-by at 75, 50, and 20 metres, before hovering over the participants. In the case of the toy drone, the pilot was visible in addition to the drone, and walked nearby the participants. This comparative design allowed the effect of the pilot being in or out of plain sight to be established.

All experiments were conducted at the University of Southern Denmark in a recreational setting. After the experiments, 16 focus group interviews with the participants were conducted (72 participants in total). The experiments lasted between 12 and 20 minutes and produced over 9 hours of video footage in total. Focus groups lasted between 25 and 30 minutes and were transcribed verbatim (7 hours of recordings and approx. 210 pages of transcript in total). The videos and transcripts were triangulated as reflexive depending data (Flick 2009).



In total, 72 individuals participated in the study. Table 1 shows the sample according to average age and gender. Participants were recruited through bulletin boards, social media and word-of-mouth among students at the University of Southern Denmark from all faculties and levels who did not have expert knowledge of drones. Participants received financial compensation.

Pre-screening guaranteed a diverse sample and ensured that all safety regulations could be accounted for. As is customary for reflexive experimental designs, the sample is not intended to be representative with regard to individual socio-demographic characteristics, but instead allows for ecological validity (Cicourel 1982) by focusing on a social group (local university students) while ensuring diversity within the sample of interactional units (Denzin 1969), for example by including different nationalities, genders, and social backgrounds.

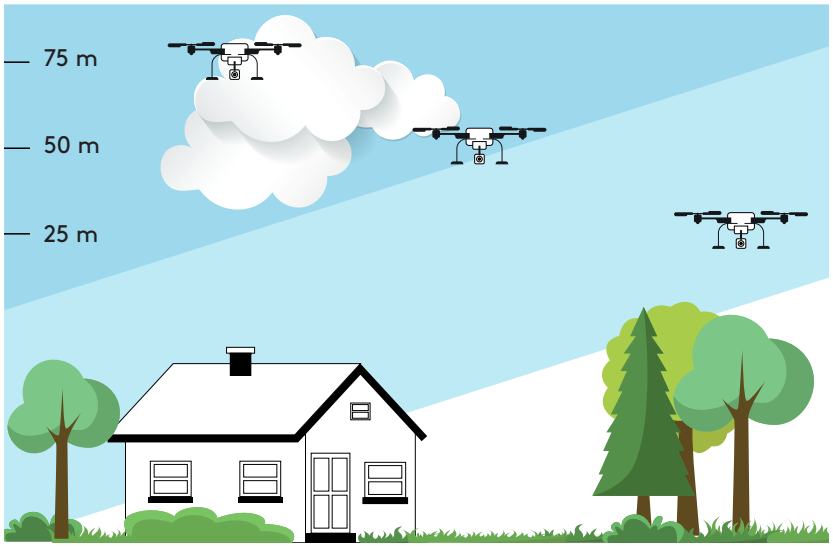
Table 1: Description of participants in Study 1

Participants (Total)	72
Average Age	23.56

		Number of participants	Share of participants (%)
Gender	Female	34	47.2
	Male	38	52.8
Nationality	Danish	32	44.4
	Not Danish	40	55.6

STUDY 2: INTERVIEWS IN RESIDENTIAL SETTINGS

The residential setting interviews were conducted in two stages. In the first stage participants were interviewed in their homes to obtain a base understanding of their level of knowledge about drones, their attitudes toward drones and their personal views on privacy. Some days after the initial interview the participants were visited again to conduct a drone test in their private gardens (all participants lived in attached or detached houses with gardens) and a second interview aimed at obtaining their reactions to the drones and reflections on the presence of drones in the vicinity of their homes.



The drone overflying participants' gardens was a Matrice 600 at the altitudes of 25m, 50m and 75m. The participants were also shown a smaller toy drone (Silverlit Spy drone II; below 250g), and asked to share their views on recreational drone use in the vicinity of their homes and other places, such as public areas and parks.

In total, 16 participants who were not experts in drones, were recruited through personal networks (see Table 1). Although not representative of the Danish population, the sample includes significant diversity across gender (50% of the participants are female/male), age (24-83, average 41), residential areas (6 locations spread across larger-city central and suburban areas, as well as village settings), and occupation.

