8-2021

Aerial Flight Paths for Communication

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by

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A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfilment of Requirements

For the Degree of Master of Science

Major: Computer Science

Under the Supervision of Professor Brittany A. Duncan

Lincoln, Nebraska

August, 2021

Aerial Flight Paths for Communication

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University of Nebraska, 2021

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This body of work presents an iterative process of refinement to understand naive perception of communication using the motion of an unmanned aerial vehicle (UAV). This includes what people believe the UAV is trying to communicate, and how they expect to respond through physical action or emotional response. Previous work in this area sought to communicate without clear definitions of the states attempting to be conveyed. In an attempt to present more concrete states and better understand specific motion perception, this work goes through multiple iterations of state elicitation and label assignment. The lessons learned in this work will be applicable broadly to those interested in defining flight paths, and within the human-robot interaction community as a whole, as it provides a base for those seeking to communicate using non-anthropomorphic robots. We found that the Negative Attitudes towards Robots Scale (NARS) can be an indicator of how a person is likely to react to a UAV, the emotional content they are likely to perceive from a message being conveyed, and it is an indicator for the personality characteristics they are likely to project upon the UAV. We also see that people commonly associate motions from other non-verbal communication situations onto UAVs. Flight specific recommendations are to use a dynamic retreating motion from a person to encourage following, use a perpendicular motion to their field of view for blocking, simple descending motion for landing, and to use either no motion or large altitude changes to encourage watching. Overall, this research explores the communication from the UAV to the bystander through its motion, to see how people respond physically and emotionally.

DEDICATION

Dedicated to my parents Bob and Mariann Bevins, and my husband Jace Pinkerton.

GRANT INFORMATION

This work was supported by the National Science Foundation under IIS-1638099, IIS-1750750, CNS-1757908, and IIS-1925368.

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Chapter 1

Introduction

As UAVs increase in popularity and functionality, they are becoming easier to obtain and significantly more visible in standard occurrences for the general public. In addition to the increasing visibility of use to the public in everyday occurrences, they are being used in many professional environments such as disaster relief, agriculture, and product delivery. One of the problems with this increased visibility and use, is that not everyone who comes in contact with the UAV will have context for its purpose or current task. This becomes an even larger issue when a malfunction or abnormality occurs. UAV manufacturers, programmers, and users need to be able to understand how they can expect the uninformed person to react to their vehicle. In addition to this, a bystander needs to be able to understand what is occurring to minimize concern and unnecessary intervention.

The main purpose of this work is to inform future researchers, and UAV developers, about an understanding of how participants perceive UAV paths. This includes what they believe the system to be communicating, what they find to be most important, and their intended interactions based on those communications.

To do this we began by running an initial study to explore how consistently people label motions (Phase 0) [1] in Chapter 4. The labels curated within that phase were then presented to a new set of participants to create their own motions, with the goal of seeing if they aligned (Phase 0) [2]. A base of 16 motions to include the motions from both portions of Phase 0 were then presented to participants to see if the new user generated paths had more label agreement than the originally chosen motions(Phase 1-3) [3], presented in Chapters 5, 6, and 7. In pursuit of those answers we were able to provide crowdsourcing recommendations for other robotics researchers[4]. Finally in Chapter 8, states which were more effective at generating responses as chosen from Phase 3 were presented back to participants to see if they would create motions that aligned with the expected path characteristics (Phase 4).

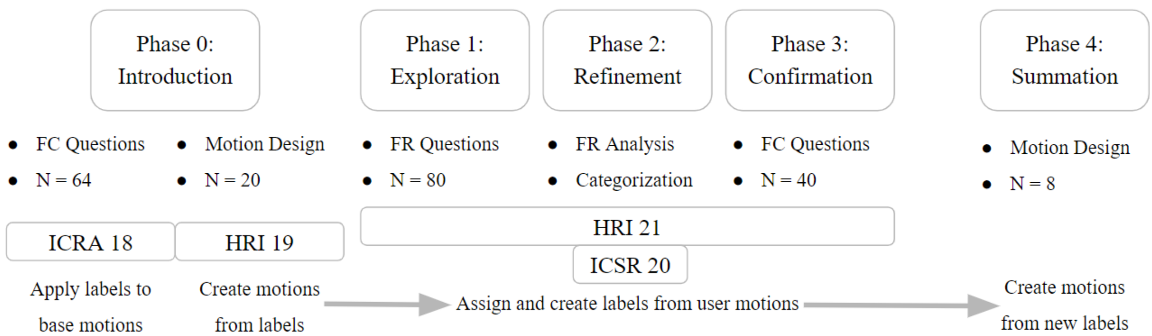

Figure 1.1: Breakdown of Phases: initial introduction, followed by an interative creation/labeling exploration, and finally a summative study.

Overall lessons from this work indicate that:

- frequent motions or gestures applied in non-UAV situations are associated and understood on UAVs,
- landing is conveyed by direct movements with an altitude change,
- people will follow a UAV's path when the motion approaches and then retreats towards a location when in the absence of altitude changes and,
- flights across an area are likely to cause participants to avoid the vehicle or that area (regardless of the altitude).

We found that people have a high likelihood of interpreting states in more similar ways when the motions are simpler. In the most basic cases people took the front-back motion on the y-axis to mean to follow the vehicle, a side to side motion focused on the x-axis to stay back(or to not follow it), and an up-down motion on the z-axis to mean landing. We also found that NARS can be an indicator of how people expect to react,if they are likely to expect a negative message to be conveyed, and their expectation for the UAV to have negative personality traits.

1.1 Contributions

This work seeks to provide assistance to UAV operators, users, and programmers in the form of motion design, with brief interaction notes, to be used with their systems as a method of communication to bystanders not involved in their design or creation of process. The proposed paths work towards making a safer interaction space and higher level of understanding of what may happen in a mission for all involved. This means that bystanders may have a greater idea of what is being communicated to them, or how to interact. This in turn means that operators may have a better idea of how a bystander may react. The main contributions include:

- Recommended motion primitives to design communicative UAV flight paths.
- Lessons learned on eliciting participant agreement in crowdsourcing.
- Design methodology to assess communicative ability of new technology.
- A foundational set of UAV flight paths broadly agreed to communicate to bystanders and inform future research in this area.

These contributions are completed through the iterative process presented in this work. In pursuit of these contributions I have published the following works:

- "Aerial Flight Paths for Communication: How Participants Perceive and Intend to Respond to Drone Movements" at 2021 International Conference on Human-Robot Interaction (HRI) [3]
- "Content is King: Impact of Task Design for Eliciting Participant Agreement in Crowdsourcing for HRI" at 2020 International Conference on Social Robotics (ICSR) [4]
- Contributing author for "Investigation of Communicative Flight Paths for small Unmanned Aerial Systems" at 2018 International Conference on Robotics and Automation (ICRA) [1]

In addition to published works, there is one journal submission currently under review:

- "Aerial Flight Paths for Communication" for Frontiers in Robotics and AI, under the research topic Rising Stars in Human-Robot Interaction

Chapter 2

Literature Review

When considering the topics discussed in this paper, the related work is broad and inherits best practices across many fields. This chapter discusses the most relevant work that needed to be reviewed when developing the studies and provides pointers to those hoping to adopt these practices in the future. This section also presents on prior research in social UAVs, UAV proxemics, and the communication gap from the UAV to person.

2.1 Question Design

Best practices for creating questions are that they should be: concise, easily interpreted, and use accessible language in order to appeal to the diversity of participants likely to be recruited in crowdsourcing studies [5] [6]. Previous works with anthropomorphic robots have shown that free responses yield the most diverse or creative results [7] [8]. The non-anthropomorphic nature of many robots can lead to participants simply describing the motion of the vehicle, rather than inferring requests or deriving information from the actions. In order to elicit more human-like responses to the UAV, questions can be worded to request more human-like descriptions, as seen in anthropomorphic studies. Anthropomorphic studies tend to include questions that imply that the robot had intention and was intelligent[9][8] [10] which increased participants' confidence in the robot [7].

2.2 Crowdsourcing

Although running in-person studies may typically be preferred, online crowdsouring can be very useful in certain cases. there are a few cases where it may be more appropriate to use a crowdsourcing method. A few examples of these may include: when a large range of participants are needed, materials are targeted for refinement through many different proto-studies, or the work can be delegated into small tasks. When comparing crowdsourced results to in-person, Toris et al. [11] and Casler et al. [12] have seen minimal to no difference in their results between the participants who came in person and those who completed tasks online.

2.3 Social UAVs

Interest in UAVs for social purposes has been increasing in recent years, which has resulted in overviews of work in UAVs as flying interfaces [13] and design recommendations for UAVs in inhabited environments [14]. A relevant finding from Baytas et al. [14] suggests future work on "Intuitive Comprehension" of UAV movements to understand what a UAV is trying to convey without other explanation. We defer to these works for a more comprehensive discussion of social uses for UAV systems.

2.4 UAV Communication

UAV Communication has been explored in other works, but typically in the human to UAV direction [15] [16]. This difference in focus is important to note as the work presented here will focus on how a UAV can communicate to a person who may or may not be it's operator.This can be achieved through a variety of methods, with the most popular discussed further here.

2.4.1 Lights, Stereo, and Video

Audio or video methods can be very direct in their communication by providing speech, either verbal or written, or even figures that people associate frequently with message. Adding components to a UAV to aid in these communication methods has been done in a few ways including: lights [17], video through a projector [18] [19] [20], and speakers [21].

Adding components to a system always comes with the natural drawbacks of impacting system weight limits and battery usage, which can then in turn impact the system performance. The other drawback for these components is simply that they require additional hardware that is not standard with most UAV systems. Finally, the methods mentioned here have a reduced communication range, as they can only communicate as far as their screens can be seen or their speakers heard clearly.

2.4.2 UAV Proxemics

Proxemics, or the impact of distancing on interactions, is another component that can be manipulated to assist or change the overall message attempting to be conveyed through a system [14]. Previous work has explored UAV distancing in interactions with vehicles at different heights[22] [23] and as compared to ground vehicles [24]. Generally, participants indicated that UAVs should interact with them from the social zone rather than personal zone, in contrast with human-human or human-ground robot expectations.

2.4.3 Flight Paths

A few studies have explored the benefits of using the flight paths of a UAV to communicate an intended message. Sharma et al. [25] explored how UAVs could use their paths to communicate affective information, suggesting that the use of space directly vs indirectly and making the motion quicker or slower has a direct effect on the valence, with a direct quick motion giving higher valence. Szafir et al.[26] explored using flight motions to help communicate intended destination, while also completing goals. They also found that the effect of easing into the motion in addition to the effect of arcing it, both of which make the motions more expressive, made participants feel the motions were more natural and safe.

2.5 Personality Model

To obtain a full picture of how people would respond to a UAV, it is also important to understand their projected emotion in relation to the UAV. [27] suggests that stereotype personalities can be created using immediate response emotions. [28] and [29] explored this concept and presented an emotional model space for UAVs. [28] then also used these models to represent a full personality, such as an *Exhausted* or *Anti-Social* Drone, which were then categorized based on varying speed, reaction time, altitude and additional movement characteristics.

Chapter 3

Experimental Methods and Design

3.1 Research Questions

This work is motivated by two research questions:

- How do people interpret flight paths?
- What do they intend to do based on that interpretation?

The answers for these questions should come in the form of motion-specific recommendations. These questions prompted us to use an iterative phase approach, using the following independent and dependent variables:

Table 3.1: Variables manipulated and observed for each phase

	Independent Variable	Dependent Variable
Phase 0 [1]	Videos / Number of labels	Forced choice label applied
Phase 0 [2]	Labels provided	Flight paths created/ Taxonomy
Phase 1	Videos	Free response label
Phase 2	Categories for assignment	Interrater reliability
Phase 3	Videos & Labels	Forced choice label applied
Phase 4	Labels provided	Flight paths created

3.2 Pre & Post Interaction Surveys

Participants were asked to complete a consent form followed by a demographic questionnaire, the first half of the Positive and Negative Affect Scale (PANAS) (based on their condition), and the Negative Attitude towards Robots Scale (NARS). The Positive and Negative Affect Scale, PANAS, was used to assess how participant affect changed throughout the study to understand the impact of manipulation. The Negative Attitudes towards Robots Scale (NARS), introduced in [30], was used due to the findings of [31] that found people with high NARS have been found to have difficulty in recognizing robot motions in humanoid robots.

After their main task, they all completed a post-survey questionnaire consisting of a few questions about the study. If they completed PANAS prior to their task, they were asked to complete the second half of PANAS at this time.

3.3 Materials

For both Phase 0 studies an Ascending Technologies (AscTec) Hummingbird and Vicon motion capture system were used. For Phase 1-4 we used the DJI flamewheel f450, Pixhawk flight controller, and Vicon motion capture system. The flamewheel with mounted Pixhawk can be seen in Figure 3.1. The space used, and a few of the Vicon cameras circled, can be seen in Figure 3.2.

3.4 MTurk

This section presents further details about the methods used for studies that were completed on Amazon Mechanical Turk (MTurk) (Phase 0 [1], Phase 1, Phase 3). The participants were recruited and participated online via MTurk, choosing our study based on a short description provided. To qualify they had to be considered an MTurk "master",

Figure 3.1: DJI flamewheel f450 with mounted Pixhawk

Figure 3.2: View of NIMBUS Lab testing space with some Vicon cameras circled

as determined by Amazon through analyzing worker performance over time. They must continue to pass the statistical monitoring in place to retain that qualification. All participants are unique and were not allowed to participate in multiple phases.

Following any pre-interaction surveys participants were redirected to a Google Form where they were asked to watch unique videos of a UAV flying in specific motions. The motions used for each phase are mentioned in their respective sections. Each video was 30 seconds in length with repetitions of the flight added to reach the desired length of the video, as necessary. In order to better compare our videos to prior work, we also leveraged the *Exhausted* Drone template speed from [28] and the *Anti-Social* Drone altitude template. The flight paths executed potentially included the characteristic movements (wobble and start/ stop, respectively), but that was based on the underlying motions described above. Once randomly in their study they were given an attention check video that had a word in the middle of it. This was placed to make sure they were reading the questions and watching at least part of the videos.

3.5 Motion Design

Participants in Phase 0 [2] and Phase 4 were presented with states and asked to create motions to communicate those states. In the case of Phase 0 [2] this was completed completely in person. For Phase 4 the design and pre-interaction surveys were administered over Zoom and Google Forms respectively. Following this they were asked to verbally describe and physically demonstrate their motion using a small object. In Phase 0 they were provided with a miniature drone model, but for Phase 4 they had to use an object they had available (around the size of a cell phone).

Chapter 4

Phase 0

We now present the first phase of the project which includes two different studies. The first study explores label assignment at a high-level, looking for general agreement amongst participants. The second study explores user-defined flights created to convey the labels presented within the first study.

