Exploring the Effects of Experience

on Drone Piloting

by

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A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved November 2019 by the
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ARIZONA STATE UNIVERSITY

December 2019

ABSTRACT

The current study aims to explore factors affecting trust in human-drone collaboration. A current gap exists in research surrounding civilian drone use and the role of trust in human-drone interaction and collaboration. Specifically, existing research lacks an explanation of the relationship between drone pilot experience, trust, and trust-related behaviors as well as other factors. Using two dimensions of trust in human-automation team—purpose and performance—the effects of experience on drone design and trust is studied to explore factors that may contribute to such a model. An online survey was conducted to examine civilian drone operators' experience, familiarity, expertise, and trust in commercially available drones. It was predicted that factors of prior experience (familiarity, self-reported expertise) would have a significant effect on trust in drones. The choice to use or exclude the drone propellers in a search-and-identify scenario, paired with the pilots' experience with drones, would further confirm the relevance of the trust dimensions of purpose versus performance in the human-drone relationship. If the pilot has a positive sense of purpose and benevolence with the drone, the pilot trusts the drone has a positive intent towards them and the task. If the pilot has trust in the performance of the drone, they ascertain that the drone has the skill to do the task. The researcher found no significant differences between mean trust scores across levels of familiarity, but did find some interaction between self-report expertise, familiarity, and trust. Future research should further explore more concrete measures of situational participant factors such as self-confidence and expertise to understand their role in civilian pilots' trust in their drone.

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CHAPTER 1

Exploring the Effects of Experience on Drone Piloting

Recently, the United States has seen a rapid increase in the purchase and use of small, remotely piloted aircraft, commonly referred to as drones. In 2016, a report published by the United States Federal Aviation Administration (FAA) predicted that small “hobbyist” drone purchases will grow from 1.9 million drones purchased in 2016 to 4.3 million purchased in 2020. These small, commercially available drones are often equipped with high-definition cameras, Bluetooth connection to smartphones, and even some autonomous capabilities such as gesture recognition and auto-sensing to control their own flight (Floreano & Wood, 2015). Floreano & Wood (2015) also point out that these functions are highly desirable for completing several tasks which previously relied on satellite or car-based imaging that is usually economically unviable for small companies or organizations. Industries such as agriculture, real estate, utilities, construction, filmmaking, local law enforcement, public safety agencies and more are adopting this technology alongside the growing drone hobbyist industries (Canis, 2015). Additionally, large scale companies such as Amazon (U.S.) and Facebook (U.S.) have alluded to the potential use of these devices to deliver packages, internet, and even medical supplies (Canis, 2015). With this rise in drone adoption comes a demand for pilots of these technologies and, undeniably, increasing public concern over safety and privacy of who is operating these drones and how they are being regulated.

It is no question that safety is taken seriously in commercial airline industry in the United States, with programs being implemented by the FAA to actively monitor safety risks such as the Aviation Safety Action Program (ASAP) (2017) and the Line

Operations Safety Audits (LOSA) (2014) which is a proactive system of risk assessment. Unlike in the airline industry, remotely piloted aircraft systems (RPAS) pilots are not subject to as many guidelines. RPAS will be referred to as "drones" in this study, as we are not including autonomous vehicles nor large scale systems such as are used by the military in the current scope (as per Clarke, 2014). As of 2019, the FAA requires drone pilots to be: at least 16 years old; able to read, speak, write, and understand English; in a physical and mental condition to safely fly a drone; and pass the initial aeronautical knowledge exam, all to be certified under FAA's Small Unmanned Aerial Systems (or drones) Rule Part 107 (FAA, 2019a). Drone pilots operating devices under 55 pounds must renew Part 107 certification every two years and are expected to register their drones with the FAA as well (FAA, 2019b).

After drone pilots meet these minimum qualifications, they are not actively monitored by the FAA unless reported to be in breach of regulations. Additionally, it is expected that drone pilots know to file a Part 107 waiver if necessary, for reasons including: flying a drone at night (Part 107.29); flying a drone beyond your line of vision (Part 107.31); operating a drone over a person/people (Part 107.39), among other reasons (FAA, 2019c). For recreational users, these requirements may be easily overlooked. Beyond these regulations, little is known about how recreational and commercial drone pilots make decisions about their operations after certification, and whether they are maintaining regulations and are flying safely. These requirements are concerning considering the applications in the various industries described above may demand and attract many of these recreational users. Additionally, there is potentially a high economic value of being able to use drones for small deliveries, traffic or utility surveillance, agricultural surveillance, and more to be able to provide outcomes or products quickly. Jenkins & Vasigh (2013) predict that by 2025 the influence of drones in the industries of precision agriculture and public safety alone can expect $82.1 billion in economic impact, and over 100 thousand jobs created across the U.S. With this growing economic and social pressure on companies to partake and hire drone pilots that will operate quickly and accurately, the biggest question is if safety will become a secondary concern to profitability. Drones have been used in the military for much of the early twenty-first century, and there is a wealth of research on tactical flight and operation of these large drones (Asaro, 2012); however, there exists a research gap on the flight operations and safety choices of civilian and commercial small drone pilots. It is no question that the operation of these devices poses privacy, data collection, and ethical concerns (Finn & Wright 2012, 2016; Bracken-Roche, 2016; Clarke, 2014). However, in order to approach solutions to the above concerns, we must gain a better understanding of novice versus more experienced drone users, with attention paid to drone pilots' operations and decision-making regarding safety.

Human-Drone Interaction and Pilots

Though small, commercially available drones are becoming increasingly popular in a variety of domains, still there is much to be studied about how these drones are flown and how humans interact with them. With their uses in real estate, photography, government and utility surveillance, search and rescue, and other industries becoming more prevalent, still little is known about how the design of the drone affects its social and performance-oriented affordances. The more that is known about this relationship, the better we can prepare these industries to train civilian drone pilots. It is important to note that though there are many studies exploring observers' interactions with "autonomous" drones (Abtahi, Zhao, E, & Landay, 2017; Karlajainen et al., 2017; Obaid, Kistler, Kasparaviciute, Yantac, & Fjeld, 2016) little is known about drone operators' interactions with the technology alone. Studies about civilian or hobbyist drone pilots themselves are few. By reaching an understanding about drone pilots' performance decisions, we will be closer to understanding the public's perception of how drones are operated thus further informing human-drone interaction and drone design.

Fong, Thorpe, and Baur (2001) define human-robot interaction (HRI) as, "the study of humans, robots, and the ways they influence each other". The idea of human-drone interaction (HDI), according to Karlajainen et al. (2017) is an extension of HRI in that drones can be utilized as a social robotic agent. The scope of the current study does not include autonomous or semi-autonomous drones that can take control of tasks when necessary. However, when the drone and a human work together to accomplish a task, it can be considered human-drone or human-computer collaboration, specifically in terms of the pragmatic, human complementary approach (Terveen, 1994). The human complementary approach aims to improve HDI by making the drone a more intelligent partner via direct intent recognition through design and portrayal of information, rather than making agents more "human-like". This facilitates intent and provides cognitive artifacts to the human rather than relying on language or text (Terveen, 1994, p.18). In order to further understand HDI and human-drone collaboration existing research on human-robot teaming and human-automation interaction must be considered.