Table 2: Description of participants in study *2*

Participant	Gender	Age	Type of residence
Jane	F	30	Attached house with shared garden in urban centre
Michael	M	24	Attached house with shared garden in urban centre
Tina	F	28	Attached house with private garden in urban centre
Jesper	M	29	Attached house with private garden in urban centre
Eva	F	59	Attached house with private garden in urban centre
Anton	M	55	Attached house with private garden in urban centre
Erik	M	42	Detached house with private garden in suburban area
Emma	F	52	Detached house with private garden in suburban area
Peter	M	30	Detached house with private garden in a village
Mette	F	26	Detached house with private garden in a village
Minh	M	37	Detached house with private garden in suburban area
Hans	M	83	Detached house with private garden in suburban area
Dennis	M	47	Detached house with private garden in a village
Tine	F	27	Detached house with private garden in suburban area
Ellen	F	58	Detached house with private garden in suburban area
Freja	F	28	Attached house with private garden in suburban area

All interviews were audio-recorded and transcribed in full. The names and addresses were anonymised to protect the privacy of the participants. The transcriptions were analysed by reducing the data into shorter summaries, based on which patterns were identified and tested across the data set.

FINDINGS OF STUDY 1 (EXPERIMENTS IN PUBLIC SETTINGS)

The field experiments produced great homogeneity in results, despite variation in the types of drones used, types of public settings, and participants conducting either social activities (such as playing different games or sports) or focused activities (such as answering an IQ test) either alone or in groups. Further, both pre-reflexive reactions (such as briefly glancing at a drone while continuing the current activity) that were captured through video analysis, and participants' explicit reflections in post-experiment interviews confirm the same general pattern.

REACTIONS TO FLY-BY VS. HOVERING

Reactions to the unannounced presence of drones can be divided into two categories: First, as drones fly by at a certain distance, participants react to the noise and establish the distant presence of the drone by briefly glancing up. Participants engaged in an activity capturing their attention will not react outwardly other than this short moment of visually attending to the drone. After the drone has been established as a background feature of the situation in that participants consider it too far away to require further attention, participants no longer react outwardly to the drone even if it flies by a second time. Reflecting upon their behaviour, participants explain that they thought the drone had "nothing to do with me" or their current activity, and given its distance and short presence, was not considered intrusive.

Second, the reaction pattern changes markedly once a drone flies at a distance that participants consider "close to me" (see below for further discussion) – now the presence of the drone requires attention and invokes a range of reactions. Participants start looking at the drone for longer periods and visibly alter their bodily posture so that their observing the drone becomes apparent for others in their group. This, in turn, will cause other group members to likewise look at the drone. Participants frequently express a negative stance towards the drone by showing negative facial expressions, uttering negative emotions, and expressing bewilderment, curiosity, or disturbance. If interacting in a group, participants start to communicate about the drone, sharing their negative experience and eventually engaging in sensemaking regarding the possible purpose and legitimacy of the drone.

MAKING SENSE OF A DRONE

A drone that lingers in public areas and comes too close to bystanders is disruptive or intrusive because it requires attention and sensemaking. Participants speculate that they are being filmed or followed, or feel unsafe or bothered.

When seeing a drone, bystanders try to ascertain its purpose and legitimacy by either trying to interpret its flight pattern, lights, or design. Furthermore, most participants begin looking around in order to identify the pilot of the drone in order to hold them accountable. In several tests, we intentionally hid the pilot from view. This caused participants to either consider other members of the research team as the pilots, or caused repeated visual searching for a pilot in the vicinity. In no case did the participants seem content with what they could understand from just looking at the drone itself. In the post-experiment interviews, participants univocally explained that it is decisive for them to know who is flying the drone, or who is responsible for it. For example, participants would trust a fireman to fly the drone safely, and would accept drones practically regardless of where and how they fly if they knew that they were being used to help saving lives. In contrast, if they consider a drone to be piloted by an untrustworthy person, the size and flight pattern of the drone does not make much of a difference: they are univocally rejected.

Crucially, by observing a drone from the ground, it is hard for participants to understand how high a drone is flying, what it is doing, and who is responsible for it. The experiments unexpectedly confronted participants with drones and offered little indication of the responsible entity (e.g. public authorities, commercial or private users). Only after participants concluded that the drones where probably a part of the experiments, did they pay less attention and become more comfortable with the drone. In a naturally occurring situation where members of the public would be entirely unable to ascertain the purpose and legitimacy of a drone, more pronounced feelings of insecurity and stronger reactions seem probable.