4.1 Broad Agreement

Phase 0 [1] involved 64 participants in total (43 Male, 21 Female). Each participant was paid 2 dollars and Amazon was paid 1 dollar for recruitment. Participants took 24.63 minutes (SD=12.18) in the two alternative forced-choice (2AFC) task, and 26.15 minutes (SD=12.29) in the seven alternative forced-choice (7AFC) task. An example of what they saw when completing the study is shown in Figure 4.1

This was an initial study to address the question: Do novice users show broad agreement on the meaning of UAV gestures? From a methodology perspective we start exploring this question by following established protocols used to investigate human gestures presented in [32], which seek to understand the level of agreement by exposing participants to a limited gesture set and then requesting those participants to apply a

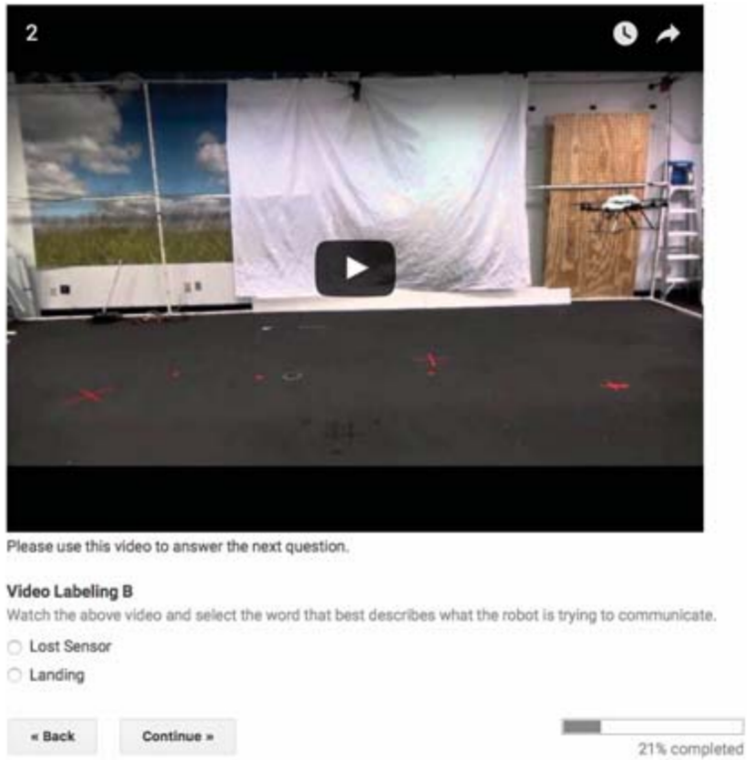

Figure 4.1: Example display screen participants saw

label from a limited set. From the UAV gesture perspective, we began by adopting flight paths used in nature, which are robust to viewing angle or occlusion, oscillatory in nature to allow looping, and adapted from biological inspiration to explore any templates that might exist. Given the formative stage of the work, we limit the impact of environmental factors (through being performed in an indoor space), constrain the labels (to understand agreement rather than generation), and do not introduce a visible goal state (to assess understanding rather than inference).

The initial paths created from this work were developed from flight patterns used by birds in order to leverage the advantages inherent in biologically inspired behaviors, as described in [33] and [34]. This section will describe the available labels, flight path selection, programming environment, and video creation for the experiments.

The labels for this study were chosen based on likelihood that they would be encountered in flights and generally would require redirection or intervention from the operator, or awareness from bystanders. It was also anticipated that these states would be understood by novice users due to the widespread use of hobbyist systems or observations of other aircraft (e.g., Landing, Low Battery, Draw Attention), commonality with other taskable systems (e.g., Missed Goal, Change Position), and potential similarities to states encountered in smart phone technology (e.g., Lost Sensor, Lost Signal). Another consideration was to choose states that were domain independent rather than focusing on possible applications of the technology (e.g., not Deploying Sensors nor Taking Pictures)

The avian flight paths selected were originally identified by [35] as oscillatory motions (those with a steady periodic motion and which could be created from sinusoid functions). More details on their inclusion/exclusion criteria can be found in the original work, but these motions were of interest to this work because they are biologically inspired, can be created in a replicable way, offer the ability to scale and loop as needed, and can generally be perceived in the presence of occlusion or multiple viewing angles. The requirement for biologically inspired behaviors also takes into consideration the requirements for deployment of these motions, such as the need to be observable against a natural background, able to contend with energy constraints, and understandable by other animals (or in this case humans).

The eight cyclic motions used by birds and identified in [35] are: Circle, Figure-8, Left-Right, Loop, Spiral, Swoop, Undulate, and Up-Down. Four of these can be seen in Figure 4.2. When designing the labels for this study, we considered states that may impact and may need to be communicated to bystanders. The states we chose were: lost signal, lost sensor, draw attention, landing, missed goal, change position and low battery. We then performed an initial assignment of those labels to the motions to later gauge whether participants would confirm these assignments or realize alternative ones.

The initial assignments with a brief description of the thought behind these assignments follows:

- Circle: lost signal, in which the movement could help the UAV regain signal
- Figure-8: lost sensor, which looks like the motion used to recalibrate your phone's magnetometer
- Left-Right: missed goal, which looks like shaking head
- Loop: draw attention, which might be reminiscent of a ferris wheel
- Spiral: landing, which could be used in indicating a position of landing
- Swoop: draw attention, since this is eye catching
- Undulate: change position, since this motion could be performed while starting in the direction
- Up-Down: change position, which looks like nodding to acknowledge the command

4.1.1 Results

Results indicate a strong understanding across users for a spiraling path to communicate "landing", but users primarily gravitated towards well understood states (draw attention and landing) while avoiding more technical states (lost sensor). From this work, it was recommended to explore open-ended responses, and user generated flight paths. An initial finding questions whether the findings from humanoid robots that

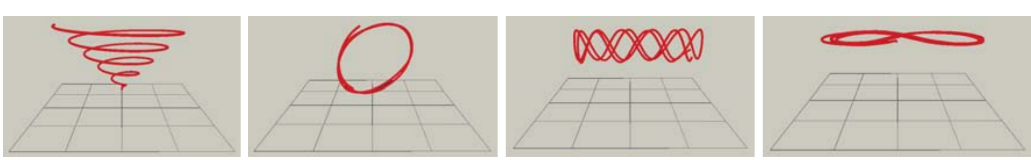

Figure 4.2: Spiral, Loop, Undulate, and Figure-8 paths from the flight log

negative attitudes towards robots decrease understanding of gestures also applies to UAVs, and leaves a more broad question on whether a version of NARS should be revised to apply specifically to UAVs, which we investigate in future work presented here.

4.2 Motion Elicitation

Phase 0 [2] presents concrete states to twenty participants(10 Male, 10 Female). As an incentive for participation they were each put into a lottery for a $25 gift card. The seven states provided to participants were: Attract Attention, Sensor Lost, Low Battery, Signal Lost, Area of Interest, Missed Goal / Target, and Landing. After eliciting a total of 140 gestures, an objective classification and taxonomy was created to group the motions according to specific, common characteristics. This taxonomy is presented in Table 4.1.

Looking at all of the designed gestures, the gestures were also grouped with

Table 4.1: Taxonomy for UAV flight classification

Taxonomy for User-Designed Flight Paths		
Complexity	*Simple*	Single movement
	Compound	Collection of movements
Space	*Direct*	Focused approach to a point
	Indirect	Deviates from direct path
Cyclicity	*Cyclic*	Repeated motion (same path)
	Random	Singular flight path
Command	*Roll*	Left or right movement
	Pitch	Forward or back movement
	Yaw	Rotation
	Throttle	Up or down movement
Altitude	*Increasing*	Increase flight height
	Decreasing	Decrease flight height
	Variable	Increase and decrease
	Stable	No height change
Motion	*Rectilinear*	Only straight movement(s) and 90-degree turns
	Curvilinear	Only curved movement(s)
	Rotational	Only rotates
	Combinational	Combination of the above

common features according to the taxonomy. A few of the states had more prevalent common motions. Landing had thirteen people assign it as descending, area of interest and missed goal/target both had horizontal circles, and low battery had up-down motions.

Chapter 5

Exploration: Phase 1

We used the initial exploration into how participants would use a drone's motion to communicate, to begin an iterative approach, in the hopes of refining and collecting the different interpretations. The motions created and pulled from both portions of phase 0 were presented to participants, and they were asked to respond to different questions about what they believed the drone was communicating.

5.1 Approach

One of the goals of this section of the work was to validate the proposed videos for participant agreement, prototype questions for ability to elicit consistent responses, and understand the impact of asking multiple questions on participant responses. Throughout the study, other interesting considerations were encountered including the impact of pre- and post-questionnaires on the quality of participant response, which can be seen in further detail in [4]. The questions and processes developed were then used to better understand participant perception of and anticipated reaction to UAV flight paths. These questions are presented in Table 5.1 with "type" being the response anticipated from the participant (speech, gesture, or physical). All forms of the questions were posed to get a realistic answer to the question of how the participant would expect to perceive and react to a UAV's motion.

5.1.1 Question Variants

Three variations of question types were investigated to elicit a variety of responses. The groupings were based on whether they were expected to elicit a replication description, speech, or physical response from the participant. Each participant received 1 or 2 free-response questions chosen from Questions 1 through 6 as shown in Table 5.1. Two questions were available for each of the three question types. A full listing of the test conditions used, which question was with each test, and whether that test used PANAS can be seen in Table 5.2. Each test line represents 8 participants.

Gesture-based questions are meant to elicit a response regarding how the participant may relate the action of the UAV to an action they are familiar with seeing in other people (of similar culture/area). Speech based questions were asked to see how participants may assign verbal communication to the UAV's actions. One question from the Speech type and one question from the Gesture type were selected to run together in order to see if people would give complementary responses across both types and whether these responses would give greater insight into their responses.

Table 5.1: Study Questions

	Type	**Question(s)**	**Chars**
1	Speech	If you saw this drone in real life, what would it say to you?	61
2	Speech	If this drone could speak what would it tell you to do?	55
3	Gesture	What human gesture does this remind you of?	43
4	Gesture	If you had to replicate this movement with your head and/or body, what would you do?	84
5	Physical	If you were in the room with the robot, what would you do immediately following the robot's action?	99
6	Physical	If you were in the room with the robot, how would you respond immediately following the robot's action?	103

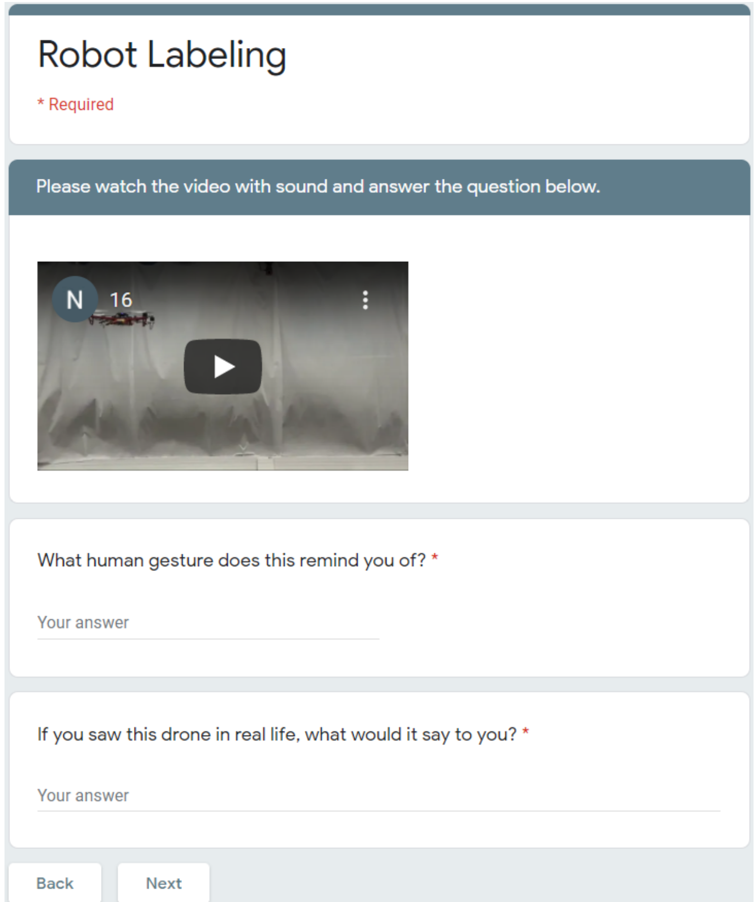

Figure 5.1: Phase 1 Google Form

Table 5.2: Study question combinations for phase 1

Condition	Question Numbers Asked	PANAS
1 Speech	1	Yes
1 Speech	1	No
2 Speech	1, 2	Yes
1 Gesture	4	Yes
1 Gesture	4	No
2 Gesture	3, 4	Yes
1 Speech, 1 Gesture	1, 4	Yes
1 Speech, 1 Gesture	1, 4	No
1 Physical	5	Yes
1 Physical	6	Yes

After briefly looking at the preliminary results for the Speech and Gesture Questions, we noticed a gap within the responses received. The responses, in general, did not include many physical responses that indicated how the person watching the action would respond, which was one of the the original intents of the first portion of the study. Returning to the literature, a set of [7] questions were reformatted to ideally capture both the speech and gesture question types, while allowing the participant to answer in either way or with a more physical response.

5.2 Participants

Phase 1 involved 80 participants (46 Male, 33 Female, 1 No Answer). They ranged in age from 24 to 68 (M = 38.6, SD = 10.7). Of the 80, 76 identified as American, 3 as Indian, and 1 as Chinese. Education level ranging from high school (12) to graduate-level Degrees (4), and everything in-between including those with a college degree (46) or some college without a degree (17). Each participant was paid 4 dollars and Amazon was paid 1 dollar for recruitment. Participants took roughly 35 minutes on average across all of the tests.

When examining the initial data that was collected from MTurk, the participants seemed to produce less diverse results towards the end of tasks (particularly those with double videos). To investigate the possible impact of participant fatigue, we removed the PANAS and additional videos during retests of selected conditions.

5.3 Videos

Participants were asked to watch 16 unique videos of a UAV flying in specific motions that were created to include the motions from Phase 0 [1], as well as additional videos that corresponded to both the taxonomy and the most popular flight paths from Phase 0 [2]. The base flight paths included: front-back, straight descend, descend and shift (descend then shift horizontally), diagonal descend, horizontal figure 8, horizontal circle, hover in place, left-right, plus sign, spiral, undulate, up-down, U-shape, vertical circle, X-shape, and yaw in place. Visualisations of these flight paths can be seen in Figure 5.3. Each video was 30 seconds in length with repetitions of the flight added to reach the desired length of the video, as necessary. Still images of the plus motion are shown in Figure 5.2 , and all of the flight paths can be seen at https://youtube.com/playlist?list=PL1rEtKLAOfrV3_3JBKMztg2y9uu7krizJ.