An integral aspect of human-robot teaming is trust, which plays an important role in decision-making, delegation of tasks, and expectation-setting in an environment where the drone is seen as a collaborator (Oleson, Billings, Kocsis, Chen, & Hancock, 2011). A human-drone team incorporates the above factors in that the human is relying on the drone to be their “eyes”, and the human must trust that the drone can carry out the task of recording audio/visual and remaining somewhat stable in the air (assuming no capability of automation). Trust is a complex construct, but it is understood that appropriate reliance on the drone is necessary (Freedy, DeVisser, Weltman & Coeyman, 2007). The human-related characteristics of this relationship such as experience and self-confidence are key to understanding how to best design this technology in the future (Freedy et al., 2007).

Operator Characteristics and Trust

A systematic review of factors that influence trust in automation by Hoff & Bashir (2015) aimed to model aspects of trust prior to and during an interaction with autonomation. The researchers identified the following groups of factors: situational, dispositional, and initial learned trust, and initial reliance on automation (prior to an interaction); and, dynamic learned trust, design features, system performance, and reliance on the system (during an interaction) (Hoff & Bashir, 2015, p.427). The researchers discuss internal variability as a factor related to situational trust—specifically, that operators tend to form trust based on context, self-confidence, and subject-matter expertise in a task regardless of enduring dispositions (Hoff & Bashir, 2015). Self-confidence can be described as one’s trust in their own capabilities and has been associated with trust in HRI (Oleson et al., 2011).

The relationship between past experiences, familiarity, and trust has been discussed in a variety of fields as they are interlocked in complex ways. In philosophy, familiarity is said to reduce the uncertainty of expectation as understanding of the past is accumulated (Luhmann, 1979). Furthermore, familiarity, confidence, and trust are considered to be measures of expectation-setting and self-assurance (Luhmann & Niklas, 2000). Luhmann & Niklas (2000) make the distinction between the constructs of familiarity and confidence in that familiarity is a distinction between known and unknown, whereas confidence is exhibited more in situations of contingency and danger. In consumer behavior research, Ha and Perks (2005) found that brand experience directly affects brand trust, with familiarity being a partial mediator. These findings support the notion that drone operators' familiarity with drones may have an affect on their trust and interaction with drones. Work by Freedy et al. (2007) calls for more research in this domain, finding that familiarity of previous behavior of a drone affects subjective trust in the drone.

Graff (2016) looked to explore effects of familiarity with video games and drone operation further to design more effective drone controllers (i.e. joystick). The researchers examined the difference between types of controllers on task completion time in a simulated drone study. They found that users who were familiar with flying drones completed three simulated piloting tasks much faster than other participants. Interestingly, the researchers found that participants who were familiar with the particular remote-control toys themselves were not that much better at the tasks, suggesting that familiarity with the process of piloting drones may have had a greater effect on task completion speed than the controller that is used. In order to explore the effects that familiarity and experience have on human-drone relationships, the construct of trust must be explored further.

Lee and Moray (1992) found that trust alone cannot describe why an operator may delegate or control certain tasks in a human-robot team, and that the operator's previous experience affects their self-confidence to complete the task. Further examination by those researchers found that self-confidence in human-autonomy teaming shows that trust in the system and self-confidence correlate, such that as self-confidence increases, allocation of tasks or trust to the autonomous system decreases because the operator feels able to do the task (Lee & Moray, 1994). Similarly, if the operator has low self-confidence then they trust the automation to take over certain tasks. Furthermore, research by Prinzel III (2002) found that self-efficacy and self-confidence do affect perceptions of workload and offloading of tasks to automation in pilots with varying experience. In cases of non-autonomous drones, the drone cannot take over tasks but there are still certain functionalities that the drone has that the operator does not, such as flight or ability to take pictures. Thus, critical aspects of this relationship are both trust and reliance. Lee and See (2004) argue that trust guides reliance and can be used to describe human-robot interaction in both laboratory and naturalistic settings.

Trust can be defined as the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability (Lee & See, 2004). Vulnerability alludes to one's reliance on the collaborator to perform as expected to achieve a goal, which can also insinuate a dependence of the trustor on the trustee because of a function or ability the trustor does not possess or cannot perform (Lee & See, 2004). By further examining dimensions of trust, we can begin to observe a more sensitive measure of trust in a human-drone collaboration.

Dimensions of Trust

The current study looks to explore this relationship further using known dimensions of trust, specifically performance, process, and purpose as defined by Lee and See (2004). *Process* refers to the notion that the drone adheres to a set of principles that the pilot finds acceptable, specifically in terms of its operations and algorithms. *Performance* can be described as current and historical operation of the drone and includes characteristics such as reliability, predictability, and ability, while *purpose* refers to the degree to which there is benevolence in the team and the drone is being used within the realm of the designer's intent (Lee & See, 2004). In order to understand the relationship between the pilot and the drone in the context of trust, the pilot's perceptions of trust dimensions purpose and performance regarding the drone must be measured. The trust dimension of performance, in terms of the operation of the drone in this context, is referring to the idea that the drone is skilled at flying and recording video. Purpose refers to the idea that the drone maintains a positive orientation towards the pilot and will not crash or sabotage the task. Process, in the context of the current study, is constant as the scope only includes non-autonomous drones that act directly according to the operator and thus will not be explored.

Drone Design

The functional design of the drone may also be related to these dimensions of trust, as some capabilities are chosen by the pilot before flight. Removable propeller guards are often included with drones to provide the pilot with an option to protect the drone's propellers and/or objects and people that the drone may come into close contact with. Observations of online drone communities on platforms such as

PhantomPilots.com, YouTube, and MavicPilots.com informally suggests that many experienced pilots do not use these guards for a number of reasons related to performance. However, the guards are still included by the manufacturers as a safety measure, for the purpose of protecting the drone and those around it. For example, user Joesrevolution says, “Prop guards are a great way to learn…However they greatly reduce efficiency and…it will handle a bit more sluggish” (PhantomPilot.com forum, 2015). Abtahi et al. (2017) suggest that such propeller guards may decrease the mental demand of those interacting with the drone and they facilitate a feeling of safety. For this reason, propeller guards act as a social factor in that they are not necessary for the drone to operate successfully in all scenarios. The drone will reach its destination faster when it does not have the added weight of the propeller guards. The guards add a sense of safety and confidence that the drone will be able to get through riskier scenarios better because they will be able to bump into things without damage or breaking course. For this reason, the guards facilitate the trust dimension of purpose, as their intent is to provide protection or safety of the drone. Without the propeller guards, the pilot is choosing a more efficient flight in that the drone will weigh less and thus get to the destination sooner. The removal of propeller guards facilitates the performance dimension of trust in that the drone is assumed to be expert at flying and flying quickly.