The drone designs used offered participants little opportunity to understand the purpose or direction of flight of the drone. For example, participants could not tell the meaning of red and blue lights on the drone, or were surprised by the hovering and sudden changes of direction. Additionally, participants could not estimate whether or not current regulations were being followed by the drone and its pilot. However, in line with sociological research, participants expressed that checking if a pilot follows the rules and laws is an important strategy to assess the trustworthiness of the drone, and the safety of the situation more generally (Goffman 1963). For example, if even relatively minor formal or informal rules of normal behaviour in public are being visibly ignored by someone, bystanders will keep their distance and monitor that person. However, with regard to a drone, people cannot asses if the drone is behaving like a ‘good citizen’

or not, because they neither know the rules nor are able to tell if the rules are being followed. This is particularly true with regard to rules about minimum flight altitude.

PARTICIPANTS' PERCEPTION OF ALTITUDE AND DISTANCE

Participants were generally unable to estimate the drone's flying height. Indeed, they failed to notice that the drone was flown at three different altitudes during each experiment (i.e. 75 metres, 50 metres and 20 metres). While some participants experienced the changing altitudes during the various fly-bys, others did not notice any change. However, all participants noticed when the drone began to descend directly above them:

> *"I felt it like above me a lot of the time, I know it was like flying around but I think it like stopped, right?" (Vera, 24)*

Further, participants generally reported on the drone's altitude in relative terms, by using phrases such as "closer to" and "further away from":

> *"I was not really paying attention to the drone; only when its sound increased if it got closer for some reason. Then I looked up. But I haven't been paying attention to where it was flying or anything..." (Birgit, 23)*

> *"Especially the noise [was distracting]. Because even though [the drone] was far away, you could still hear it like it was close, or near." (Line, 20)*

As these quotes reflect, there was a general tendency to infer the drone's altitude and distance based on the noise level. In the follow-up interviews, participants were asked to use the metric system to estimate the drone's varying altitudes. Given the absence of measurement tools and altitude/distance markings, however, their estimations were incorrect. They generally had the impression that the low-flying drone was much lower, providing estimates as little as five metres when in fact the drone was flying at 25 metres:

> *"I didn't pay attention, but she (i.e. another participant) said like 20 metres [...] so 15 [meters up] maybe? I think it should be higher because you never know if the person faint or something and the drone is like... yeah, I guess higher..." (Vera, 24)*

Thus, participants were unable to estimate the drone's altitude. Nevertheless, they generally emphasised that drones should not fly "too close" to them if they are to feel safe in their presence. We conclude that perceptions of safety and intrusiveness of drones are not a linear function of the absolute flight level or distance, but instead de-

pend on a) the noise level and b) the perceived appropriateness of the drone given the current situation. In other words, whether or not a drone is considered as "flying too close to me" depends on the setting (e.g. public vs. private space, recreational or work environment, etc.) and whether the drone fits this setting. The closer the drone flies to them, the more participants feel the need to trust the drone pilot not to put them in danger or do something reckless. Therefore, participants become more active in trying to ascertain the legitimacy of the flight and the trustworthiness of the pilot as the drone comes closer.

> *"For me it was the same. When it was very close, it was very distracting. But when it was further away, then it was not that bad." (Ronny, 23)*

> *"When they [i.e. drones] come near me, I have this thing that they will bump into me so I have to, you know, just kind of take a look. So, I was kind of distracted, because the thing is when it was far away, it took me a while to understand where the noise came from, like what it was about." (Liza, 23)*

THE PERCEPTION OF SAFETY DISTANCE

Generally, there was little consent amongst participants regarding the optimal safety distance for a bystander from a drone. Thus, their opinions varied as the following passage shows:

> *Lisa, 29: "[The small drone] won't bother me if it is far away from me. Or, not far-far, but if is it in the area I am in."*
> *Interviewer: "So how far is far? Like how would you say?"*
> *Linda, 22: "Eh... maybe... three meters, four metres, away from me."*
> *Fernando, 25: "Well, I would say more. Like, eh... yeah 20 metres."*
> *Interviewer: "20 meters, okay. So, was this drone closer than that?"*
> *Fernando: "Yeah I think he was like, was it 10 metres from me in, at the end."*
> *Andreas, 25: "Well, I would say the guy playing with the drone I would say if he was closer than 10 metres I would think it was weird but the drone I would want like 50 metres away."*

To conclude, our findings reveal that people are concerned with the distance and altitude of drones whenever they either feel annoyed by them or that their private space is being violated. In most cases, the noise made by the drone was the first thing that triggered these negative feelings. Further, it is impossible to specify an optimal altitude and distance since different people have different thresholds and conceptions. However, it is evident that the context of the encounter is of decisive importance. As some of the participants noted, their reactions would have been different had they encountered the drones in everyday (i.e. non-experimental) settings without knowing either the drone's purpose or who was flying it.