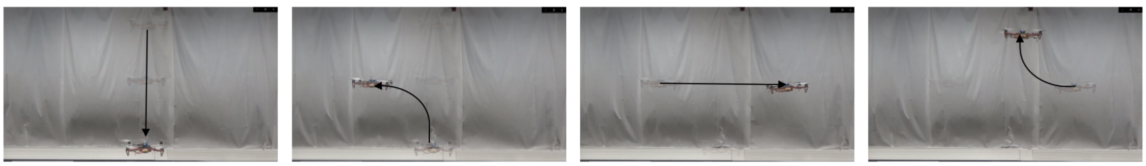

Figure 5.2: Still motion captures of the plus motion

Flight paths were held constant for speed, around 0.5 m/s, and distance covered as much as possible. Participants would see each video either once or twice depending on their condition, followed by 1 or 2 questions about each video. Although they were requested to watch the entire video each time, they did have the capability of answering the question and proceeding on to the next question, as there was not a confirmation check on every page.

When considering the number of videos that were presented to participants, it was necessary to repeat the set of videos when asking two questions from the same category (two speech or two gestures), so they would appear on separate pages.

5.4 Free Response Question Findings

The questions were analyzed based on the responses they elicited to see which question type would give the most productive answers, specifically answers that indicated an intention for verbal or physical response to UAVs. The wording that proved

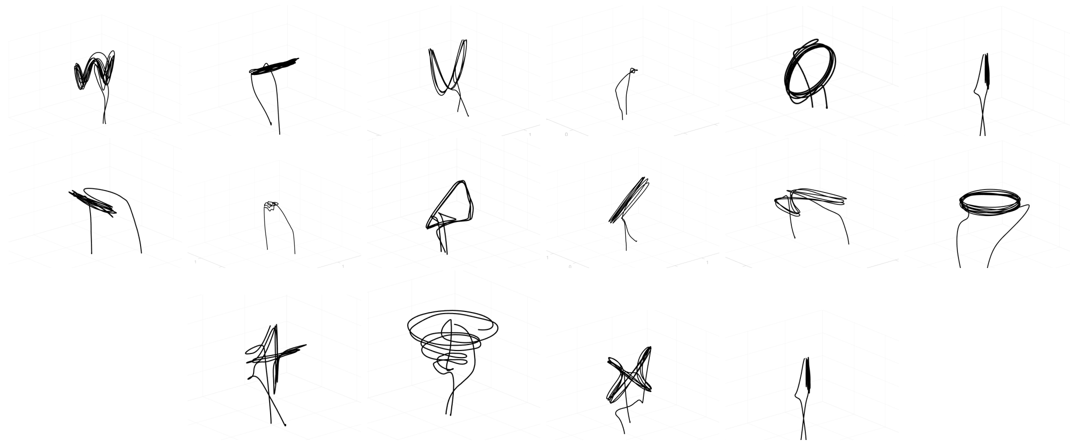

Figure 5.3: Flight paths from top left to bottom right: undulate, left-right, U-shape, hover, vertical circle, up-down/descend, front-back, yaw, descend and shift, diagonal descend, horizontal figure 8, horizontal circle, plus, spiral, X-Shape, and up-down

to be most effective towards this goal were the two different "Physical" questions. Since they elicited similar results, we decided only one of them was necessary and proceeded with "If you were in the room with the robot, how would you respond immediately following the robot's actions?" This analysis is expanded upon in [4], but the responses were collapsed here and viewed as a single set for analysis in Phase 2 based on the fact that responses were relatively consistent and seemingly more related to the flight path rather than the question.

Chapter 6

Refinement: Phase 2

The data from Phase 1 was used to determine which labels contained the most value and information, in addition to which question would be most effective. This section discusses that process and all of the steps taken for refinement.

6.1 Frequency Analysis

The responses of these 80 participants from Phase 1 were roughly categorized into a list of top responses by finding the most commonly used words through visualizing using a word cloud and then going back to the full set of data to group responses into rough categories based on the intent behind the words used. An example of this is with the hover motion the word “stand” appeared 21 times and “still” appeared 13 times, these could both be grouped into a stare/ observe category. Using this method, a list of 13 categories emerged that appeared to cover most of the concepts expressed in the responses. Some of the other most frequently reported words were: “back” for front-back (25), “around” for yaw (20), and “side” for left-right (17).

This analysis showed that many of the responses for the free response involved participants describing the motion in some way and which reinforced the impact of question choice, discussed further in Section 6.2. Another common type of response would be if a motion was associated with a human gesture already, such as "nodding" for up-down (12) and "cross" for plus (6).

6.2 Category Formation

In addition to states that were consistently reported, we included categories that were relatively low frequency in free response but are states commonly attempting to be conveyed within UAV research, such as delivery. The full category list combined multiple direct actions into one category in an attempt to better convey to the raters what types of responses belonged in each respective category based on the frequency groupings discussed above. The full list included:

- Follow / Follow a Path
- Blocked / Stop / Restricted / Do Not Pass
- Go Away / Back Away / Leave
- Move Towards / Approach
- Yes / Approval / Accept / Nodding
- No / Nagging
- Welcome / Hello
- Land / Falling / Lower
- Delivery
- Help
- Watch it / Caution / Slow Down / Investigate

- Stare / Hover / Look / Observe
- Power off

6.3 Independent Categorization

These categories were then presented to two raters who categorized the responses into these categories. The raters were instructed to choose a category if they believed it appropriately fit the free response answer. They did not have to choose a categorization from the list above, but could rather choose “Other” if they believed there was not an accurate fit available. While this method allows for an extra margin of error, it encourages a level of understanding of what intentions people may have had past the use of keyword detection. The raters overall had over .93 for kappa agreement scores in relation to these categories, which shows excellent agreement [36] amongst their categorization.

When sorting the responses into categories by video, a few results emerged that both raters agreed upon. All of these are out of 80.

- Fifteen hover as “Stare/ Hover/ Look/ Observe”
- Ten front-back, eleven horizontal circle, and eleven horizontal figure 8 all as “Go Away/ Back Away/ Leave”
- Eleven straight descend as “Land/ Falling/ Lower”
- Eight undulate responses sorted into “Blocked/ Stop/ Restricted/ Do Not Pass”
- Eight vertical circle as “Watch it/ Caution/ Slow Down/ Investigate”

6.4 Forced Choice Definition

Using the categorization from the raters, we separated out the highly chosen categories for further examination. As we looked at the categories used by raters and the questions we had piloted in Phase 1, we found that multiple questions were likely necessary to elicit answers in these categories and then split the options presented to participants in order to assess convergent ideas.

When considering the set of categories, there were five that also seemed well suited for our investigation of how participants plan to physically respond to a UAV: "Watch it/ Look at it/ Stare", "Investigate", "Follow it", "Move Away", "Help it", and Other.

The remaining highly-selected categories appeared better suited for a speech-based question. These categories helped communicate the states being conveyed to the person, rather than a reaction to them. We also believed that this could elicit a more complete picture of how a person would expect to respond by comparing the perceived communication with the intended reaction. Due to this, we chose to add Question 1, "If you saw this drone in real life, what would it say to you?", in addition to Question 6 when designing for Phase 3. The responses chosen were states that could be communicated, thus some of the categories were placed as options for response to both questions, as they were both a way to respond to the UAV and a state that was being communicated to the participant. The full list of forced choice options for Question 1 included: "To Follow It/ Move Towards", "Do Not Follow/ Do Not Pass/ Restricted/ Go Away" (DNF), "Yes/ Approval", "No", "Welcome", "Landing", "Delivery", "Help", "Caution", and Other. All categories used by raters in Phase 2 except for "Power Off" ended up being presented to the participants in Phase 3.

Chapter 7

Confirmation: Phase 3

Following the process refinement, we are able to present a new set of participants with the new labels and questions. Table 7.1 shows the main results from these participants.

7.1 Participants

Phase 3 consisted of 40 participants (19 Male, 20 Female, 1 No Answer), who ranged in age from 25 to 57 (M = 39.1, SD = 8.1). They were presented with forced choice options to Question 1 and Question 6 from Table 5.1. These two questions were selected in Phase 2, based upon the responses in Phase 1, to elicit participant perceptions of robot communication and anticipated response.

We performed a chi-squared test to find the statistically significant responses at $\alpha = 0.01$ with the participants from Phase 3. All of Table 7.1 (excluding yaw in the Say column and the 8.2 rows) reports significant results. The effect sizes for these tests is shown in Table 7.2.

Table 7.1: Q is Quantity of People providing that response, N is the total number of participants, the "Respond" column refers to responses to question 6, the "Say" column refers to responses to question 1, and RFP refers to rotated flight paths with results only discussed in Section 10

<table>
<tr><th>Motion</th><th>Respond:
Winning Response(s)</th><th>Q</th><th>Say:
Winning Response(s)</th><th>Q</th><th>N</th></tr>
<tr><td>Undulate</td><td rowspan="6">Move Away</td><td>15</td><td rowspan="10">Do Not Follow/
Do Not Pass/
Restricted/
Go Away (DNF)</td><td>14</td><td rowspan="12">40</td></tr>
<tr><td>Left-Right</td><td>17</td><td>14</td></tr>
<tr><td>Horizontal Figure 8</td><td>15</td><td>14</td></tr>
<tr><td>Horizontal Circle</td><td>18</td><td>15</td></tr>
<tr><td>X-Shape</td><td>18</td><td>15</td></tr>
<tr><td>U-Shape</td><td>17</td><td>13</td></tr>
<tr><td>Hover</td><td>Tie: Watch it/
Look at it/Stare
Tie: Move Away</td><td>14</td><td>12</td></tr>
<tr><td>Plus</td><td rowspan="3">Watch it/Look at it/Stare</td><td>15</td><td>11</td></tr>
<tr><td>Vertical Circle</td><td>14</td><td>13</td></tr>
<tr><td>Up-Down</td><td>16</td><td>Yes/ Approval</td><td>15</td></tr>
<tr><td>Front-Back</td><td>Follow it</td><td>15</td><td>To Follow it/
Move Towards</td><td>23</td></tr>
<tr><td>Spiral</td><td>Move Away</td><td>19</td><td>Tie: DNF
Tie: Landing</td><td>10</td></tr>
<tr><td>Yaw</td><td rowspan="3">Watch it/ Look at it/ Stare</td><td>13</td><td>Caution</td><td>7</td><td rowspan="4">32</td></tr>
<tr><td>Descend and Shift</td><td>15</td><td rowspan="3">Landing</td><td>21</td></tr>
<tr><td>Diagonal Descend</td><td>14</td><td>23</td></tr>
<tr><td>Straight Descend</td><td>Move Away</td><td>12</td><td>22</td></tr>
<tr><td>RFP: Figure 8</td><td>Tie: Follow it
Tie: Move Away</td><td>3</td><td>DNF</td><td>4</td><td rowspan="4">8</td></tr>
<tr><td>RFP: U-Shape</td><td>Watch it/ Look at it/ Stare</td><td>3</td><td>DNF/ Landing/ Help</td><td>2</td></tr>
<tr><td>RFP: X-Shape</td><td rowspan="2">Move Away</td><td>3</td><td>DNF/ Landing</td><td>2</td></tr>
<tr><td>RFP: Undulate</td><td>4</td><td>DNF</td><td>5</td></tr>
</table>

Table 7.2: Effect Sizes for results presented in Table 7.1

	Respond: Effect Sizes	**Say: Effect Sizes**
N= 40	0.206	0.324
N = 32	0.190	0.252
N = 8	0.372	0.373

7.2 Perceived Communication

Participants were asked to report "If you saw this drone in real life, what would it say to you?". The majority of responses were for DNF or for "Landing".

Regarding the significant states: undulate, X-shape, U-shape, left-right, horizontal figure 8, and horizontal circle were all significant for communicating DNF. Front-back was significant for communicating "To Follow It/ Move Towards" while both diagonal descend and straight descend were significant for communicating "Landing". From these results, we can assume that participants would perceive a UAV to be blocking a path given large movements across the x-axis, with or without movement in the z-axis as well. The simple motions with changes to the altitude of the vehicle were clearly understood to communicate "Landing", but more complex movements incorporating a second direction (such as descend and shift) or axis of motion (such as spiral) were not as clearly understood.

Out of 640 total responses for all of the videos this was the breakdown of how many times each was chosen:

- DNF (165),
- "Landing" (102),
- "Caution" (87),
- "To Follow It/ Move Towards" (82),
- "Welcome" (48),
- "Delivery" (40),
- "Yes/ Approval" (38),

- “Help” (38),
- “No” (28), and
- Other (12).

The full list of most chosen responses can be seen in Table 7.1.

7.3 Anticipated Physical Response

Participants were requested to report “If you were in the room with the robot, how would you respond immediately following the robot’s actions?” (Question 6 from Table 5.1). The majority of the responses were for “Move Away” or “Watch it/ Look at it/ Stare”, with the only significant deviation being front-back receiving an answer of “Follow it”.

All “Watch it” responses have a key motion on the z-axis or do not move along any axis. Motions that follow this trend include: vertical circle, descend and shift, yaw, up-down, plus, diagonal descend. Almost all of these have a second highest choice of “Move Away”, which likely explains the dissent within the straight descend and spiral paths. In these cases results were more evenly split between “Watch it” and “Move Away”, of which the latter ultimately won out. From these results, we can assume that people would either watch or move away from vehicles that are relatively static or undergoing large altitude changes.

Out of 640 total responses for all of the videos:

- “Move Away” was chosen 231 times,
- “Watch it” was chosen 192 times,
- “Investigate” was chosen 120 times,

- “Follow it” was chosen 67 times,
- “Help It” was chosen 29 times, and
- Other was only chosen once for hover.

As will be expanded upon in Section 10.2, “Follow it” only appeared within the movements that were confined to the x-axis or x-y plane and approached relatively closely to the participant. This was observed first with front-back and then with the horizontal figure 8 when it was rotated to have its larger motion along the x-axis rather than the y-axis.

7.4 Free Response within Forced Choice

With all Forced Choice responses, participants did have the option to fill in their own response if they felt none of the ones provided accurately portrayed their answer. The large majority of people chose from the options we provided them, with few exceptions. None of the motions received more than 4 write-in answers. 12 in total were written in for the perceived communication question from 8 different people, and only 1 answer was written in for the anticipated physical response question. The full list of written answers for the perceived communication question includes:

- “Searching” for descend and shift
- “Scanning”, “Confusion”, and “Why are you here?” for yaw
- “We are watching you” for spiral
- “Playing or having fun” and “stay away” for plus
- “idling/waiting”, “nothing really”, “We are watching”, and “What do you want?” for hover

- “Surveying the area” for horizontal circle

For the anticipated physical response, the only write in is “leave it alone” for hover.