Niichel (2018) aimed to examine whether the use (or not) of propeller guards affected the viewers’ perceptions of trust and likeability of drones as a baseline measure using Jian, Bisantz, & Drury’s (2000) modified trust scale and Bartneck, Kulic, Croft, & Zoghbi’s (2009) likeability scale. It was hypothesized that a drone portraying a social influence of safety (with propeller guards) would facilitate higher levels of trust and likeability. In a survey of 107 online users, the previous study randomized participants into the protected or exposed propeller groups and measured trust and likeability of the drone. It was found that there was no significant relationship between these factors, and that familiarity and experience with drones may be a confounding variable.

Current Study

When people have interacted with a system and gained prior experience or expertise of it, this experience has been seen to influence trust because one is forming expectations about the system which help predict the system’s behavior (Oleson, Billings, Kocsis, Chen, & Hancock, 2011; Hoff & Bashir, 2015). This corresponds to research on the role of self-confidence mentioned previously, specifically that self-confidence in a system is directly related to one’s prior experience with the system such that as one’s experience with a system increases so does their confidence in using or collaborating with the system. Prior research found that drone pilots’ trust is influenced by perceptions of system safety, reliability, and capability to perform similarly when operated out of the immediate line of sight (remotely) as to when the operator is physically present (Salcedo, Ortiz, Lackey, Hudson & Taylor, 2011). These factors all relate to trust but failed to measure the viewers’ perceptions of the purpose of the drone and whether they believed it could perform a task effectively, thus failing to measure more relevant dimensions of trust sensitively in this context.

In another study related to drone design, Cusack and Khaleghparast (2015) looked at the feasibility of small drones for use in traffic surveillance, and considered propeller guards, weight, speed, range, and other factors. The researchers chose relatively small and cheap commercially available drones and found that the above factors should be heavily considered when choosing a drone due to the discovery that lightweight drones were susceptible to stability issues caused by wind (Cusack & Khaleghparast, 2015). This is one of the few studies on lightweight civil drone design that shows how companies would design the "optimal" drone and what features they may consider priority. The researchers' consideration of propeller guards, weight, speed and range influenced what aspects were considered most important in the current study.

The current study looks to distinguish between experienced and novice drone users to determine if level of experience in drone usage affects drone pilots' perception of purpose, performance, and overall trust in drones, and if this relationship affects the participant's choice to use safety features (propeller guards) over performance efficiency (no guards, i.e. lighter weight) to complete an imaginary task given as a scenario. These features were chosen as to reflect simple performance changes that may affect both the safety of and flight efficiency of the drone (Cusak and Khaleghparast, 2015).

It is hypothesized that more experienced drone users will choose not to use propeller guards to minimize the weight of the drone, such that lower weight may mean faster speeds in most scenarios. They are expected to have higher trust scores due to the nature of the task and to the specific trust dimension of performance—experienced users understand the drone's purpose and know it will operate reliably so they will report higher overall trust score and will not use the propeller guards in order to maximize efficiency. Inexperienced drone users are expected to have lower self-confidence in their piloting skills and will add the propeller guards in an effort to restore the trust dimension of purpose—the drone will be safer and protected from risk because the operator designed it so.

Operator experience was assessed by self-report measures of prior drone experience (e.g. drone ownership, flight hours), drone piloting expertise, and familiarity. The questions related to experience were devised by the researcher, as there is not a scale known to specifically measure these scores in civilian drone pilots. The scale for familiarity was created in Niichel (2018) to gauge general familiarity with drones. The self-report expertise scale was developed based on Benner's (1984) levels of proficiency. Due to the limitations of these study scales, the primary subject variable of experience used for quantitative analysis towards the hypothesis is reported familiarity (four levels) with flying a drone. This specific item was developed for Niichel (2018) and was the motivation for the current study. To address whether or not experience affects trust in drones, the modified Jian et al. (2000) trust scale will be the primary dependent variable. "the system" was changed to "the drone" to coincide with Niichel's (2018) previous work and the context of the current study.

The current study looks to expand this research to determine if participant factors affect trust in drones. Ownership of a drone, reported expertise of flying drones, flight hours, purpose and performance measures, and other qualitative items will be examined on an exploratory basis to determine if there are relationships between experience variables on trust in drones. Two questions regarding purpose and performance were developed by the researcher using the aforementioned dimensions of trust. One asked about the intent of the drone while the other asked about the drone's ability to perform the task. While these were not validated by the researcher or previous work, they served as preliminary measurements to see if there was any relationship to overall trust or drone choice. Each question should be looked at individually to see if they are related to the overall trust scores or choice of drone. One question regarding the purpose dimension of trust as to best reflect the definition by Lee & See (2004) is “Do you believe the drone you chose is being used as it was intended?” The other question regarding the performance dimension is “Do you believe the drone you chose is able to complete the task?” The answer options for both are “yes” or “no”. Because these answers are binary, analysis may be limited to correlation between variables. Knowing the relationship between two dimensions of trust (purpose and performance) and overall trust scores and drone design choice may help explain later findings on the relationship between experience and trust.

By exploring the relationships between experience and different dimensions of trust on drone design and overall trust in drones, a better understanding of human-drone interaction will be reached. It is hypothesized that previous experience will affect overall trust in drones and choice of drone design. This phenomenon may be further explained by the relationship between the dimensions of trust and their relationship to aspects of experience. If there is a relationship between experience and trust in drones, it may be possible to further understand what dimensions of trust are being affected. The results of this study will provide insight into the effects of experience on the perceived purpose, performance and overall trust in drones, exploring how HDI affects design of future drones as they become more readily available and used by the public.

CHAPTER 2

Method

Participants

A statistical power analysis was performed for sample size estimation, based on data from Niichel (2018) comparing familiarity (“never”, “once or twice recreationally”, “often recreationally”, or “often professionally”) to trust scores (average composite score). With an alpha = .05 and power = 0.80, the projected sample size needed with a medium Cohen’s effect size = 0.25 using RStudio 3.5.2 is approximately n = 44.6 per group. Thus, the proposed sample size of 200 participants was considered adequate for the main objective of this study and should also allow for expected attrition/exclusion and our additional objectives of controlling for possible limitations due to the recruitment method.