FINDINGS OF STUDY 2 (INTERVIEWS IN RESIDENTIAL SETTINGS)

The 16 interviewees have varied conceptions of home and privacy. Nevertheless, some patterns can be discerned in the expectation that participants have regarding privacy in the context of their homes. The home is regularly seen as a private space that includes both the house and the adjoining garden, a space where 1) people can relax and enjoy life free from disturbances and intrusions of uninvited others, 2) people are freed from the gaze and judgements of others, and 3) people have control over things and make their own decisions.

These conceptions and experiences of home and private space shape the expectations and concerns that people voice about the use of drones in the vicinity of their home. The newly acquired data permits us to extend the findings of our initial study (Bajde et al, 2017). We identify three dimensions of privacy concerns – the privacy triangle (Figure 1):
1) informational privacy
2) spatial privacy
3) uncertainty

Explanation and evidence for each dimension is presented below. We pay particular attention to the dimension of spatial privacy as this dimension was less apparent prior to the study and was found to be particularly central to reactions to the presence of a Matrice 600 drone. In the last part of this section we discuss the participants' reactions to recreational use of smaller drones and their views on recreational drone regulation.

The participants had very limited experience with larger commercial drones, so a substantial majority was surprised by the size of a Matrice 600. Their reactions to experiencing the drone in action were mixed as they simultaneously found the drone impressive and troublesome. While far less common when the drone stayed at the height of 75 metres, negative reactions became dominant at the lower altitudes, 25 metres in particular. This conclusion holds for all three elements of the privacy triangle. We begin by considering informational privacy.

INFORMATIONAL PRIVACY

Informational privacy refers to concerns that the drone will capture unauthorized personal information (Finn et al. 2014). The most common concern expressed is being photographed or filmed in one's own house or garden.

> *"I think I would have a hard time if they [drones] fly in front of the windows. I have my boundaries... I also think that people should have privacy in their house and likewise in their own gardens, so that you can wear a bikini without being photographed from above." (Tine, 27)*

In Tine's case the concern is illustrated with the example of unauthorized capture of sensitive personal information. Other participants list concerns such as being spied upon by governmental institutions or nosy neighbours. The distance at which drone surveillance and information capture take place, can play an important role.

> "Oh boy, now you can actually see it... There are almost too many details... You think that when it's way up there [75m], then it only gives you [only] a rough overview. I know that's a bit naïve, because it [the drone's camera] is capable of so many things, but... you're thinking that it's not that close." (Ellen, 58)

Ellen feels that at 25m the drone becomes very visible, and at the same time she becomes very visible to the drone. She notes that while it might be naïve to underestimate the drone's capacity to observe from a greater height, she still feels much more uncomfortable with the prospect of being observed from the lower altitude (25m). There is a difference between actually being observed and having the feeling of being observed. Irrespective of whether the drone is actually collecting information about her, Ellen feels that she is observed. As discussed in the section devoted to uncertainty, not knowing much about the drone's capacities and purpose makes the problem of informational privacy worse.

In addition to the distance, Ellen also points out that the movement of the drone is an important factor in determining the negative experience of being observed. It is when the drone hovers over her house that she feels most observed. Similar concerns regarding informational privacy are expressed by other participants, who fear being observed and recorded while inhabiting a space that should not be subject to the eyes and cameras of unwelcomed strangers (drones included).

SPATIAL PRIVACY

Spatial privacy refers to being protected from uninvited intrusions into one's physical and/or psychological sphere (Laurie 1999), in a manner that disrupts a person's right to be left alone (Solove 2008). In the case of drones, spatial privacy might relate to discomforting feelings of being disturbed by the physical presence and noise of a drone in one's private space, or even feeling physically threatened by drones (e.g. fears of injury).