Chapter 8

Summation: Phase 4

As a summative exploration, we presented 8 participants (6 Male, 2 Female) with the 8 states used in Phase 3, in an attempt to see if their created motions would agree with the findings of Phase 3. Participants were asked to create flight paths to communicate those states, similar to the methods of [2], but over Zoom instead of in-person. If available, they then came in-person to see their flight paths on a real UAV. This section also discusses the work of Phase 4 as compared to other related works.

8.1 Methods

After being greeted and consented, participants were asked "for each of the tasks, please design an appropriate gesture, a flight path, for a drone to fly to communicate the state". After designing an appropriate gesture, they were asked further details about their motions, such as specific height, speed, and characteristics they would apply to their motions. They filled out a form on Google Forms to answer all of these questions and then verbally described and physically demonstrated using a small object surrounding them (around the size of a cell phone).

For height, participants were given the options of "Above Head", "Eye Level", “Chest Level”, “Waist Level”, “Knee Level”, “Ground”, and “Other” to associate with each motion. Waist, knee, and ground produced the fewest responses and were thus grouped together for results.

For speed, participants were given the options “Fast”, “Average”, “Slow”, and “Other” as options for association. No further details about what concrete speed this actually was were provided. All eight answered this question, but one person chose “Other” for Do Not Follow, and one person did not answer the question for Follow it.

Since participants created the gestures online they had no concept of where these motions would be used (i.e. indoor/outdoor) and thus how much space their UAV would have to fly. Some people created motions that were either fully or slightly dependent upon the space that the UAV was flying in. One person created motions that should go to the extremity of a person’s view (fly as far as the operator could see it), or to the extremity of an available space (edges of a room). A more frequent variation on this was to slightly scale up motions for a larger space/interaction area or size of UAV. The size of the UAV was also left open-ended, this caused some people to think of the UAV as the size of the object they were holding.

Two additional participants were ran, in addition to the eight, and they were excluded from the results and analysis presented here in case they were unknowingly biased by the experimenter. During their task descriptions they were shown brief demonstrations of possible flight characteristics, for one person a circle and for the other line movements along axes. Both of these participants then showed these demonstrated characteristics consistently within their created flight paths. For the participant shown the circle 6/8 of their motions were categorized as curvilinear, and for the participant shown axis movement all of their motions were categorized as rectilinear. The remaining participants were not shown any example flight demonstrations.

8.2 Results

We had participants design their preferred characteristics for an entire interaction space, broken down into speed, height, and motion. The designed interactions section below provides high level details for each of the states, in addition to their speed and height characteristics.

Table 8.1: Height Breakdown

	Above Head	Eye	Chest	Waist & Below	Other
Do Not Follow / Go Away	1	3	2	1	1
Watch It / Look at it	1	5	1	0	1
Investigate	2	1	4	1	0
Caution	2	1	4	1	0
Follow It / Move Towards	2	1	5	0	0
Yes / Approval	3	3	2	0	0
Landing	1	2	1	3	1
Delivery	2	1	0	4	1

Table 8.2: Speed Breakdown

	Fast	Average	Slow
Do Not Follow / Go Away	4	1	2
Watch it / Look at it	0	4	4
Investigate	1	3	4
Caution	1	3	4
Follow It / Move Towards	1	4	2
Yes / Approval	2	5	1
Landing	1	2	5
Delivery	0	4	4

8.2.1 Designed Interactions

Starting with "Do Not Follow / Go Away", five participants created different variations of a motion retreating from them, in addition to that two others chose small back-forth juts. This later motion is well reflected in the dominant speed trait, with fast being the most popular choice. For this motion it was also most common to place it around eye level.

For “Watch it / Look at it”, two participants chose a yaw motion, for this motion we also see the first dynamic designs. With participants creating motions that either circled, created a diagonal line, or yaw-ed towards the object of interest. There were also designs involving all three of those motion components that did not have a mentioned attachment to a specific area or object to observe. Five participants designed motions that they placed at eye level, and split their speed preference evenly between average and slow.

For “Investigate” the most dominant trait contained having movement along the x-y plane. Four of these motions involving a circle, three of which were horizontal. Most of them contained a line either moving left-right or front-back, but not both. Both Investigate and Caution were placed at a majority of chest level(with some eye level and above), and have a split for speed between average and slow. Looking deeper into the per-person break-down shows that even though these two ended up with the same values, many of the people chose different answers for each one (i.e. the same people didn’t pick the same answers for both). The motions for “Caution” also don’t have any curvilinear characteristics, and while three people designed a left-right motion, three more people also designed a vertical motion (up-down, vertical triangle) creating a further difference between the two states.

The “Follow it / Move Towards” motions, similar to the “Do Not Follow / Go Away”, had six people create motions that moved away from the person. In these cases though the motions were more dynamic. A great example of this from one person is that they wanted the motion to make a line towards their destination with periodic yaws back towards the person. The remaining two suggested up-down changes. Overall the speed and height also show distinction between the two states. People here wanted the motion to be at chest level rather than eye, and chose an average speed rather than fast.

For “Yes”, all eight designed motions in the vertical plane, four of which were simply an up-down motion. Participants commonly noted that as reason for this was because it matches current human non-verbal communication in nodding or because it matches yes in sign language. These motions were placed at above head/eye levels with an average speed.

Landing also showed high agreement among participants, with six including a down motion, three of which were straight down. All of the motions involved the vertical plane, and two of them incorporated a yaw component. Every height category received placement, with slight majority going to waist and below, but there is much greater agreement that the motion should be slow in speed.

Finally, Delivery involved four participants involving an approach and three including a curved motion in various ways (curved approach, vertical circle, and "D" shape). Again placing the height at waist and below, and speeds of average or slow.

A couple people mentioned when choosing motions placed below eye level that they wanted to be able to clearly see the UAV. One person described having it fly at this lower height gave them what felt like more control over the situation.

8.3 In-person

Five of the eight participants were able to come in-person to view their created gestures performed by a Flamewheel, the same vehicle that was used in the video recordings and in the same space. After viewing they were asked if they would change anything. Most didn't want any major changes to their originally designed motion, but all five mentioned changes they would make to at least one of their motions after viewing.

Typically these changes were in relation to the overall size of the motion, such making it larger or smaller. The amount that these motions were made larger was not consistent or a direct multiple of their small demonstration object to the size of the UAV.

One participant designed motions that were originally proposed to be six inches in size, after viewing they determined it was not as clear as they desired. Another participant's motion was originally proposed to be a foot size and instead wanted to change it to six feet. One of the reasons participants requested size changes so much was likely because they didn't consider that a UAV, even in a highly controlled space with a Vicon system, has small drifts while hovering. Because of this the smaller motions were not usually large enough to form a clear distinction that it was doing a specific motion. Besides size changes, the biggest change request a participant made was to have the UAV move away instead of towards.

At the end of their interaction, each person was asked if they could add any modality what it would be. The responses were: Speaker/Sound x2, LED Panel x2 (green= good, red = bad/stop) (green = follow me, yellow/orange = caution), and an on-board distance sensor to have the ability to act with a perception of the space around them.

8.4 Comparison to previous work

8.4.1 Comparison to Phase 0 [1]

Only two of the states map to those presented in [1], "Landing" and "Draw Attention" which map to "Landing" and "Watch it / Look at it". The methods for Phase 4 are significantly different than in [1], so we don't expect anything to fully confirm findings of that paper. Breaking down commonalities between their responses we can see in it that all motions with a draw attention label (Circle, Loop, Swoop) are curvilinear, which we also see that trait presented in two of the eight here "Watch it / Look at it" state. For "Landing", while one person did create a spiral in this set for landing, we don't have support that it is the best way to communicate landing. A similarity between that and the motions here though is a significant movement along the z-axis. From the similar characteristics found between the two works, we see very light support for Phase 0 [1] results from Phase 4.

8.4.2 Comparison to Phase 0 [2]

The motions were all categorized according to the taxonomy presented in [2].

Table 8.3: Taxonomy and labeling from Firestone (2019)

State	Complexity	Space	Cyclicity	Command	Altitude	Motion
Do Not Follow / Go Away	Simple (5)	Direct (5)	Random (6)	**Pitch (7)**	Stable (5)	**Rectilinear (7)**
Watch it / Look at it	Simple (5)	Direct (4) Indirect (4)	Random (4) Cyclic (4)	**Throttle (6)** **Roll (4)**	Variable (3)	Rectilinear (4)
Investigate	Compound (5)	Indirect (5)	Random (5)	**Roll (6)** **Pitch (5)**	Stable (4)	**Combinational (4)**
Caution	**Compound (6)**	**Indirect (6)**	Random (5)	Roll (4)	Stable (5)	**Rectilinear (6)**
Follow it / Move Towards	Simple (5)	**Direct (6)**	**Random (7)**	**Pitch (6)**	Stable (5)	**Rectilinear (7)**
Yes / Approval	**Compound (6)**	**Indirect (6)**	**Cyclic (5)**	**Throttle (7)**	**Variable (6)**	**Rectilinear (6)**
Landing	Simple (4) Compound (4)	Direct (4) Indirect (4)	**Random (7)**	**Throttle (7)**	**Decreasing (6)**	Rectilinear (5)
Delivery	Simple (4) Compound (4)	Direct(5)	**Random (8)**	Roll (4) Pitch (4) Throttle (4)	Stable (4)	Rectilinear (3)

Three states here are considered similar to those from Firestone. The first being “Landing”, which is referred to by the same name here. In both of these states Throttle and Decreasing are considered significant. And not as strong support for Direct.

The second is area of interest, which we map to Investigate here. For both of these we see Roll and Pitch as significant commands. Four of the motions here are also curvilinear, supporting the motion finding.

Finally, the third is attract attention, which we map to “Watch it / Look at it”. For this one, roll and throttle is the only characteristic that was considered significant for attract attention, and we see both of those represented here, with six out of eight motions containing throttle and four containing roll.

It should be noted these latter two states do not perfectly map to states in this phase, but rather convey similar intents.

8.4.3 Comparison to Phase 3

Once again, when comparing these two works, the expectation for Phase 4 to show support for Phase 3 findings would be seen if the participants here created motions that demonstrated a weaker version of what was presented in Phase 3 since they were presented with options there and are creating them here. The same state options as Phase 3 are presented here, with only “Do Not Follow // Do Not Pass // Restricted / Go Away” condensed down to “Do Not Follow / Go Away” differing.

What we see is as follows: This phase shows strong support for the idea that movement along the z-axis is distinguished as a characteristic of landing, with all participants having movement along the z-axis (six descend, two up-down). It also supports that “Follow it / Move Towards” should have large motions along the y-axis (six based on y-axis), although the motions are split five/three in terms of having an associated movement on the z-axis.

The recommendation to stay and watch a UAV was to minimize the amount of motion or have large altitude changes. Three of the states are presented as minimized motion, two yaw only and one circle defined as being only big enough to see movement. In addition to this, six participants include a throttle component, three of which were defined as moving a large amount (in these cases at least six feet). So we see some support for both sides of this claim.

For “Yes” we again saw people associate up-down here, four provided basic up-down movements. In both works they noted it was because they associated the movement with nodding or yes in sign language.

In terms of the "Do Not Follow" state, we saw five of the participants design a motion that involved retreating (moving away) in some capacity, which is strange because many of the participants also designed a retreating motion to signify "Follow it / Move Towards". Phase 3 found it likely that movement along the x-axis would mean to not follow, so this phase does not support that finding. Another finding from phase 3 states that complex motions should also signify moving away from an area by making complex motions. These results see some support shown by the "Caution" state, which has six motions defined as compound when compared to Firestone.

We see some support from the motions designed by participants in this phase for each of the claims except for "Do Not Follow / Move Away". Due to the small amount of participants in this phase, the results are meant to re-enforce results, but neutral results are not conclusive enough to negate previous findings.

Phase 4 is the final iteration of this document with the labels working to describe what participants would do or say in response to a specific motion. The following chapters explore emotional characteristics, personality, and other additional exploratory studies that can be further explored in the future.

Chapter 9

Emotion and Personality Characteristics

During the free response analysis in Phase 2, we quickly noticed people were putting feelings within the responses regardless of whether we asked for it. Considering the findings from [28], we hoped to elicit similar personality traits, but were curious how participants would respond to flight paths when not explicitly varying the factors from that work. Asking this question also allowed us to investigate if we would elicit similar or different personalities with different flight paths.

We presented 2 raters with the data from Phase 1 and asked them to attempt to categorize the responses into the emotional states from [28]: Dopey/ Sleepy/ Sad, Grumpy/ Shy, Happy/ Brave, and Scared/ Stealthy/ Sneaky. They had high agreement (Kappa =.63 and above) but had difficulty with the task. Feedback from raters indicated that they felt they were making a lot of assumptions by categorizing into these states, since it was typically inferred from an unrelated response. We decided to explicitly ask the questions to the participants moving forward in order to collect more accurate responses and with the goal to gain complementary information regarding the states being selected. In regards to the raters, the overwhelmingly popular (by more than three times) category for both of them when sorting Phase 1 responses was Happy/ Brave.

9.1 Forced Choice Definition

Modeled after [29] and [28] who presented the stereotypes of personality, each of the participants were given five scales they had to rank each of the videos using a 5 point Likert scale beginning in Phase 3. One extremity paired to the left side and the other to the right. The questions represented five traits conveyed by two opposite poles: Openness to Experience, Conscientiousness, Agreeableness, Extraversion, and Neuroticism. Figure 9.1 is a visual example of how this was presented to participants, and Table 9.1 is the full list of presented characteristics.

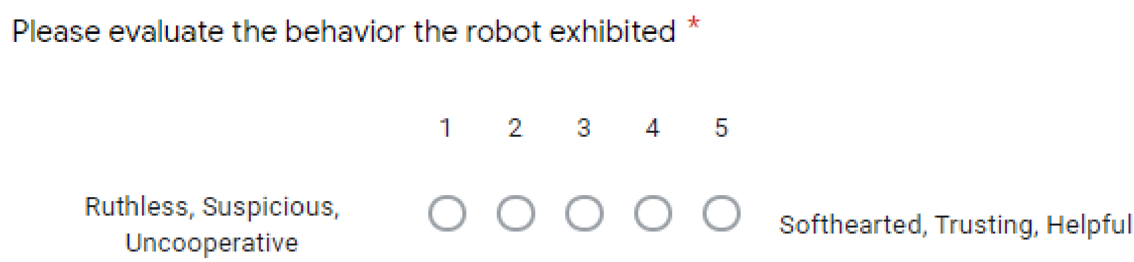

Figure 9.1: Example of emotion question as displayed to the participants in Phase 3 and 4.