Following Institutional Review Board approval, participants were recruited from the online survey site Amazon Mechanical Turk (M-Turk). Basic guidelines and practices for inclusion of participants from M-Turk were used. Participants were all English-speaking citizens of the United States and were paid $0.25 USD. Participants were required to have over 500 HITs with 95% completion rate to control for some biases that recruiting from a paid online subject pool sampling often attracts. By selecting participants who are used to this type of work or survey situation, the researcher attempted to control for participants who are prone to decision fatigue. Over three days and varying time frames (e.g. early morning, afternoon, evening, night) and 17 batches of participants, two-hundred and thirty-eight participants responded to the online survey. Of these 238 participants, 51 participants’ data had to be excluded from analysis due to incomplete survey responses. These participants excluded from the study were allowed to continue the study but did not answer any questions or items past the consent form even though they selected that they agreed to consent and submitted the consent form question. This is most likely due to subjects simply leaving the page or allowing their survey to expire—it is unclear given the data Qualtrics measures. Excluded participants were still paid for the study.

Of the 187 participants whose data could be analyzed for the study, there were 104 men, 79 women, and 4 reported other or preferred not to answer. Participants ranged from 22 to 70 years old (M=35.9). 12 participants reported having a high school diploma or equivalent, 16 reported having an associate's degree, 77 reported holding a bachelor's degree, 26 reported a master's degree, 43 reported "some college" education, and the rest were spread among having doctorates, some high school, or some post undergraduate work or vocational training. Most participants were reportedly white/Caucasian (n=123), 27 were Asian, 14 were Black or African American, 10 were Hispanic, Latino, or Spanish Origin, and the other 13 reported Native Hawaiian or other Pacific Islander, Alaska Native, other, or some combination of the above. No specialized populations were targeted for recruitment and no exclusions were made on the basis of the above demographic information.

Materials

An online survey was constructed using Qualtrics online survey software and was administered to participants recruited through Amazon M-Turk. The survey (Appendix A) consisted of a consent form, a scenario (Appendix B), 11 items regarding experience, their drone choice, and explanations. There was one question regarding the purpose dimension of trust (“Do you believe the drone you chose is being used as it was intended?”) and one regarding the performance dimension (“Do you believe the drone you chose is able to complete the task?”). The 12-item Jian et al. (2000) scale (Appendix C) was administered following the questions regarding experience, drone choice, and explanations but prior to demographics to avoid potential identity bias. The Jian et al. (2000) scale was administered as-is (Appendix C) and the order of the questions were not randomized. The Jian et al. (2000) trust scale has been used as a research measure over 100 times but has its own sets of biases attached which should be considered (Gutzwiller et al., 2019).

As described in previous sections, the items the researcher focused on for the hypothesis of the study were familiarity (prior experience) and its effect on participants’ perceptions of trust in drones. Other items were included on the survey as exploratory measures to identify points for future research to examine. Some of these items will be discussed in the Results section.

In order to elicit participants’ choice of safety versus performance measures via drone design, a theoretical scenario was constructed (Appendix B) in which there was mild risk to the drone’s safety (e.g. wind, trees in the area) and a sense of urgency (e.g. task needs to be completed in a certain amount of time) to complete the “task”. Following the scenario, participants were asked to choose a drone that they felt would be best for the task. The only difference between the drones were the inclusion or exclusion of propeller guards and the resulting “specifications” (e.g. maximum speed). Following the participant’s choice in drone design were items regarding their experience with drones, the trust scale, and other measures.

Procedure

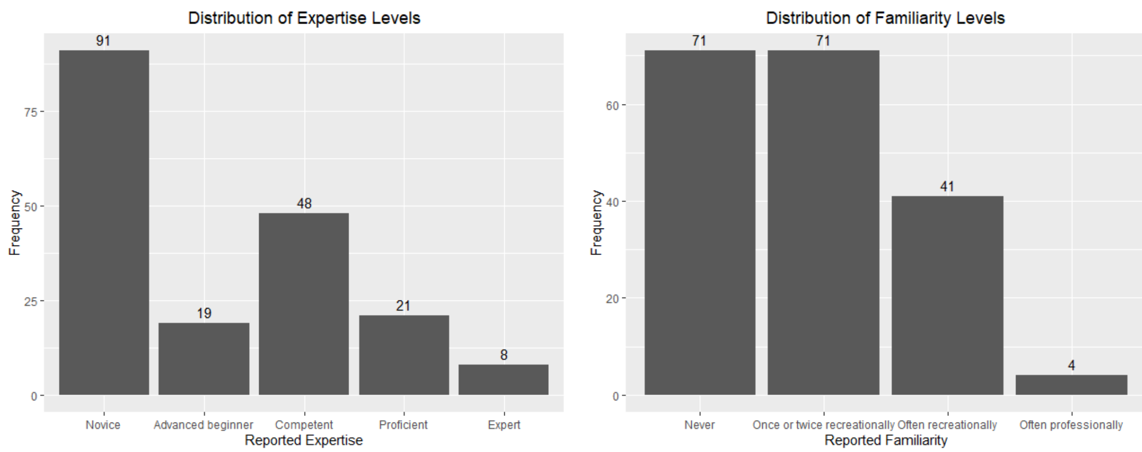
Participants recruited from M-Turk were asked to complete a short survey made via Qualtrics, which was estimated to take ten minutes based on Qualtrics' metrics for item completion time. Participants were given 45 minutes to take the survey. All participants received the same survey. Following a consent form, participants were asked about their experience operating drones in a series of a few questions. Then, they will be instructed to read a brief scenario (Appendix B) and will be asked to choose a drone that would best suit the needs of the task (given both have the ability to complete the task). Afterward, the participants were asked about their responses and a series of questions related to trust, the drone, and basic demographic questions. All participants' personal information was kept confidential/anonymous and only descriptions of demographic data will be represented in any published works.

The Jian et al. trust scale was reverse scored prior to data analysis so that the five questions relaying negative connotation towards the drone (e.g. the drone is deceptive) were scored as "low trust" or a score of one. Then, a composite score was calculated by taking the average of the 12 items.

CHAPTER 3

Results

Statistical analyzes were run using RStudio 3.5.2 and SPSS v.24 (IBM) for their respective data visualization and analysis techniques. Figures 1 and 2 below show the spread of participants' reported familiarity and expertise. Overall, the participants leaned toward novice drone users who had never flown drones before.



Figures 1 & 2: Distribution of reported expertise and familiarity.

To address the hypothesis that drone pilot familiarity with flying drones affects pilots' trust in the drone, a one-way analysis of variance (ANOVA) was performed on the familiarity question (four levels) and the Jian et al. composite score using RStudio. An ANOVA was run to examine the effects of level of familiarity (categorical variable) on overall trust scores (treated as a continuous variable). It was found that there was no significant difference in mean trust scores between reported familiarity levels as determined by the one-way ANOVA ($F(3,183) = 0.67$, $p = .57$; $\eta_p^2 = .01$). Figures 3 and 4 below show the recorded means of familiarity and trust with 95% confidence intervals shown on Figure 3. The Jian et al. (2000) composite scale scores are the average of 12 items, all on a seven-point Likert scale.