We find that the problems of spatial privacy are significantly reduced when the drone overflies a private garden or house at 75 metres. In contrast, they become particularly acute at the lowest altitude. While some participants begin to express annoyance with the drone's presence at the 50 metre altitude, virtually all participants express some concerns when the drone descends to 25 metres:

> *"Now I think it's getting way too close, and it's making more noise. So, now it's starting to become disturbing... It's entering into my personal bubble." (Freja, 28)*

> *I'm sick of the noise right now. Definitely. Now it's turning into a somewhat more annoying noise than when it was higher up [50m and 75m]. (Erik, 42)*

> *"When it comes a bit too close... You are not able to control the situation. It is rather uncomfortable. It's a bit monster-like... It's a bit spider-like." (Hans, 83)*

The participants feel discomforted by the presence of the drone at the 25 metre altitude. They point out that the drone intrudes into their private space with a disturbing noise, and with its visual presence. As indicated by Freja's reference to the drone's invasion into her "personal bubble", the drone does not invade private territory in the usual sense of passing across the ground boundary demarcating private land. Instead private territory is experienced in 3-dimensional terms: as a space that can be equally disturbed by entities that fly (too low).

There is no universal rule of thumb as to how high the bubble of private space extends (i.e., the participants do not have a clear sense how high their private space reaches. Further, the size of the bubble depends on the properties and behavior of the drone. Our data shows that in the case of a large, noisy drone such as a Matrice 600, the private bubble seems to reach at least 25 metres for most of the participants. In contrast, spatial privacy works differently with smaller, less noisy drones, where the participants are more willing to tolerate the drone at a lower altitude, as long as it is not filming them or compromising their safety.

In summary, the participants experience the space enveloping their home (house and adjoining garden) as a private space, where they are to be left alone and undisturbed. Their claims are not based on explicit appeals to property rights (i.e., owning the space around the house), but rather to culturally shared norms and psychological experiences of "spaces of non-intrusion" (Hoeyer 2010, p. 271). Technologies such as drones, reopen questions of "domestic boundaries" (Garvey 2005). Prior to the presence of the drone, the participants had rarely considered what separates their private space from the collectively owned airspace. The tests we conducted, compelled the participants to figure out (in practice) at what point a drone crosses the borders of their private space. Put differently, they figure out in situ at what point the "U-space" (European Commission 2017) occupied by drones starts to impinge upon private "Me-space".

For example, there are marked differences in reactions between the higher altitudes and the lowest altitude. While at 75 and 50 metres the sound of the drone is likened to the noise of street traffic or lawnmowers, at the 25 metre altitude the participants become bothered and annoyed by the noise of the drone. When expressing their discomfort with the proximity of the drone, participants describe the drone as "monstrous" and "otherworldly", that is, as something that does not belong in the context of their home. While we can assume that such reactions might dissipate as drones become more common, our results clearly indicate that both the sound and the visual design of the drone plays an important role in shaping the public's response to drones (e.g., feelings of vulnerability, intrusion and annoyance).

Finally, although the tests were organized in a manner that removes any doubt regarding who is using the drone and for what purpose (i.e., the participants knew that the drone is being operated by the research team), the participants regularly raised the issue of uncertainty in regard to the purpose of drones, which we discuss next.

UNCERTAINTY

Not knowing who is operating a drone, and for what purpose, significantly exacerbates feelings of privacy violation. As argued by Jesper (29), this relates to "wanting to know where it [the drone] came from… Who's at the other end. Because that's what

maybe affects me the most, when it comes to privacy." In a similar manner, several participants argue that not being able to tell if the drone has a camera, and whether it is recording, and who is observing/recording, causes considerable distress even if no leakage of private information is actually taking place. As explained by Jane (26), better access to information can help mitigate this problem: "[I]f you just tell people what you are using it [the drone] for, police work or something like that, then I don't think it would bother anyone. I think it [privacy concerns] very much depends on the information about why they [the drones] are there." Put differently, privacy concerns can be mitigated by providing information about the purpose of the drone.

"Not knowing", on the other hand, exacerbates the experience of violation of both informational and spatial privacy. Being informed about the presence of a drone in advance, or at least being able to obtain information about it once it is noticed, might enable participants to cope with the presence of drones in the vicinity of their home. For example, Michael (26) argues that having information would enable him to minimize the disturbance: "Then you can prepare yourself that you shouldn't run about buck-naked on your patio."