Table 9.1: Big Five opposing characteristics presented as anchors to the Likert scale

1	5
Practical, Conforming, Interested in Routine	Imaginative, Independent, Interested in Variety
Disorganized, Careless, Impulsive	Organized, Careful, Disciplined
Ruthless, Suspicious, Uncooperative	Softhearted, Trusting, Helpful
Retiring, Sober, Reserved	Sociable, Fun-Loving, Affectionate
Anxious, Insecure, Self-Pitying	Calm, Secure, Self-Satisfied

9.2 Phase 3: Personality Characteristics

As a whole participants classified the videos with Practical / Conforming, Organized/ Disciplined, and Calm / Secure characteristics. According to [28] this meant that almost all of them would classify as brave, which would be the *Adventurer Hero* Drone, regardless of the motion depicted.

X-shape and undulate stand out as being more Imaginative, Disorganized, Ruthless, and Anxious in nature than the other motions. These four characteristics don't perfectly match any of the models, but come closest to Sad, Dopey / Sleepy, and Scared, which closely resemble the *Exhausted* Drone. This is interesting because they involve significant altitude changes, and thus would be unlikely to be designed this way to convey such a state. The difference in perceived personality is also interesting given that both of these flight paths still elicited the most common forced choice responses of "Move Away" and DNF.

Plus and Left-Right show opposite emotions when the participants had free response versus when they were presented with forced choice options. The responses for these two showed significantly more imaginative traits assigned in free response, as categorized by the raters, and more practical in forced choice, as chosen by the participants. We believe this may be partially due to them projecting their emotions onto what they see the UAV doing.

9.3 Phase 4: Personality Characteristics

During the online creation of participants' motions, they were also asked to assign a UAV model to each state. Those responses are shown in Table 9.2.

Overall there is strong representation across the board for *Adventurer Hero*, which is the model most applicable to the results of Phase 3. A few of the states that have a clearer chosen model include *Anti-Social* for "Do Not Follow / Go Away", *Sneaky Spy* for "Investigate", *Adventurer Hero* for "Follow it / Move Towards" and "Delivery", and *Exhausted* for "Landing".

Table 9.2: Applied Characteristics

	Sneaky Spy	Adventurer Hero	Anti-Social	Exhausted	Other
Do Not Follow / Go Away	0	1	6	0	1
Watch it / Look at it	2	3	0	0	1
Investigate	4	2	1	1	0
Caution	0	2	2	2	2
Follow It / Move Towards	2	4	1	1	0
Yes / Approval	1	3	0	1	3
Landing	1	1	1	5	0
Delivery	1	4	0	1	1

Cauchard places *Anti-Social* at about chest height and at a middle speed. Looking at our findings, "Follow it / Move Towards" motion had a high result of people placing it at chest height with an average speed, but it is classified as *Adventurer Hero* by these participants. None of the states have both a categorization of above head height and fast speed in this work, the closest resembling this is for Yes / Approval, which participants also classify as *Adventurer Hero*, which matches the classification of Cauchard for the same characteristics. The final set of parameters in Cauchard are for *Exhausted* personality profile. For this, the speed is slow and the altitude is best understood to be waist or below in this case. This best matches Delivery, which is also classified as *Adventurer Hero* by these participants.

9.4 Phase 4: Emotional Characteristics

The participants that came in-person to complete their study were presented with the same labels presented in Table 9.1, but on a scale of 1-6 instead. All eight states had a classification of Practical, Organized, Softhearted, and Calm when sorted as {1,2,3} and {4,5,6}. Practical / conforming, organized / disciplined, and calm / secure were the same characteristics applied to the majority of videos in Phase 3. In addition to these four classifications, the only state that had a significant result on the Retiring/Sociable scale was for “Retiring, Sober, Reserved” for “Landing”, which had all five people classify it as a 3 (which is slightly agree on this scale). As before, this collection of characteristics doesn’t map perfectly to any of the models, but of the options 3 of the 4 map to brave, happy, and shy. Happy and Brave are condensed into the *Adventurer Hero* Drone, and shy falls under *Anti-Social*, regardless of the requested state.

Chapter 10

Next Steps

Throughout these studies there were different opportunities to gain additional knowledge about both state labels and the effect of the different axes of motion within the flight paths. Some of these findings are the result of small proto-studies that were run in-between the larger studies to better inform them. These additional investigations were not necessary for the narrative above, but do provide complimentary information for completeness.

10.1 State Elicitation

Between Phases 2 and 3, an additional sixteen people (not included in any of the above studies) were asked for 3-5 states they believe a UAV should convey. Eight of these participants were also asked what information they believed a UAV should be able to communicate to those not involved in the UAV's operations. The question placement was switched between the beginning and the end to see if they were more creative prior to the rest of the study, or if they would provide the same states we provided if their question was at the end. The placement didn't seem to have an effect overall. Regardless of placement, each of the participants submitted at least one of the states or labels that were included in the forced choice responses. The remaining portions of this study were not analyze further due to poor data quality.

10.2 Axis Investigation

After brief examination of the initial results of Phase 3 (the first 32/40 participants), we noticed a need to better understand the impact of the primary axis of motion. The inital observation that lead to this was that motions moving mostly along the x-axis would elicit a blocked response while motion mainly on the y-axis would encourage motion of the participant in that direction (to follow it). This seemed to hold true for the only action that was solely on the y-axis, front-back. Additionally, all of the actions that were significant for the DNF choice were either based or had significant movement on the x-axis (U-shape, X-shape, undulate, left-right, and horizontal figure 8). These paths all moved relatively the same distance along the x-axis and all except horizontal figure 8 came to relatively the same distance from the participant on the y-axis.

To test this observation regarding the primary axis of movement impacting the expected response, we switched out 4 of the motions that received the least amount of DNF categorizations (front-back, straight descend, yaw, and diagonal descend) with 4 that received some of the highest (undulate, U-shape, X-shape, and horizontal figure 8), but with their primary axis of motion switched to the y-axis for an exploratory condition for the final 8 participants of Phase 3. Participants viewed these four motions with the primary axis in both the x-axis and y-axis to assess any differences in response. This would mean that one video would be the X-shape on the x-z plane, while another video would be the same X-shape but on the y-z plane. For a visualization of the axes of motion relative to the participant, see Figure 10.1.

Figure Description Figure 4 shows a stick person facing the x-z plane. The x-axis

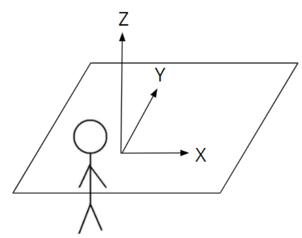

Figure 10.1: Direction of axes relative to person

moves left-right, the y-axis moves front-back, and the z-axis moves up-down in relation to the stick figure.

Ultimately there was not support for this claim within this small dataset. The motions when rotated were still DNF, but on the flip side we do see the "Move Away" category receive less representation here than in the earlier results. A different takeaway from these results is that it appears simplicity of the flight still holds a priority in effect, as with added complexity to the simple front-back motion showed the changes we see here to a DNF action.

A noteworthy exception to the findings here is that horizontal figure 8, although initially classified DNF, when rotated received a tie for DNF and "Follow it" classifications. This could be due to the fact that this motion is unique from the others in that it moves a similar total x and y distance, with the distance on the y-axis from the participant being similar to that of the front-back motion. Another distinction this motion has from the other turned motions, is a lack of motion on the z-axis. Overall this proto is small and further exploration into these concepts would prove beneficial.

10.3 Phase 3 NARS Explorations

The states from Phase 3 can be sorted into Positive, Neutral, and Negative categories based on their general applied sentiment.

- Positive: “To Follow It/ Move Towards”, “Yes”, “Welcome”, “Help”, “Follow it”, “Help it”
- Neutral: “Landing”, “Delivery”, “Watch it”, “Investigate”
- Negative: DNF, “No”, “Caution”, “Move Away”

When using these groupings and seeing their overall use when they possess different NARS scores we can see that people with a NARS score classified as negative were more likely to pick negative states (M:13), and overall they were not as likely to choose one of the positive responses (M:9) when compared to people whose NARS score was classified as positive (M:10 and M:11, respectively). Both positive and negative NARs score participants classified motions as one of the neutral options about 12 times on average.

There is also a correlation between the NARS scores and the traits chosen. The 14 participants who had a negative NARS score were more likely to define the UAV as conveying practical, disorganized, ruthless, retiring, and anxious characteristics as seen in Figure 10.2. Whereas the 5 participants who had a positive NARS score presented the opposite (imaginative, organized, softhearted, sociable, and calm). The average of all 56 participants fell within the middle on all of the traits. The upper bound for number of uses shown in Figure 10.2 is 16 per participant.

10.4 Future Work

It would be interesting to explore created gestures when participants are given a specific scenario or use case to see how they change for each situation. It could also prove beneficial to explore having animators, or artistic individuals create the motions, as they are already trained in thinking about how to have people interpret motion that communicates messages. An extension of specifically Phase 3 would be to run the

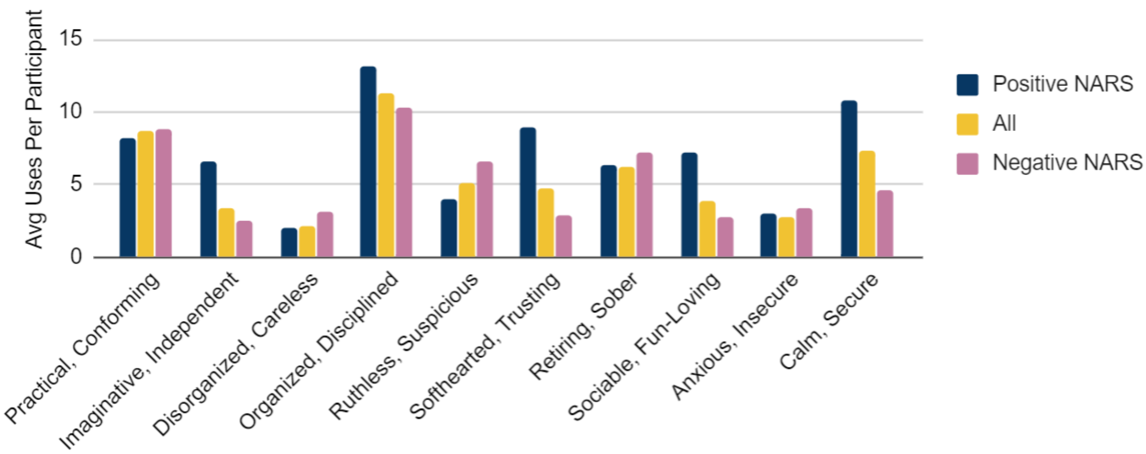

Figure 10.2: Average number of times a personality category was chosen by a participant based on their NARS score

motions from Phase 3 in-person to see the full effects of being near the UAV as opposed to just viewing it online. In addition to seeing how the message interpretation changes based on how loud the UAV is, how far away from the UAV they are (and if there's anything in-between them, such as safety netting), and how large the room is. Other factors to explore in the future that would compliment this work include adding light components, as mentioned by participants throughout, or changing the vehicle design.

Briefly addressed above and in Phase 4 would be further separation of categories combined here for simplicity, specifically the"Do Not Follow/ Do Not Pass/ Restricted/ Go Away" category. This category did give a general intent, which was it's purpose. Because this was such a popular category choice participants' intent may be better understood with separation of it into individual components, especially since it was in general the most popular response in Phase 3 and likely caused a mix of focus in Phase 4. Finally, a common note from in-person participants in Phase 4 was that they had imagined the motion would be more noticeable. This gap could exist for a few reasons, the most likely being that people did not consider that a UAV doesn't remain perfectly stable when hovering. Providing a more rounded explanation of typical UAV movement during describing the task could clarify, but there are concerns with causing undesired bias when providing further details or demonstrations.

Chapter 11

Discussion and Implications

This work sought to understand how the general public would perceive and respond to communicative flight paths from UAVs. The limitations, implications, recommendations, and our reflections on this work will be presented in this section.

11.1 Limitations

An overall restriction of our system was that the flight controller used did not have high precision control of the altitude of the UAV over time, because of this the paths were slightly varied most strongly impacted by the battery levels. This is more of a concern for this videos since these motions were intended to be held at exactly the same center position. This was also less of a concern in-person as the in-person flights were typically much shorter than the 30 seconds, and if a significant change was noticed in the flight controller's ability to hold the altitude the battery was just switched between demonstrations.

11.1.1 Video

A limitation of the work is that Phases 0 [1], Phase 1, and 3 were presented to the participants remotely through video recordings. While an effective preliminary method, the main concern is that it likely impacted their ability to provide their true reaction, as there is almost always a difference between an expected reaction and a natural true reaction. Another layer that impacts people's ability to accurately gauge what their true reaction would be, is the lack of previous UAV interaction most of these participants have likely had. This would naturally widen the gap between their expected reaction and actual reaction, or interpretation. This concern is further reinforced by the fact that every person who came in-person during Phase 4 had at least one motion they wanted to modify.

Video use also eliminates the ability to explore varied UAV size and sound effect. While participants were asked to always have their sound enabled for the videos, there was no sound verification. This likely means that some participants had their sound off, or at a barely audible level. This is a problem that needs to be further explored in-person because of the high level of impact these factors can have on presence, fear, and interest in the machine.

The height, size, and speed of the recorded motions presented were held relatively constant in these studies, as opposed to being varied to elicit emotional responses as in [28]. This is a limitation because varying these factors may allow exploration of additional communicative functions (rushing, thoughtful, contemplative, etc). This was not an oversight, but a priority for the study to reduce those factors and see what emotions or states were elicited from users. This is briefly explored in Phase 4.

In general, when presented with a forced choice option, most people either believed these states appropriately conveyed the message they were looking for, or they didn't care enough to write-in a response. Unfortunately we can't know for sure, but since the results of Phase 4 confirms those of Phase 3, the categories were likely appropriate choices.

11.1.2 Phase 4

A similar limitation of the final phase was that the participants had to create the motions remotely over Zoom. As mentioned in further detail within Section 8, this caused participants to not have any reference as to how and where this motion would be used. Any confusion from that is amplified because they are purposefully not provided with any details about intended use or demonstrations so that they ideally create gestures that are able to be broadly applied.

11.2 Implications

This research explored how people would perceive varied UAV flight paths, including: perceived communication, physical response, and emotional response. This work presents important practical implications for UAV developers and future researchers to provide safe and knowledgeable interactions. It indicates that people associate motions applied in other situations well onto UAVs, especially in the cases of Landing being conveyed with an altitude change, and a controlled up-down communicating Yes. If a UAV begins to move forward at a lower height and slower speed, it is highly likely to be understood to follow it, especially if the motion is dynamic (periodic yaw to "look back" at the person, or clearly going in a specific direction). Because we also saw Do Not Follow have a retreating motion, it's highly important to note the need for speed and height situational control for proper context.