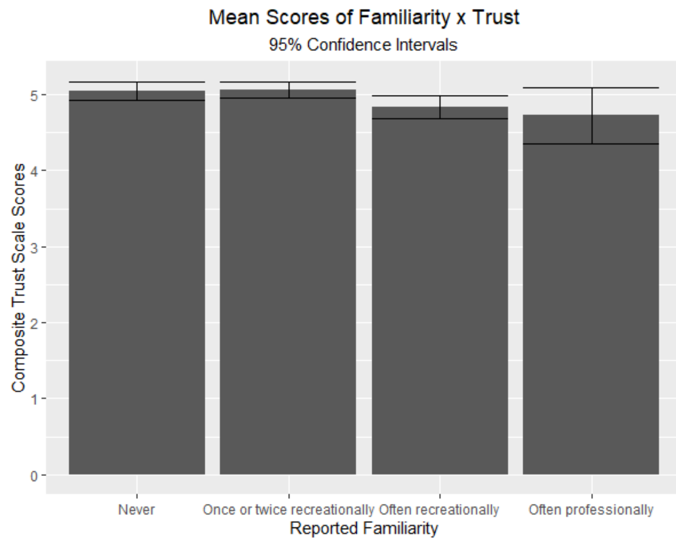


Figure 3: Mean scores of trust across reported familiarity.

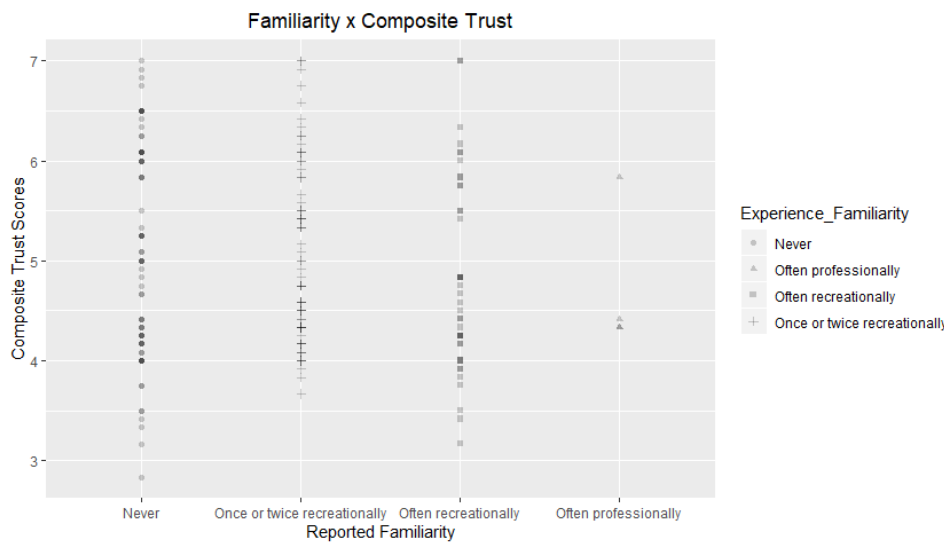


Figure 4: Plot of composite trust scores across reported familiarity levels.

Figure 4 shows a general distribution of the composite trust scores, by level of familiarity. A Levene's test was carried out and it was found that the assumption of homogeneity of variance was met, $p = 0.13$. Since this assumption was met, there is less likelihood that rejection of the null hypothesis (no difference in trust scores due to familiarity) is due to random chance or variation in groups. The effect size measured is a small partial eta squared of .01, meaning that approximately 1% of the variance in overall trust scores can be attributed to levels of familiarity. Figure 5 shows the fitted residuals and potential outlier (points above and below 1 and -1), which skewed the results.

Following the ANOVA, a chi-square test of association was conducted to provide further insight into the relationship between levels of familiarity and overall trust. A chi-square test revealed no statistically significant association between reported familiarity and overall trust scores alone, X(132)=118.5, $p > .05$.

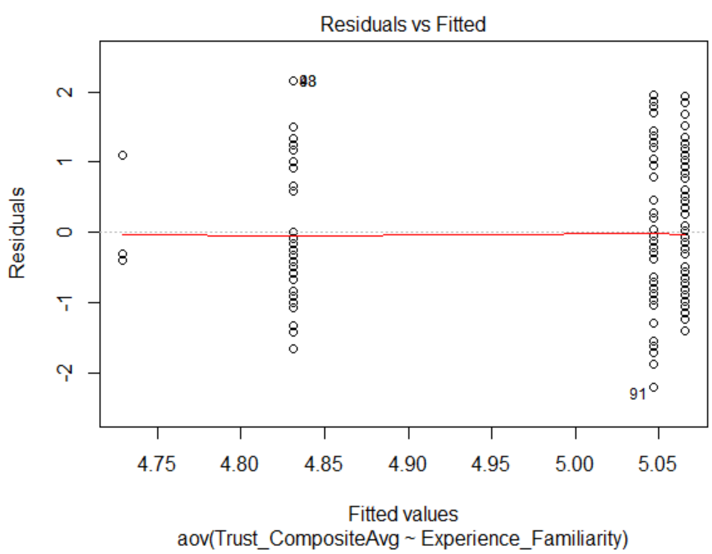


Figure 5: Fitted residuals to check for homogeneity of variance.

A two-way ANOVA was performed to explore the interaction between reported expertise and familiarity on trust in drones. A Levene's test yielded a significance of p<.05, meaning that any potential findings are prone to Type II error. Keeping this in mind, interaction effects were examined. There was a significant interaction between expertise * familiarity, which yielded an F ratio of $F(6, 173) = 2.19$, $p = .05$. Due to this significant interaction, it cannot be assumed that familiarity alone affects overall trust in drones. In order to investigate these effects further, the interaction plots were examined to look for potential main effects. Because there were no observations for “novice x often professionally,” “advanced beginner x often professionally,” nor “proficient x often professionally,” a lack of significant main effects is not surprising.

Additional analyses were performed to explore other trends in the data not directly related to the hypotheses. A chi-square test of independence was performed to examine the relation between familiarity and drone choice. Figure 6 below shows the distribution of participants’ reported expertise and their choice in drone.

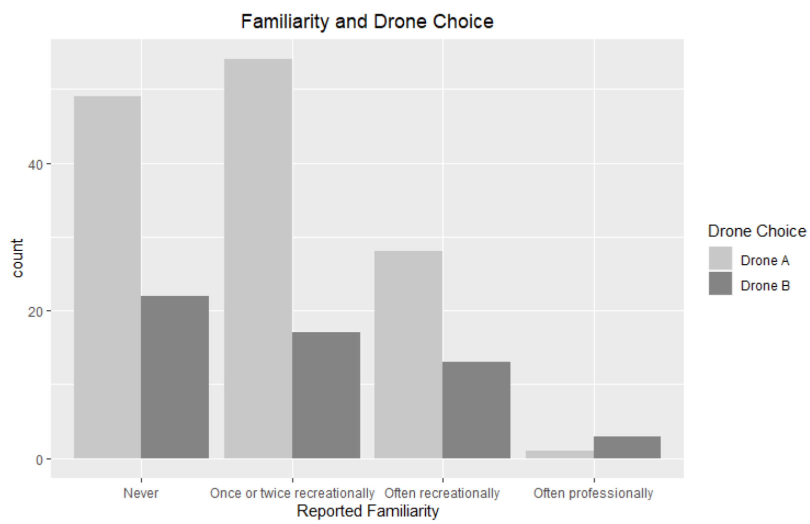


Figure 6: Distribution of reported familiarity and drone choice.