Others like Mette (26) argue that in the absence of specific information they would not know how to react or what to do in case of drone intrusion. Therefore, providing advance notice that drones will be taking photographs or filming in the vicinity of one's home, and helping people to identify the drone and its mission, can help people reassert a sense of control over their private space and mitigate the disturbing effects of drone presence. In addition to amplifying informational and spatial privacy concerns, uncertainty might be experienced as a fundamental aspect of privacy in its own right. Additional analysis is needed to test this hypothesis.

Finally, our data also hints that public reactions and willingness to tolerate a decrease in privacy due to drone presence, are mediated by the overall knowledge about and disposition toward drones. Problems of uncertainty are exacerbated by the public's limited overall knowledge about drones, and uncertainty about the actual benefits and hazards they pose. When people perceive drones to be beneficial to them or to society at large, the willingness to tolerate and compromise increases. This stresses the need for public institutions and industry to communicate with the public and engage in emergent discussions about the benefits and costs of drones to society and individual citizens.

VIEWS ON RECREATIONAL USE OF MICRO DRONES

After witnessing the flight of a Matrice600, the participants were shown a smaller toy drone and asked to share their views on recreational use of smaller drones by ne-

ighbourhood residents. Participants express a high degree of tolerance for use of toy drones in residential settings under certain conditions.

> *"I don't think the toy drone is a problem. I mean, children should be allowed to play. So, if the neighborhood kids play with drones and one ends up in our garden – oh well. It doesn't matter! It's like if a football ends up in there [in your garden]. Yes, they are welcome to do that." (Hans 83)*

There is a general strong consent among the participants that people should be allowed to play with drones in their own gardens. The participants feel less bothered by a drone, if it is small and less noisy. However, their tolerance has limits. After expressing his approval of toy drone use, Hans stresses that this does not apply to drones flying around the neighbourhood with a camera. His opinion corresponds to a clear pattern across participant reactions to toy drones, that drones with cameras should be restricted to the users' own gardens, and unauthorized filming of neighbours was entirely unacceptable. Several participants find it disturbing that the purpose of using a toy drone equipped with camera is unclear (uncertainty), and various "transgressive" misuses can be imagined.

Nevertheless, there is a reluctance to call for strict regulation, and communication between neighbours and reliance on established neighbourhood norms that apply to other play activities (e.g., kite-flying) is seen as a better solution to addressing the potential problems arising from recreational drone use. The use of larger, more dangerous drones is seen as inappropriate outside of designated areas that ensure safety and minimize the disturbing effects of drone noise.

Reactions to toy drone use in public spaces such as playgrounds or parks are mixed. Although the participants express a higher degree of tolerance for smaller toy drones (compared to larger commercial drones) and tend to be less concerned with being observed or filmed in public space than in private space, some participants voice concerns regarding safety, noise and the appropriateness of technological objects in public spaces designed for children to play safely, or for adults to relax in natural surroundings. As a result, participants voicing higher levels of concern suggest that drones should only be used in designated public areas.

CONCLUSION

The first study has two clear implications for effective regulation. Firstly, drone flights at 50 metres and above have little effect, while flights at 20 metres disturb social activities. Secondly, regulators and drone designers need to think about ways to make it easy for people to understand what a drone is doing, if it is legitimate, and who is responsible. Uncertainty and disturbance occur primarily in situations in which the purpose and legitimacy of a drone are not easily identifiable. If regulators and designers can succeed in making drones easier to understand and to trust, they would be better accepted by the public. The experimental methods used in this study provide an effective toolbox to test a range of possible future solutions to these challenges.

The second study identifies a similar problem of uncertainty in a residential setting. By delving deeper into the public's privacy concerns, we uncover two main concerns: informational privacy and spatial privacy. We show that both forms of privacy are impacted by the public's uncertainty regarding drones and their use. What is more, we discover that experiences of privacy concerns vary according to the height at which a drone flies and the type of drone used (e.g., large commercial drone vs. smaller toy drone). Our data indicates that the presence of larger drones at a 25-metre altitude significantly impinges on people's private space (understood in 3-dimenisonal terms). While this problem is less significant in the case of smaller toy drones, informational privacy concerns do not diminish, if toy drones are perceived to record photographs and video footage.

In-depth interviews conducted prior and after direct exposure to drones were found to be an effective tool in investigating how the presence of drones impacts the public's understanding of private space and concerns about privacy. Combined with observational methods, this approach offers valuable insight into public reactions to drone use in urban areas.

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