We were able to elicit different personalities, as described by [28], without varying the flight characteristics, which extends that work. One of the more significant deviations from [28] is that the undulate motion is used as a prototype *Adventurer Hero*, but the participants here classify that motion as one of few to be *Exhausted*. Overall, participants classified the motions as Brave, and in turn the UAV as an *Adventurer Hero* type, which held across both phases despite the UAV base characteristics being more closely aligned with those of the *Anti-Social* Drone and *Exhausted* Drone.

Overall, the work presented here builds and presents aspects in each new phase that support previous findings with at least a low level of confirmation. It does this through involving the participants in creating the labels and leverages the earlier findings as a starting point for exploration.

11.3 Recommendations

From our results we noticed that complex motions frequently indicated an intention to move away from the UAV and/ or area. Whereas, simplifying or minimizing the motion would encourage them to stay and watch what the UAV is doing.

People associate motions applied in other situations well onto UAVs, especially in the cases of "Landing" being conveyed with an altitude change, and a controlled up-down communicating "Yes / Approval". If a UAV begins to move forward at a lower height and slower speed, it is highly likely to be understood to follow it, especially if the motion is dynamic (periodic yaw to "look back" at the person, or clearly going in a specific direction). Because we also saw "Do Not Follow / Go Away" have a retreating motion, it's highly important to note the need for speed and height situational control for proper context.

11.4 Reflection

It is interesting that in the final Phase the “Do Not Follow / Go Away” motions contained such a large amount of movement along the y-axis. At least one participant mentioned that if they weren’t supposed to follow it they wanted it out of the area / out of sight. Whereas the participants from Phase 3 responses make more sense in terms of applying it to Go Away, as it is more similar to a guarding or protecting motion seen in a variety of communication scenarios (such as basketball guarding, a patrol team or dog). The dissonance that could be happening between the two could be from focus on different portions of the state they were provided with, as the state attempting to be conveyed had “Do Not Pass” and “Restricted” removed from it between Phase 3 and 4. While the authors assumed this condensing would have little to no effect on the responses, if this were a correct assumption, it could be assumed that a movement in-front of a person would give off a message that an area is blocked/ to not approach, and to communicate not to follow is more associated with a speed and height than a particular motion (i.e. too fast and high). Another consideration for this difference could just be because there is always a natural disconnect whenever people are provided with options and when they have to create their own options.

Throughout this work the most popular and recognizable characteristics of motion seem to frequently be tied back into an already recognized motion in a variety of domains. We see this represented most prominently with yes being associated with up-down and landing being associated with a straight descend, in addition to the note about guarding above. Everyday people, regardless of their design ability, have seemingly pulled these characteristics they notice from either human, object, or animal movement, and applied it as being effective in human-UAV communication.

While the current work has limitations, it extends the state-of-the-art in understanding how aerial vehicles may communicate to people and teased these communications into multiple, convergent types of responses. There is certainly still space for future exploration, but this work has taken a meaningful step towards bringing together previous work and understanding what people perceive about these systems.

Chapter 12

Conclusion

Through this work we have been able to understand how participants would respond, both physically and emotionally, as well as better understand their perception of the messages naturally being conveyed within vehicle flight paths. To do this we first explored how consistently people label motions (Phase 0) [1]. Those labels were then presented to participants to create their own motions to see if they aligned (Phase 0) [2]. Next, these motions were presented back to participants to determine whether user generated paths displayed higher label agreement (Phase 1-3)[3]. Finally states which were more effective at generating responses were posed as prompts for user generated motions to understand whether the previously observed path characteristics would be present in their designs.

This works presents as it's main contributions:

- A foundational set of UAV flight paths broadly agreed to communicate to bystanders and inform future research in this area [3], first shown in Chapter 5.
- Lessons learned on eliciting participant agreement in crowdsourcing [4], discussed in Chapter 6.

- Design methodology to assess communicative ability of new technology [4], discussed in Chapter 6.
- Recommended motion primitives to design communicative UAV flight paths [3], presented in Chapters 7 and 8.

This work suggests that NARS can be an indicator of how a person may expect to respond and perceive the general sentiment of the message being conveyed. This work also indicates that people associate motions applied in other situations well onto UAVs. Especially in the cases of "Landing" being conveyed with an altitude change, and a controlled up-down communicating "Yes / Approval". If a UAV begins to move forward at a lower height and slower speed, it is highly likely to be understood to follow it, especially if the motion is dynamic (periodic yaw to "look back" at the person, or clearly going in a specific direction). Because we also saw "Do Not Follow / Go Away" have a retreating motion, it's highly important to note the need for speed and height situational control for proper context. Finally, flights crossing (moving along the x-axis) an area are likely to cause participants to avoid that area.

ACKNOWLEDGMENTS

Special thanks to Brittany Duncan, Siya Kunde, Paul Fletcher, Urja Acharya, Ajay Shankar, Evan Beachly, Carrick Detweiler, Sebastian Elbaum, Justin Bradley, Bonita Sharif, Justin Firestone, Rubi Quiñones, Elizabeth Weber, Nina McPhaul, Jake Chanenson, and all of the NIMBUS Lab from the University of Nebraska-Lincoln for their assistance throughout the completion of this body of work.

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Appendix A

Materials used during user studies

This appendix contains the materials used during the user studies which include recruitment, consent forms, and three main questionnaires (Pre-questionnaire, Questionnaire, Post-questionnaire) in their printed form. These same questions were used in Google Forms when those portions were completed virtually. It also contains one page of the google form questions used in Phase 3, and the brainstorm sheet used by participants in Phase 4 on Google Forms. They are presented in the following order:

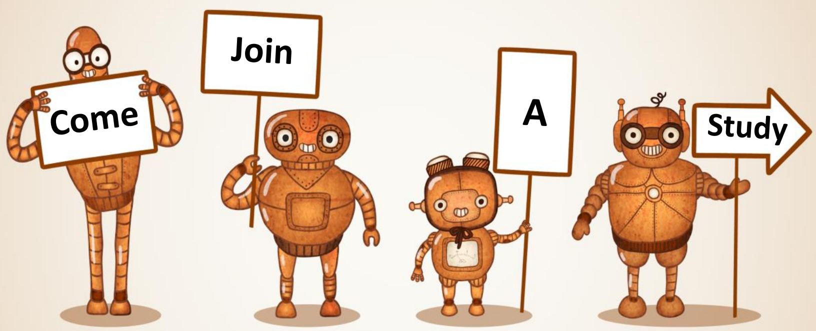
1. Recruitment Flyer
2. Online Only Consent Form
3. 2 Session Consent Form
4. Pre-questionnaire
5. Questionnaire
6. Phase 3 form for one video
7. Phase 4 brainstorm sheet
8. Post-questionnaire

9. Interview

ROBOTS

Human-Robot Interaction Study

You're invited to be a participant in an exciting study which evaluates unmanned aerial vehicle (UAV) technology!



Participants will have the opportunity to evaluate a UAV through video recording, assessment responses, and brief interviews of the participant. This study is open to anyone 19 years of age or older.

The study will consist of two sessions, one virtually over zoom and one in-person at a NIMBUS Lab facility on the UNL campus. Each session should take about 45 minutes, and up to 1 hour and 30 minutes total. Social distancing guidelines and safety protocol must be followed at all times during the study.

Participants will be compensated with a $15 Amazon gift card!

Sign up today, by sending an email to:
mUAV.study@gmail.com
and inquire about the Flight Paths Study!

NIMBUS LAB

Computer Science and Engineering Department

Project Title: CAREER: CHS: Drones in Public: foundational interaction research

You are being invited to take part in a research study being conducted by University of Nebraska, Lincoln. You are being asked to read this form so that you know about this research study. The information in this form is provided to help you decide whether or not to take part in the research. If you decide to take part in the study, you will be asked to sign this consent form. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefit you normally would have.

WHY IS THIS STUDY BEING DONE?
The purpose of this study is to assess the impact of the design of robot gestures and movements for communication with the general population.

WHY AM I BEING ASKED TO BE IN THIS STUDY?
You are being asked to be in this study because you are a willing adult (above the age of 19) volunteer and a member of the Lincoln community.

HOW MANY PEOPLE WILL BE ASKED TO BE IN THIS STUDY?
A maximum of 96 people (participants) will be enrolled in this study locally.

WHAT ARE THE ALTERNATIVES TO BEING IN THIS STUDY?
The alternative is not to participate.

WHAT WILL I BE ASKED TO DO IN THIS STUDY?
Your participation in this study will last up to one and one half hours and includes one interaction at one of the NIMBUS Lab facilities or via Zoom. The procedures you will be asked to perform are described below.

In-Person
This visit will last about one and one half hours. A pre-questionnaire will be administered before the experiment. You will be presented with an aerial vehicle and asked to author gestures to communicate concepts (e.g., surprise, landing) by demonstrating what path they think a robot would take to communicate that information to someone who was observing its flight. At that point, you will be asked to complete another questionnaire, and then your gestures will be demonstrated by the aerial vehicle for you to make any adjustments you deem necessary. A post-questionnaire and an interview will be administered after the experiment.

Online
This interaction will last about one and one half hours. A pre-questionnaire will be administered before the experiment. You will be asked to author gestures to communicate concepts (e.g., surprise, landing) by demonstrating what path you think a robot would take to communicate that information to someone who was observing its flight. At that point, you will be asked to complete another questionnaire, and then your gestures may be re-iterated by the researcher to make any adjustments you deem necessary. A post-questionnaire and an interview will be administered after the experiment.

WILL VIDEO OR AUDIO RECORDINGS BE MADE OF ME DURING THE STUDY?
The researchers will make a video recording during the study in person or a zoom recording of the interaction online so they can observe body language, verify approach distances, and/or verify that the participant did not change position. If you do not give permission for the video recording to be obtained, you cannot participate in this study.

ARE THERE ANY RISKS TO ME?
The things that you will be doing have no more risk than you would come across in everyday life.

365 Avery Hall / P.O. 880115 / Lincoln, NE 68588-0115
(402) 472-8196 / FAX (402) 472-7767

There may be minimal risks from the moving parts on the robots, but these risks are mitigated by having you wear safety glasses and closed-toe shoes. This risk has been minimized by using consumer-safe robot parts. Although the researchers have tried to avoid risks, you may feel that some questions/procedures that are asked of you will be stressful or upsetting. You do not have to answer anything you do not want to. You may leave at any time with no penalty.

ARE THERE ANY BENEFITS TO ME?
There is no direct benefit to you by being in this study. What the researchers find out from this study may help other people with having better interactions with robots in the future.

WILL THERE BE ANY COSTS TO ME?
Aside from your time, there are no costs for taking part in the study.

WILL I BE PAID TO BE IN THIS STUDY?
You will be compensated $15 for your participation in this study either in Cash in-person or an Amazon GiftCard delivered digitally.

WILL INFORMATION FROM THIS STUDY BE KEPT PRIVATE?
The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely and only Dr. Brittany Duncan will have access to the records upon completion of the study, but other research study personnel will have access during the trial.

Information about you will be stored in locked file cabinet and computer files will be protected with a password. This consent form will be filed securely in an official area.

Information about you will be kept confidential to the extent permitted or required by law. People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the University of Nebraska, Lincoln IRB may access your records to make sure the study is being run correctly and that information is collected properly.

WHOM CAN I CONTACT FOR MORE INFORMATION?
You can call the Principal Investigator to tell her about a concern or complaint about this research study. The Principal Investigator Brittany Duncan, PhD can be called at 402-472-5073 or emailed at bduncan@cse.unl.edu.

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research and cannot reach the Principal Investigator or want to talk to someone other than the Investigator, you may call the IRB office.

- Phone number: (402) 472-8196
- Email: irb@unl.edu

MAY I CHANGE MY MIND ABOUT PARTICIPATING?
You have the choice whether or not to be in this research study. You may decide not to participate or stop participating at any time. If you choose not to be in this study, there will be no effect on your student status, medical care, employment, evaluation, etc. You can stop being in this study at any time with no effect on your student status, medical care, employment, evaluation, etc.

STATEMENT OF CONSENT

I agree to be in this study and know that I am not giving up any legal rights by signing this form. The procedures, risks, and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available and that the researcher will tell me if I must be removed from the study. I can ask more questions if I want. A copy of this entire, signed consent form will be given to me if requested. If completing the study online, verbal consent may be given and recorded.

_________________________________ _________________________________
Participant's Signature Date

_________________________________ _________________________________
Printed Name Date

INVESTIGATOR'S AFFIDAVIT:
Either I have or my agent has carefully explained to the participant the nature of the above project. I hereby certify that to the best of my knowledge the person who signed this consent form was informed of the nature, demands, benefits, and risks involved in his/her participation.

_________________________________ _________________________________
Signature of Presenter Date

_________________________________ _________________________________
Printed Name Date

University of Nebraska Lincoln
Computer Science and Engineering Department

Project Title: CAREER: CHS: Drones in Public: foundational interaction research

You are being invited to take part in a research study being conducted by University of Nebraska, Lincoln. You are being asked to read this form so that you know about this research study. The information in this form is provided to help you decide whether or not to take part in the research. If you decide to take part in the study, you will be asked to sign this consent form. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefit you normally would have.

WHY IS THIS STUDY BEING DONE?
The purpose of this study is to assess the impact of the design of robot gestures and movements for communication with the general population.

WHY AM I BEING ASKED TO BE IN THIS STUDY?
You are being asked to be in this study because you are a willing adult (above the age of 19) volunteer and a member of the Lincoln community.

HOW MANY PEOPLE WILL BE ASKED TO BE IN THIS STUDY?
A maximum of 96 people (participants) will be enrolled in this study locally.

WHAT ARE THE ALTERNATIVES TO BEING IN THIS STUDY?
The alternative is not to participate.

WHAT WILL I BE ASKED TO DO IN THIS STUDY?
Your participation in this study will last up to one and one half hours and includes two interactions, one interaction via Zoom and one at a NIMBUS Lab facility. The procedures you will be asked to perform are described below.

Online
This interaction will last about 45 minutes. A pre-questionnaire will be administered to start the interaction. You will be asked to author gestures to communicate concepts (e.g., surprise, landing) by demonstrating what path you think a robot would take to communicate that information to someone who was observing its flight. At that point, you will be asked to complete another questionnaire. That will conclude the online interaction.

In-Person
This visit will last about 45 minutes. Your gestures will be demonstrated by an aerial vehicle for you to make any adjustments you deem necessary. A post-questionnaire and an interview will be administered after the experiment. All social distancing guidelines and safety protocol must be followed at all times during this portion of the study. Any violation will result in immediate disqualification without compensation. Please check the UNL COVID 19 Information Sheet for Research Participants attached at the end of this consent form for further information.