The relationship between these variables was not significant, X2 (3, N = 187 = 5.22, $p > .05$). As Figure 6 shows, most participants, except those who reported they use drones “often professionally”, chose the drone that is protected. A chi-square test of independence was performed to examine the relation between reported expertise and drone choice. The relation between these variables was not significant, X2 (4, N = 187 = 5.64, $p > .05$). There was also no significant relationship between the performance-related question and trust ($p > .05$) nor the purpose-related question and trust ($p > .05$).

Given the above analyses and limited control of the sample population subject variables, further analyses were run excluding the participants who reported they fly drones “often professionally” because there were only four participants in this category. They may be considered a specialty population as “highly trained” drone pilots. Thus, the following analysis only considered less-familiar levels of “never”, “once or twice recreationally”, and “often recreationally”. These pilots have likely not encountered a situation similar to the scenario given to them, which is more typical of professional drone use. A chi-square test revealed no statistically significant association between reported familiarity and overall trust scores alone, X(88) = 98.3, $p > .05$.

CHAPTER 4

Discussion

A previous study by Niichel (2018) found that there was no significant relationship between manipulation of drone design (with or without propellers) and measures of trust and likeability. The researcher hypothesized that this was due to participants' familiarity with drones—participants may have been assigned to evaluate a drone they were not familiar with or did not use that way. The current study aimed to address these discrepancies by surveying a range of drone users and their familiarity with drones and preferred drone design in order to better understand factors that affect trust in human-drone collaboration.The findings of the current study do not support the hypothesis that trust in drones is affected by or related to self-report measures of familiarity with drones, reported drone-piloting expertise, nor choice of drone design considering the dimensions of trust.

The results of the current study show that there is no relationship between familiarity with and overall trust in drones. There does seem to be an interaction effect between self-report levels of familiarity and expertise and trust in drones, which may be related to previous findings on the relationship between situational trust containing related sub-factors like past experience and self-confidence (Hoff & Bashir, 2015). The tests for analysis of variance considered familiarity as an independent variable instead of a subject variable, which is a limitation of this study. Neither of the tests for analysis of variance found statistically significant results for familiarity nor expertise alone, which is not surprising given the fairly skewed sample towards novice users.

An interesting finding is that 132 of 187 participants chose Drone A, with protected propellers. After looking through the written response explanations of why participants chose their drone, it is apparent that many participants still chose the safety of the drone over speed regardless of prior experience. This finding could be due to the fact that the scenario is given via survey and does not present any real risk or perception of risk to the participant or is not relatable or translatable to the participants who were mostly unfamiliar with drone piloting. Another explanation is that familiarity is not a strong enough measure to influence trust in remotely piloted, "toy" drones, at least in this survey-based and case-based study.

What does seem to stand out in the results is that there was a skew in familiarity—71 participants reported never having flown a drone, another 71 having flown a drone once or twice, and another 41 reported flying drones often recreationally. Though the goal sample size from the *a priori* power analysis was achieved, the study really did not reach enough users experienced in drone piloting. Considering the additional analyses ran on only participants who reported "never" to "often recreationally," there still was no evidence of a relationship between familiarity and trust in drones in this context. This may be due to drone pilot training and context of the task, as it is possible some people may be trained to fly their drone differently in varying conditions. Further research seems necessary on the link between self-confidence and drone piloting to understand how past experience with drones and trust in drones are related to decisions surrounding safety and performance. Current literature (Hoff & Bashir, 2015; Lee & See, 2004) points out that self-confidence, familiarity, and truly expertise influence trust, however there is still a lack of understanding as far as a quantitative relationship. The current study attempted to link familiarity with aspects of trust and overall trust scores but failed to find a significant relationship as expected. Future research should address relationships between the above constructs and develop improved measures of each that can provide insight into their role in trust.

Limitations

One limitation that must be addressed is the sampling method used. Amazon M-Turk, though great for collecting human subjects data quickly from a relatively broad subject pool, compared to the commonly used but narrower pool of U.S. college students, it also often attracts many participants who are looking to complete surveys as quickly as possible. This invites the opportunity for mis-entries and not enough time taken to read through studies or to follow instructions carefully. Though the researcher tried to control for this by using a "minimum time on page" timer on the scenario, it is always possible that the survey respondents are participating while fatigued, or burned out, or have a general lack of attention in the study. The "timer" given to participants was only there to ensure the participants stayed on the page long enough to reasonably read the scenario; however, participants were able to stay on the page as long as they needed. The participants were not shown the "submit" button on the scenario page until after 100 seconds had passed, to discourage participants from rushing ($M=157.5$, $SD=2.6$). Overall, the median completion time for the entire survey was five minutes and 42 seconds. Qualtrics' metrics predicted that it would take participants nine minutes and 54 seconds. Due to this discrepancy, it may be inferred that some participants did not take their time toread all items carefully. This may have affected participants' comprehension of the scenario. Additionally, the sample skewed towards white/Caucasian younger males and it is unclear if this is a true representative of the population of drone pilots in the U.S. or not.

In the future, this study could be conducted in-person, potentially with real drones and operators. Doing so would allow the researchers to somewhat control for effects of burnout and will allow a measurement of reading comprehension to be utilized. For example, in the current study participants were not recorded nor was there a knowledge check. In the future, these measures should be considered to ensure that participants are comprehending the scenario.

The current study supports the notion that the relationship between a drone pilot and their trust and operation of their drone is complex and may involve multiple factors related to previous experience with drone piloting, and perhaps also, people's general perceptions of drone technology. Because an increasing number of civil pilots from the public will be flying drones as industry moves towards this technology, it is important that businesses or other entities understand that training people based on their experience with drones will facilitate a more trusting human-drone team. If more experienced users recommend starting with propeller guards while training but moving towards efficiency later, it may be useful to understand where the line between novice and expert drone pilot is drawn. Understanding this relationship is imperative to fostering a safe community considering recent advances in human-drone interaction and will lead to more effective training of individuals whom will be piloting the delivery and surveillance machines of the future.

CHAPTER 5

Conclusion

The work by Lee & See (2004), Hoff & Bashir (2015) and other researchers on factors affecting trust in automation and human-robot interaction are correct in that trust is a difficult construct to measure, let alone predict. As companies like Amazon and Uber compete to bring drone deliveries and transportation to the forefront the consideration of the future employees and drone pilots must be considered. Additionally, drones will be more heavily relied on in search-and-rescue situations and being able to influence or predict the pilot's use and trust in the drone may have implications for the drone and the public's safety. There are also many implications of the importance of human-automation interaction in the near future as the demand for drone operators grows.