WILL VIDEO OR AUDIO RECORDINGS BE MADE OF ME DURING THE STUDY?
The researchers will make a video recording during the interaction in person and a zoom recording of the interaction online so they can observe body language, verify approach distances, and/or verify that the participant did not change position. If you do not give permission for the video recording to be obtained, you cannot participate in this study.

ARE THERE ANY RISKS TO ME?
The things that you will be doing have no more risk than you would come across in everyday life.

365 Avery Hall / P.O. 880115 / Lincoln, NE 68588-0115
(402) 472-8196 / FAX (402) 472-7767

There may be minimal risks from the moving parts on the robots, but these risks are mitigated by having you wear safety glasses and closed-toe shoes. This risk has been minimized by using consumer-safe robot parts. Although the researchers have tried to avoid risks, you may feel that some questions/procedures that are asked of you will be stressful or upsetting. You do not have to answer anything you do not want to. You may leave at any time with no penalty.

ARE THERE ANY BENEFITS TO ME?
There is no direct benefit to you by being in this study. What the researchers find out from this study may help other people with having better interactions with robots in the future.

WILL THERE BE ANY COSTS TO ME?
Aside from your time, there are no costs for taking part in the study.

WILL I BE PAID TO BE IN THIS STUDY?
You will be compensated $15 for your participation in this study either in Cash in-person or an Amazon GiftCard delivered digitally. All social distancing guidelines and safety protocol must be followed at all times during the in-person portion of the study. Any violation will result in immediate disqualification without compensation.

WILL INFORMATION FROM THIS STUDY BE KEPT PRIVATE?
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- Phone number: (402) 472-8196
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STATEMENT OF CONSENT

I agree to be in this study and know that I am not giving up any legal rights by signing this form. The procedures, risks, and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available and that the researcher will tell me if I must be removed from the study. I can ask more questions if I want. A copy of this entire, signed consent form will be given to me if requested. If completing the study online, verbal consent may be given and recorded.

_________________________________ _________________________________
Participant's Signature Date

_________________________________ _________________________________
Printed Name Date

INVESTIGATOR'S AFFIDAVIT:
Either I have or my agent has carefully explained to the participant the nature of the above project. I hereby certify that to the best of my knowledge the person who signed this consent form was informed of the nature, demands, benefits, and risks involved in his/her participation.

_________________________________ _________________________________
Signature of Presenter Date

_________________________________ _________________________________
Printed Name Date

University of Nebraska-Lincoln
COVID-19 Information Sheet for Research Participants

The following information is being provided to you as a potential research participant in order to assist in your understanding of the actions being taken by the University of Nebraska-Lincoln to protect your health and safety as much as possible during the current Coronavirus (COVID-19) pandemic.

What You Should Know About Coronavirus
According to the United States Centers for Disease Control and Prevention (CDC) Coronavirus is an illness caused by a virus that can spread from person to person. The virus that causes Coronavirus is a new coronavirus that has spread throughout the world. Symptoms can range from mild (or no symptoms) to severe illness. Everyone is at risk of getting Coronavirus. Older adults and people of any age who have serious medical conditions may be at higher risk for more severe illness.

You can become infected by coming into close contact (about 6 feet/two arm lengths) with a person who has Coronavirus. It is mainly spread from person to person. You can become infected from respiratory droplets when an infected person coughs, sneezes, or talks. You may also be able to get it by touching a surface or object that has the virus on it, and then by touching your mouth, nose, or eyes.

There is currently no vaccine to protect against Coronavirus. Even if you and our research personnel follow all precautions, there is no guarantee that you will not get Coronavirus through participation in a research study or otherwise.

What are UNL Research Personnel Doing to Help Protect You?

- UNL is following CDC and State of Nebraska guidelines for Coronavirus. While we have re-started our in-person research with human participants, it may be possible that the study you choose to participate in must be stopped if infections with Coronavirus increase within Nebraska or nationally. If this happens, your research study team will notify you as soon as possible.
- Research personnel will try to stay at least 6 feet away from you at all times as much as reasonably possible during the study visit.
- Research personnel have been instructed to stay home and not report to work if they are not feeling well, experiencing any symptoms of Coronavirus, or if they have had close contact with someone known to be infected within the past 14 days.

On Campus

- Custodial services have increased sanitizing efforts in high-traffic areas on campus and employees are wiping down workplace common areas after each use. Research personnel are wearing masks, washing their hands with soap and water for at least 20 seconds, or using an alcohol-based hand sanitizer that contains at least 60% alcohol in between interacting with study participants.

What Can You Do to Help Protect Yourself and Prevent the Spread of Coronavirus if You are Participating in a Research Study?

- Limit in-person contact as much as possible. Stay at least 6 feet away from others and disinfect items you must touch.
- Before you come to the research site, wash your hands with soap and water for at least 20 seconds, or use an alcohol-based hand sanitizer that contains at least 60% alcohol.
- Hand sanitizer will be available for you to use before, during, and following your study visit.

- Please wear a mask that covers your mouth and nose, to all in-person research visits. If you do not have a mask, please let your study team know and you will be provided with a mask.
- Stay home if you are sick, except to get medical care; or if you have been in close contact with someone known to have Coronavirus within the past 14 days. If you have chosen to participate in a research study that requires in-person study visits, notify your research team via phone or email that you do not feel well, or have had contact with someone known to have Coronavirus within the past 14 days, and cannot make your visit.

Pre-Questionnaire

Gender: Male Female

Age: ____

Occupation: ____

Education level: Some High School High School Some College

College Graduate School

Major: ____

Culture you most identify with: American Chinese Indian Japanese

Korean Mexican Native American Other:

Computer Experience: 1 2 3 4 5 6

Beginner Expert

Have you ever interacted with a robot? Yes No

If yes, how often? Once Yearly Monthly Weekly Daily

If yes, which type? (please circle all applicable answers)

- a consumer robot such as a Roomba or pool cleaning robot?
- an industrial robot, telepresence robot, or other robot in the workplace?
- an educational robot such as Lego Mindstorms or an interactive robot in a museum?
- an entertainment robot such as a Parrot AR.drone, DJI Phantom, or Sony Aibo?

Have you ever owned a robot? Yes No

If yes, which type? (please circle all applicable answers)

- a consumer robot such as a Roomba or pool cleaning robot?
- an industrial robot, telepresence robot, or other robot in the workplace?
- an educational robot such as Lego Mindstorms or an interactive robot in a museum?
- an entertainment robot such as a Parrot AR.drone, DJI Phantom, or Sony Aibo?

Have you ever played video games? Yes No

If yes, how often? Once Yearly Monthly Weekly Daily

Have you ever owned a pet? Yes No

If yes, what kind? ________________________________

Have you ever owned a remote-controlled helicopter or airplane or an unmanned aerial system?
Yes No

If yes, what kind? ________________________________

Have you ever operated a remote-controlled helicopter or airplane or an unmanned aerial system? Yes No

If yes, what kind? ________________________________

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you have felt this way in the **past few weeks**.

Use the following scale to record your answers.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

__ interested	__ irritable
__ distressed	__ alert
__ excited	__ ashamed
__ upset	__ inspired
__ strong	__ nervous
__ guilty	__ determined
__ scared	__ attentive
__ hostile	__ jittery
__ enthusiastic	__ active
__ proud	__ afraid

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you have felt this way **today**.

Use the following scale to record your answers.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

__ interested	__ irritable
__ distressed	__ alert
__ excited	__ ashamed
__ upset	__ inspired
__ strong	__ nervous
__ guilty	__ determined
__ scared	__ attentive
__ hostile	__ jittery
__ enthusiastic	__ active
__ proud	__ afraid

On the following pages, there are statements describing feelings about robots. Please use the rating scale below to describe how accurately each statement reflects ***your feelings***. Describe how you generally feel now, not as you wish to feel in the future. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Please read each statement carefully, and then circle the number on the scale.

Response Options

1: I Strongly Disagree

2: I Disagree

3: Undecided

4: I Agree

5: I Strongly Agree

I would feel uneasy if robots really had emotions.

1 2 3 4 5

Strongly Disagree Strongly Agree

Something bad might happen if robots developed into living beings.

1 2 3 4 5

Strongly Disagree Strongly Agree

I would feel relaxed talking with robots.

1 2 3 4 5

Strongly Disagree Strongly Agree

I would feel uneasy if I was given a job where I had to use robots.

1 2 3 4 5

Strongly Disagree Strongly Agree

If robots had emotions, I would be able to make friends with them.

1	2	3	4	5
Strongly Disagree			Strongly Agree	

I feel comforted being with robots that have emotions.

1	2	3	4	5
Strongly Disagree			Strongly Agree	

The word "robot" means nothing to me.

1	2	3	4	5
Strongly Disagree			Strongly Agree	

I would feel nervous operating a robot in front of other people.

1	2	3	4	5
Strongly Disagree			Strongly Agree	

I would hate the idea that robots or artificial intelligences were making judgments about things.

1	2	3	4	5
Strongly Disagree			Strongly Agree	

I would feel very nervous just standing in front of a robot.

1	2	3	4	5
Strongly Disagree			Strongly Agree	

I feel that if I depend on robots too much, something bad might happen.

1	2	3	4	5
Strongly Disagree			Strongly Agree	

I would feel paranoid talking with a robot.

1	2	3	4	5
Strongly Disagree			Strongly Agree	

I am concerned that robots would be a bad influence on children.

1	2	3	4	5
Strongly Disagree			Strongly Agree	

I feel that in the future society will be dominated by robots.

1	2	3	4	5
Strongly Disagree			Strongly Agree	

Questionnaire

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you have felt this way **during your interaction with the robot**.

Use the following scale to record your answers.

1	2	3	4	5
Very slightly or not at all	A little	Moderately	Quite a bit	Extremely

__ interested	__ irritable
__ distressed	__ alert
__ excited	__ ashamed
__ upset	__ inspired
__ strong	__ nervous
__ guilty	__ determined
__ scared	__ attentive
__ hostile	__ jittery
__ enthusiastic	__ active
__ proud	__ afraid

This scale consists of a number of words that describe different traits. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you felt **the robot** exhibited these traits.

Use the following scale to record your answers.

1	2	3	4	5	6	7	8	9	10
Describes very poorly									Describes very well

__ cheerful

__ disobedient

__ honest

__ extroverted

__ unkind

__ reliable

__ incompetent

__ trustworthy

__ outgoing

__ likeable

__ enthusiastic

__ dishonest

__ pretenseless

__ happy

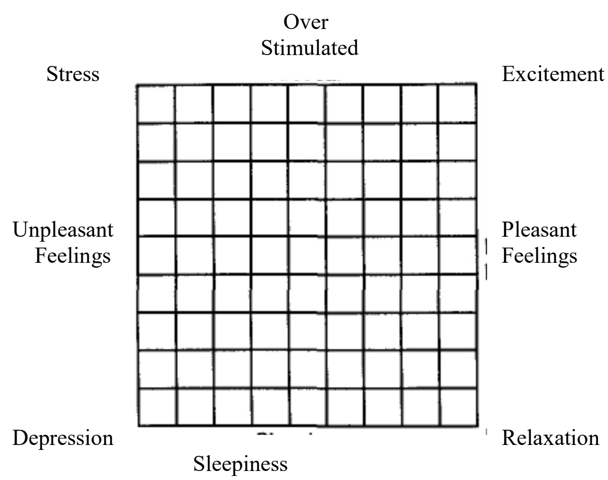
__ harsh

__ helpful

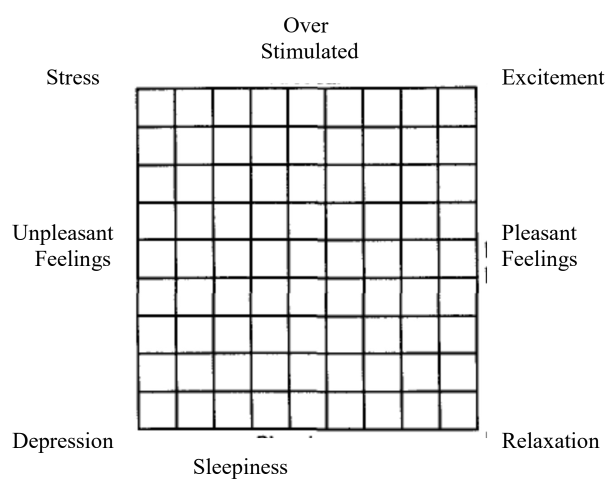
__ kind

__ warm

Please rate how you are feeling **right now** by marking an X in a square.



Please rate how you felt when **interacting with the robot** by marking an X in the appropriate square.



Did you feel the robot was looking at you during interactions? Yes No

Please elaborate:

How comfortable did you feel when the robot was approaching you?

1 Not comfortable	2	3	4	5	6 Very comfortable

How safe did you feel during your interaction with the robot?

1 Not Safe at All	2	3	4	5	6 Very Safe

How scared were you of the robot?

1 Not Scared	2	3	4	5	6 Very Scared

How trustworthy did you find the robot?

1 Not Trustworthy	2	3	4	5	6 Very Trustworthy

If you encountered this robot outside, would you approach it?

Yes No

If you encountered this robot outside, would it scare you?

Yes No

On the following pages, there are phrases describing people's behaviors. Please use the rating scale below to describe how accurately each statement describes ***you***. Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Please read each statement carefully, and then circle the number that you feel is accurate.

Response Options

1	2	3	4	5
Very Inaccurate	Moderately Inaccurate	Neither Inaccurate nor Accurate	Moderately Accurately	Very Accurate

Try to surpass others' accomplishments.

1	2	3	4	5
Very Inaccurate				Very Accurate

Break my promises.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am relaxed most of the time.

1	2	3	4	5
Very Inaccurate				Very Accurate

Often forget to put things back in their proper place.

1	2	3	4	5
Very Inaccurate				Very Accurate

Feel little concern for others.

1	2	3	4	5
Very Inaccurate				Very Accurate

Have a rich vocabulary.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am the life of the party.

1	2	3	4	5
Very Inaccurate				Very Accurate

Try to outdo others.

1	2	3	4	5
Very Inaccurate				Very Accurate

Get stressed out easily.

1	2	3	4	5
Very Inaccurate				Very Accurate

Have a vivid imagination.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am not interested in other people's problems.

1	2	3	4	5
Very Inaccurate				Very Accurate

Make a mess of things.

1 Very Inaccurate	2	3	4	5 Very Accurate

Feel comfortable around people.

1 Very Inaccurate	2	3	4	5 Very Accurate

Am afraid that I will do the wrong thing.

1 Very Inaccurate	2	3	4	5 Very Accurate

Worry about things.

1 Very Inaccurate	2	3	4	5 Very Accurate

Have excellent ideas.

1 Very Inaccurate	2	3	4	5 Very Accurate

Am easily disturbed.

1 Very Inaccurate	2	3	4	5 Very Accurate

Insult people.

1	2	3	4	5
Very Inaccurate				Very Accurate

Start conversations.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am quick to correct others.

1	2	3	4	5
Very Inaccurate				Very Accurate

Leave my belongings around.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am quick to understand things.

1	2	3	4	5
Very Inaccurate				Very Accurate

Seldom feel blue.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am not really interested in others.

1	2	3	4	5
Very Inaccurate				Very Accurate

Talk to a lot of different people at parties.

1	2	3	4	5
Very Inaccurate				Very Accurate

Feel that I'm unable to deal with things.

1	2	3	4	5
Very Inaccurate				Very Accurate

Impose my will on others.

1	2	3	4	5
Very Inaccurate				Very Accurate

Avoid responsibilities.

1	2	3	4	5
Very Inaccurate				Very Accurate

Demand explanations from others.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am exacting in my work.

1	2	3	4	5
Very Inaccurate				Very Accurate

Use difficult words.

1	2	3	4	5
Very Inaccurate				Very Accurate

Shirk my duties.

1	2	3	4	5
Very Inaccurate				Very Accurate

Get upset easily.

1	2	3	4	5
Very Inaccurate				Very Accurate

Don't mind being the center of attention.

1	2	3	4	5
Very Inaccurate				Very Accurate

Suspect hidden motives in others.

1	2	3	4	5
Very Inaccurate				Very Accurate

Want to control the conversation.

1	2	3	4	5
Very Inaccurate				Very Accurate

Make people feel at ease.

1	2	3	4	5
Very Inaccurate				Very Accurate

Spend time reflecting on things.

1	2	3	4	5
Very Inaccurate				Very Accurate

Follow a schedule.

1 Very Inaccurate	2	3	4	5 Very Accurate

Change my mood a lot.

1 Very Inaccurate	2	3	4	5 Very Accurate

Don't talk a lot.

1 Very Inaccurate	2	3	4	5 Very Accurate

Feel that my life lacks direction.

1 Very Inaccurate	2	3	4	5 Very Accurate

Am not afraid of providing criticism.

1 Very Inaccurate	2	3	4	5 Very Accurate

Feel others' emotions.

1 Very Inaccurate	2	3	4	5 Very Accurate

Am full of ideas.

1 Very Inaccurate	2	3	4	5 Very Accurate

Like order.

1	2	3	4	5
Very Inaccurate				Very Accurate

Have frequent mood swings.

1	2	3	4	5
Very Inaccurate				Very Accurate

Keep in the background.

1	2	3	4	5
Very Inaccurate				Very Accurate

Do not like art.

1	2	3	4	5
Very Inaccurate				Very Accurate

Challenge others' points of view.

1	2	3	4	5
Very Inaccurate				Very Accurate

Take time out for others.

1	2	3	4	5
Very Inaccurate				Very Accurate

Have difficulty understanding abstract ideas.

1	2	3	4	5
Very Inaccurate				Very Accurate

Get chores done right away.

1	2	3	4	5
Very Inaccurate				Very Accurate

Get irritated easily.

1	2	3	4	5
Very Inaccurate				Very Accurate

Have little to say.

1	2	3	4	5
Very Inaccurate				Very Accurate

Believe that too much tax money goes to support artists.

1	2	3	4	5
Very Inaccurate				Very Accurate

Lay down the law to others.

1	2	3	4	5
Very Inaccurate				Very Accurate

Look for hidden meanings in things.

1	2	3	4	5
Very Inaccurate				Very Accurate

Have a soft heart.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am not interested in abstract ideas.

1	2	3	4	5
Very Inaccurate				Very Accurate

Pay attention to details.

1	2	3	4	5
Very Inaccurate				Very Accurate

Sympathize with others' feelings.

1	2	3	4	5
Very Inaccurate				Very Accurate

Don't like to draw attention to myself.

1	2	3	4	5
Very Inaccurate				Very Accurate

Put people under pressure.

1	2	3	4	5
Very Inaccurate				Very Accurate

Become overwhelmed by events.

1	2	3	4	5
Very Inaccurate				Very Accurate

Hate to seem pushy.

1	2	3	4	5
Very Inaccurate				Very Accurate

Often feel blue.

1	2	3	4	5
Very Inaccurate				Very Accurate

Do not have a good imagination.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am always prepared.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am interested in people.

1	2	3	4	5
Very Inaccurate				Very Accurate

Am quiet around strangers.

1	2	3	4	5
Very Inaccurate				Very Accurate

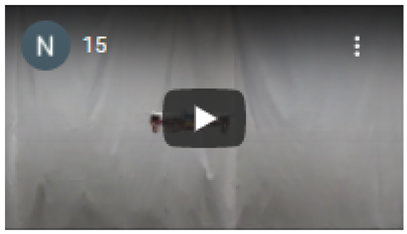
Feel lucky most of the time.

1	2	3	4	5
Very Inaccurate				Very Accurate

Robot Labeling

* Required

Please watch the video with sound and answer the questions below.



If you saw this drone in real life, what would it say to you? *

- ◯ To Follow It/Move Towards
- ◯ Do Not Follow/Do Not Pass/Restricted/Go Away
- ◯ Yes/Approval
- ◯ No
- ◯ Welcome
- ◯ Landing
- ◯ Delivery
- ◯ Help
- ◯ Caution
- ◯ Other: ____________

If you were in the room with the robot, how would you respond immediately following the robot's actions? *

- ◯ Watch it/Look at it/Stare
- ◯ Investigate
- ◯ Follow it
- ◯ Move Away
- ◯ Help It
- ◯ Other: ____________

Please evaluate the behavior the robot exhibited *

	1	2	3	4	5	
Practical, Conforming, Interested in Routine	○	○	○	○	○	Imaginative, Independent, Interested in Variety

Please evaluate the behavior the robot exhibited *

	1	2	3	4	5	
Disorganized, Careless, Impulsive	○	○	○	○	○	Organized, Careful, Disciplined

Please evaluate the behavior the robot exhibited *

	1	2	3	4	5	
Ruthless, Suspicious, Uncooperative	○	○	○	○	○	Softhearted, Trusting, Helpful

Please evaluate the behavior the robot exhibited *

	1	2	3	4	5	
Retiring, Sober, Reserved	○	○	○	○	○	Sociable, Fun-Loving, Affectionate

Please evaluate the behavior the robot exhibited *

	1	2	3	4	5	
Anxious, Insecure, Self-Pitying	○	○	○	○	○	Calm, Secure, Self-Satisfied

Back Next

Brainstorm Sheet

You will have 20 minutes to brainstorm: For each of the tasks, please design an appropriate gesture that the drone may take to communicate that state using your small object within the constraints of your piece of paper, and from the top of the table to the top of your head. During the creation of your motions you may have specific height, speed, or characteristic specifications in mind, if you do please define those specifications in the 3 questions directly following each motion.

1. It is highly recommended that you provide a gesture for each task.
2. It is also highly recommended you write notes in the space provided for each task.
3. Feel free to move between categories and go back to a previous category and change it during your brainstorm process.

For reference, the 8 motions in this order will be: Do Not Follow/Go Away, Watch It/Look at it, Investigate, Caution, Follow it/Move Towards, Yes/Approval, Landing, and Delivery

* Required

1. Participant Number *

2. Motion: Do Not Follow / Go Away

3. Height: Do Not Follow / Go Away

   Mark only one oval.

   - Above Head
   - Eye Level
   - Chest Level
   - Waist Level
   - Knee Level
   - Other:

4. Speed: Do Not Follow / Go Away

   Mark only one oval.

   - Slow
   - Average
   - Fast
   - Other:

5. Characteristics: Do Not Follow / Go Away

Mark only one oval.

- Exhausted
- Anti-Social
- Adventurer Hero
- Sneaky Spy
- Other: ____________

6. Motion: Watch it / Look at it

7. Height: Watch it / Look at it

Mark only one oval.

- Above Head
- Eye Level
- Chest Level
- Waist Level
- Knee Level
- Other: ____________

8. Speed: Watch it / Look at it

Mark only one oval.

- Slow
- Average
- Fast
- Other: ____________

9. Characteristics: Watch it / Look at it

Mark only one oval.

- Exhausted
- Anti-Social
- Adventurer Hero
- Sneaky Spy
- Other: ____________

10. Motion: Investigate

11. Height: Investigate

Mark only one oval.

- Above Head
- Eye Level
- Chest Level
- Waist Level
- Knee Level
- Other:

12. Speed: Investigate

Mark only one oval.

- Slow
- Average
- Fast
- Other:

13. Characteristics: Investigate

Mark only one oval.

- Exhausted
- Anti-Social
- Adventurer Hero
- Sneaky Spy
- Other:

14. Motion: Caution

15. Height: Caution

Mark only one oval.

- ( ) Above Head
- ( ) Eye Level
- ( ) Chest Level
- ( ) Waist Level
- ( ) Knee Level
- ( ) Other: ____________________

16. Speed: Caution

Mark only one oval.

- ( ) Slow
- ( ) Average
- ( ) Fast
- ( ) Other: ____________________

17. Characteristics: Caution

Mark only one oval.

- ( ) Exhausted
- ( ) Anti-Social
- ( ) Adventurer Hero
- ( ) Sneaky Spy
- ( ) Other: ____________________

18. Motion: Follow It / Move Towards

19. Height: Follow It / Move Towards

Mark only one oval.

- Above Head
- Eye Level
- Chest Level
- Waist Level
- Knee Level
- Other: ____________________

20. Speed: Follow It / Move Towards

Mark only one oval.

- Slow
- Average
- Fast
- Other: ____________________

21. Characteristics: Follow It / Move Towards

Mark only one oval.

- Exhausted
- Anti-Social
- Adventurer Hero
- Sneaky Spy
- Other: ____________________

22. Motion: Yes / Approval

23. Height: Yes / Approval

Mark only one oval.

- Above Head
- Eye Level
- Chest Level
- Waist Level
- Knee Level
- Other: ____________________

24. Speed: Yes / Approval

Mark only one oval.

- Slow
- Average
- Fast
- Other: ____________________

25. Characteristics: Yes / Approval

Mark only one oval.

- Exhausted
- Anti-Social
- Adventurer Hero
- Sneaky Spy
- Other: ____________________

26. Motion: Landing

____

____

____

____

____

27. Height: Landing

Mark only one oval.

- ( ) Above Head
- ( ) Eye Level
- ( ) Chest Level
- ( ) Waist Level
- ( ) Knee Level
- ( ) Other: ______________________

28. Speed: Landing

Mark only one oval.

- ( ) Slow
- ( ) Average
- ( ) Fast
- ( ) Other: ______________________

29. Characteristics: Landing

Mark only one oval.

- ( ) Exhausted
- ( ) Anti-Social
- ( ) Adventurer Hero
- ( ) Sneaky Spy
- ( ) Other: ______________________

30. Motion: Delivery

____
____
____
____
____

31. Height: Delivery

Mark only one oval.

- Above Head
- Eye Level
- Chest Level
- Waist Level
- Knee Level
- Other: ______________________

32. Speed: Delivery

Mark only one oval.

- Slow
- Average
- Fast
- Other: ______________________

33. Characteristics: Delivery

Mark only one oval.

- Exhausted
- Anti-Social
- Adventurer Hero
- Sneaky Spy
- Other: ______________________

Post-Questionnaire

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you have felt this way **during your interaction with the robot**.

Use the following scale to record your answers.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

__ interested	__ irritable
__ distressed	__ alert
__ excited	__ ashamed
__ upset	__ inspired
__ strong	__ nervous
__ guilty	__ determined
__ scared	__ attentive
__ hostile	__ jittery
__ enthusiastic	__ active
__ proud	__ afraid

This scale consists of a number of words that describe different traits. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you felt **the robot** exhibited these traits. Use the following scale to record your answers.

1	2	3	4	5	6	7	8	9	10

describes very poorly | describes very well

__ cheerful	__ likeable
__ disobedient	__ enthusiastic
__ honest	__ dishonest
__ extroverted	__ pretenseless
__ unkind	__ happy
__ reliable	__ harsh
__ incompetent	__ helpful
__ trustworthy	__ kind
__ outgoing	__ warm

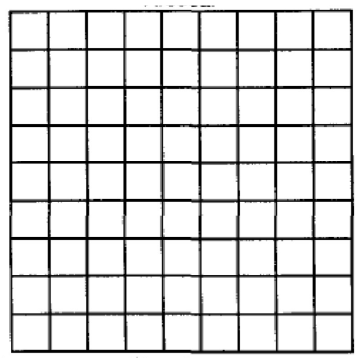
Please rate how you are feeling **right now** by marking an X in a square.

Over
Stimulated

Stress | Excitement

Unpleasant Feelings | Pleasant Feelings

Depression | Relaxation



Sleepiness

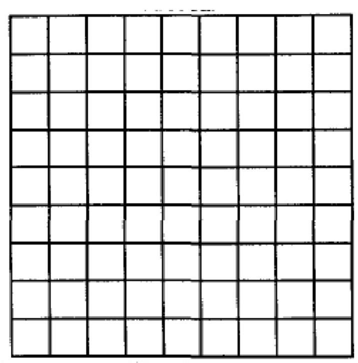
Please rate how you felt when **interacting with the robot** by marking an X in the appropriate square.

Over
Stimulated

Stress | Excitement

Unpleasant Feelings | Pleasant Feelings

Depression | Relaxation



Sleepiness

Did you feel the robot was looking at you during interactions? Yes No

Please elaborate:

How comfortable did you feel when the robot was approaching you?

1	2	3	4	5	6
Not Comfortable					Very Comfortable

How safe did you feel during your interaction with the robot?

1	2	3	4	5	6
Not Safe At All					Very Safe

How scared were you of the robot?

1	2	3	4	5	6
Not Scared					Very Scared

How trustworthy did you find the robot?

1	2	3	4	5	6
Not Trustworthy					Very Trustworthy

If you encountered this robot outside, would you approach it?

Yes No

If you encountered this robot outside, would it scare you?

Yes No

If you could add one more modality to the robot, what would you add? Which task would you most plan to use it on?

Do you have any other comments about this robot?

Do you have any comments about this trial?

Do you have any other comments about this experiment?

Is there anything that has not been addressed that you find important?

Interview

What were you feeling during the experiments?

Were there any feelings that arose during the experiments that impacted you in a positive way?

Were there any feelings that arose during the experiments that impacted you in a negative way?

Was there anything that occurred during the experiment that was problematic for you in any way?

Do you have any suggestions for improving the experimental process?

Do you have any other comments or suggestions about this experience?

Which gesture or gestures were the easiest to construct? And why?

Which gesture or gestures do you feel most confident that other people will be able to understand?

Which gesture or gestures were the hardest to construct? And why?

Which gesture or gestures do you feel least confident that other people will be able to understand?