Though it was found that the specific dimensions of purpose and performance may not differ as much as was predicted in this study, these findings were likely due to the items developed by the researcher. Additionally, drone pilots' trust in drones along the dimensions of trust is likely variable and changing depending on context as Hoff & Bashir (2015) suggest. In order to best train future drone pilots, it is recommended that future work looks into the perception of safety of the drone and of the environment (e.g. passersby, sensitive electrical equipment). Participants in the current study overwhelmingly reported that given the situation that the drone was to be used in, the drone's safety outweighed its potential performance enhancement. To further explore the complex relationship of human-drone collaboration, likely a longitudinal study of drone pilots will be necessary from when they begin learning to fly to when they become experienced pilots. Knowing the differences between novice and experienced drone pilots over time and in a variety of contexts gives insight into how experienced drone pilots operate and whether trust generalizes to human-autonomous drone teams. The current study relied on much of the foundational work in human-automation interaction, which may assume more of a social role of the drone/robot that what was included in the scope of this study. Social factors affecting perceived risk and trust in drones is critical to understanding the role that familiarity and experience have in human-drone collaboration. As discussed earlier, a more concrete, quantitative model of trust developed by observing operators over time and in differing scenarios is important to the development and design of future drones. For example, by designing drones to be better suited to the novice user (i.e. attaching propeller protectors) we may better facilitate trust in human-drone collaboration and reduce time spent training novice pilots.

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APPENDIX A

ONLINE SURVEY CREATED VIA QUALTRICS

Experience and Drone Piloting - Niichel Masters

Experience and Drone Piloting
I am an undergraduate student working with Professor Erin Chiou in the Ira A. Fulton Schools of Engineering at Arizona State University. I am conducting a research study to examine factors affecting perceptions and use of drones. I am inviting your participation, which will involve a very brief survey followed by a few demographic questions. You have the right not to answer any questions, and may stop participation at any time. Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study, there will be no penalty. If you do not complete the study, you may not receive any/full compensation.
Your responses will be used to contribute to the completion and potential publication of an graduate master's thesis. The benefits to you include compensation via Amazon M-Turk and contribution to the scientific community. There are no foreseeable risks or discomforts to your participation. This survey should take no longer than 15 minutes of your time, however you are given up to 45 minutes to complete this survey if you should need it. You will be compensated $0.25 through the Amazon M-Turk portal for your participation in this study.
Confidentiality will be maintained throughout the duration of the study and for the foreseeable future. Only individuals directly associated with this project will have secure access to the data. We will not ask your name or any other identifying information in this survey. For research purposes, an anonymous numeric code will be assigned to your responses. However, your Amazon M-Turk worker ID number will be temporarily stored in order to pay you for your time; this data will be deleted as soon as it is reasonably possible. You have the option of making your personal information private by changing your M-Turk settings through Amazon. The results of this study may be used in reports, presentations, or publications but your name will not be used, and only group characteristics reported. If you have any questions concerning the research study, please contact the research team at: Dr. Erin Chiou at Erin.Chiou@asu.edu or Madeline Niichel at Madeline.Niichel@asu.edu. If you have any questions about your rights as a participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.
You must be 18 years or older to participate in this study. By selecting "I agree" below you are agreeing to be part of the study and that you are 18 years of age or older. Please note: You may not return to questions once your answer has been submitted.

☐ I agree to participate in this study, and confirm that I am at least 18 years of age. (1)

End of Block: Pre-Test

Start of Block: Block 4

Timing
First Click (1)
Last Click (2)
Page Submit (3)
Click Count (4)

There is a timer on this page. The submit button will not appear right away, so please take the time to read this section carefully. Below is an imaginary scenario. Please read the paragraph carefully, as you will be asked questions afterward regarding the scenario. For the purposes of this exercise, please assume "drone" refers to small remotely piloted quadcopter aircraft.

You have been employed as a contracted drone pilot by a local utilities company to locate a damaged power line using the company's drone. The company knows that the power line is located somewhere within a one square-mile area but needs your help to find the exact location. In order to properly see the damaged power line with the drone's camera, you will have to maintain an altitude of 100 ft or less. In this one square-mile area, there is mild weather, tall trees, and some residential and commercial buildings. Since you are a contracted pilot, you will only get paid if you are able to identify the line that has been damaged and return the drone without harm. The company is offering you a monetary bonus if you find the downed line and return the drone within the first thirty (30) minutes. Since you are not guaranteed to get paid unless you find the downed line, you want the best drone for the job. Which drone (described below) would you choose? You will be asked to explain your choice on the next page.

Drone A

- Propeller guards attached: yes
- Maximum Speed: 25mph
- Battery life: 30 minutes
- HD Camera: yes

Drone B

- Propeller guards attached: no
- Maximum Speed: 30mph
- Battery life: 30 minutes
- HD Camera: yes

The difference between the above drones is that Drone A features propeller guards for added safety of the drone, but this difference causes the drone's maximum speed to be lower than Drone B. Drone B does not have propeller guards, making it lighter and faster than Drone A but higher risk due to exposed propeller.

Which drone would you choose to complete this task?

○ Drone A (1)

○ Drone B (2)

What do you perceive the *main* purpose of the drone to be?

○ Maintain safety of itself and others (1)

○ Complete the task the fastest (2)

○ Other (3) ____

Do you believe the drone you chose is being used as it was intended?

- Strongly Agree (1)
- Agree (2)
- Neutral (4)
- Disagree (5)
- Strongly Disagree (6)

Do you believe the drone you chose is able to complete the task?

- Strongly Agree (1)
- Agree (7)
- Neutral (8)
- Disagree (9)
- Strongly Disagree (10)

End of Block: Block 4

Start of Block: Block 5

Do you own a quadcopter drone (drone with four propellers)?

- Yes (1)
- No (2)

What kind of drone do you own? (Make, model)

____

Are you familiar with the Federal Aviation Administration's Part 107 drone regulations?

- No, I am not familiar (1)
- Yes, I have heard of them (2)
- Yes, I have my Part 107 certification (3)

Are you confident in your ability to fly a drone?

- Yes (1)
- No (2)

How many times have you flown a quadcopter drone?

- Never (1)
- Once or twice recreationally (2)
- Often recreationally (3)
- Often professionally (4)

Do you tend to use the propeller guards? How often?

- No, never (1)
- Yes, rarely (2)
- Yes, most of the time (3)
- Yes, every time (4)

Please estimate the number of hours you have flown a drone (if you have).

____

You answered "often professionally" to the question above. What is the primary use of the drone? (e.g. real estate, utilities, surveillance, etc.)

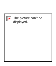
- ☐ Agriculture (1)
- ☐ Real Estate (2)
- ☐ Utilities (3)
- ☐ Construction (4)
- ☐ Filmmaking (5)
- ☐ Local Law Enforcement and Public Safety Agencies (6)
- ☐ Other (7) ____

Rate your level of expertise when it comes to piloting a drone.

- ○ Novice (1)
- ○ Advanced beginner (2)
- ○ Competent (3)
- ○ Proficient (4)
- ○ Expert (5)

End of Block: Block 5

Start of Block: Block 6



Why did you choose the drone to complete the scenario before? Please explain to the best of your ability.

____

____

____

____

____

Please rank the aspects according to which you <u>most</u> prioritized when making your decision. (1 = highest priority, 6 = lowest priority)

______ Task scenario (1)
______ Propeller guards (2)
______ Weight (3)
______ Maximum speed (4)
______ Battery (5)
______ HD camera (6)

Is there anything else you would have liked to know about the drone?

○ No (1)

○ Yes (2) ____

End of Block: Block 6

Start of Block: Default Question Block

Please respond to the following to the best of your ability.

(Note: Not at all=1; Extremely=7)

	1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	6 (6)	7 (7)
The drone is deceptive (1)	○	○	○	○	○	○	○
The drone behaves in an underhanded manner (2)	○	○	○	○	○	○	○
I am suspicious of the drone's intent, action or outputs (3)	○	○	○	○	○	○	○
I am wary of the drone (4)	○	○	○	○	○	○	○
The drone's actions will have a harmful or injurious outcome (5)	○	○	○	○	○	○	○
I am confident in the drone (6)	○	○	○	○	○	○	○
The drone provides security (7)	○	○	○	○	○	○	○
The drone has integrity (8)	○	○	○	○	○	○	○
The drone is dependable (9)	○	○	○	○	○	○	○
The drone is reliable (10)	○	○	○	○	○	○	○
I can trust the drone (11)	○	○	○	○	○	○	○
I am familiar with the drone (12)	○	○	○	○	○	○	○

End of Block: Default Question Block

Start of Block: Demographics

Please select your gender.

▼ Man (1) ... Prefer not to answer (4)

Please enter your age.

____

Which categories apply to you? Select all that apply:

- American Indian or Alaska Native (1)
- Asian (2)
- Black or African American (3)
- Hispanic, Latino, or Spanish Origin (4)
- Middle Eastern or North African (5)
- Native Hawaiian or Other Pacific Islander (6)
- White (7)
- Some other race, ethnicity, or origin, please specify: (8) ____
- I prefer not to answer (9)

Please describe your educational background (select all that apply to you):

- Some high school (1)
- High school diploma or equivalent (2)
- Vocational training (3)
- Some college (4)
- Associate's degree (e.g. AA, AE, AFA, AS, ASN) (5)
- Bachelor's degree (e.g. BA, BBA, BFA, BS, BSE) (6)
- Some post undergraduate work (7)
- Master's degree (e.g. MA, MBA, MFA, MS, MSW) (8)
- Specialist degree (e.g. EdS) (9)
- Applied or professional doctorate degree (e.g. MD, DDC, DDS, JD, PharmD) (10)
- Doctorate degree (e.g. EdD, PhD) (11)

☐ Other, please specify: (12) ____

End of Block: Demographics

Start of Block: Debriefing

Thank you for your participation and involvement in this study. The purpose of this study is to explore how we interact with drones as social instruments, and if our experience with them impacts our perception of their trustworthiness. Our hypothesis is that those who have used drones before will choose the drone without propeller guards, and those who have not used a drone before will not use them. We also expect that people trust them differently based on this experience.

Please enter the following code into the designated area on Amazon M-Turk:

########

APPENDIX B

SCENARIO

Below is an imaginary scenario. Please read the paragraph carefully, as you will be asked questions afterward regarding the scenario. For the purposes of this exercise, please assume “drone” refers to small remotely piloted quadcopter aircraft.

You have been employed as a contracted drone pilot by a local utilities company to locate a damaged power line using the company’s drone. The company knows that the power line is located somewhere within a one square-mile area but needs your help to find the exact location. In order to properly see the damaged power line with the drone’s camera, you will have to maintain an altitude of 100 ft or less. In this one square-mile area, there is mild weather, tall trees, and some residential and commercial buildings. Because you are a contracted pilot, you will only get paid if you are able to identify the line that has been damaged and return the drone without harm. The company is offering you a monetary bonus if you find the downed line and return the drone within the first thirty (30) minutes. Because you are not guaranteed to get paid unless you find the downed line, you want the best drone for the job. Which drone (described below) would you choose? You will be asked to explain your choice on the next page.

Description
Drone A

- Propeller guards attached: yes
- Max. Speed: 25mph
- Battery life: 30 minutes
- HD Camera: yes

Drone B

- Propeller guards attached: no
- Max. Speed: 30mph
- Battery life: 30 minutes
- HD Camera: yes

The difference between the above drones is that Drone A features propeller guards for added safety of the drone, but this difference causes the drone’s maximum speed to be lower than Drone B. Drone B does not have propeller guards, making it lighter and faster than Drone A but higher risk due to exposed propeller.

APPENDIX C

JIAN ET AL. TRUST SCALE (2000)

Checklist for Trust between People and Automation

Below is a list of statement for evaluating trust between people and automation. There are several scales for you to rate intensity of your feeling of trust, or your impression of the system while operating a machine. Please mark an "x" on each line at the point which best describes your feeling or your impression.

(Note: not at all=1; extremely=7)

1 The system is deceptive

1 2 3 4 5 6 7

2 The system behaves in an underhanded manner

1 2 3 4 5 6 7

3 I am suspicious of the system's intent, action, or outputs

1 2 3 4 5 6 7

4 I am wary of the system

1 2 3 4 5 6 7

5 The system's actions will have a harmful or injurious outcome

1 2 3 4 5 6 7

6 I am confident in the system

1 2 3 4 5 6 7

7 The system provides security

1 2 3 4 5 6 7

8 The system has integrity

1 2 3 4 5 6 7

9 The system is dependable

1 2 3 4 5 6 7

10 The system is reliable

1 2 3 4 5 6 7

11 I can trust the system

1 2 3 4 5 6 7

12 I am familiar with the system

1 2 3 4 5 6 7

Figure 8. Proposed questionnaire to measure trust between people and automated systems.

APPENDIX D

IRB EXEMPTION

EXEMPTION GRANTED

Erin Chiou
IAFSE-PS: Human Systems Engineering (HSE)
480/727-1589
Erin.Chiou@asu.edu

Dear Erin Chiou:

On 10/22/2019 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Exploring the Effects of Experience on Drone Piloting
Investigator:	Erin Chiou
IRB ID:	STUDY00010908
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• Qualtrics Survey , Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • HRP-503a - Protocol, Category: IRB Protocol; • Niichel_Consent Form_Fall 2019.pdf, Category: Consent Form;

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2) Tests, surveys, interviews, or observation on 10/22/2019.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator