Aerial Flight Paths for Communication: How Participants Perceive and Intend to Respond to Drone Movements

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ABSTRACT

This work has developed an iteratively refined understanding of participants' natural perceptions and responses to unmanned aerial vehicle (UAV) flight paths, or gestures. This includes both what they believe the UAV is trying to communicate to them, in addition to how they expect to respond through physical action. Previous work in this area has focused on eliciting gestures from participants to communicate specific states, or leveraging gestures that are observed in the world rather than on understanding what the participants believe is being communicated and how they would respond. This work investigates previous gestures either created or categorized by participants to understand the perceived content of their communication or expected response, through categories created by participant free responses and confirmed through forced choice testing. The human-robot interaction community can leverage this work to better understand how people perceive UAV flight paths, inform future designs for non-anthropomorphic robot communications, and apply lessons learned to elicit informative labels from people who may or may not be operating the vehicle. We found that the Negative Attitudes towards Robots Scale (NARS) can be a good indicator of how we can expect a person to react to a robot. Recommendations are also provided to use motion approaching/retreating from a person to encourage following, perpendicular to their field of view for blocking, and to use either no motion or large altitude changes to encourage viewing.

CCS CONCEPTS

• **Human-centered computing → User studies**; **HCI theory, concepts and models**; **Collaborative interaction**.

KEYWORDS

gestures; drones; UAV; motion

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1 INTRODUCTION

Drones, or Unmanned Aerial Vehicles (UAVs), are becoming more common across applications including photography, delivery, agriculture, and hobby uses. With the introduction of these vehicles into daily observation and social contexts, such as those described in [2] and [9], UAVs will be expected to communicate with diverse people in myriad situations. One open problem when developing these communications is understanding how these people will interpret flight paths and what they would intend to do based on that interpretation.

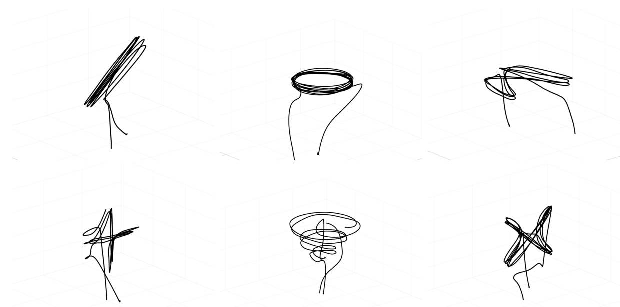

Figure 1: Selection of flight paths (top left to bottom right : diagonal descend, horizontal circle, horizontal figure eight, plus, spiral, and X-shape)

This work develops an initial understanding of what participants perceived to be communicated from sixteen unique drone flight paths and how they would intend to interact with the system based on those communications. This work suggests that NARS can be a significant indicator of how a person is likely to react and whether they are more likely to expect a negative message to be conveyed. For this study we ran 120 unique participants in iterative phases. The first phase involved 80 participants who answered our questions about how they would expect to respond to a drone using a free response method. The second phase is a refinement phase that builds on the results of the first phase to inform the third phase. The third phase involved 40 new participants who answered questions using a forced choice method.

This work indicates that:

- landing is conveyed by direct movements with an altitude change,
- people are most likely to follow a path that comes towards them before retreating (as long as it does not contain an altitude change),

- participants are more likely to watch or move away from paths with either no lateral movement or with large altitude changes, and
- flights across an area are likely to cause participants to avoid the vehicle or that area (regardless of the altitude).

2 RELATED WORK

This work builds on prior research in social drones, drone proxemics, and the communication gap from the UAV to person. This section will discuss the work we found most important in developing this study.

2.1 Social Drones

Interest in drones for social purposes has been increasing in recent years, which has resulted in overviews of work in drones as flying interfaces [9] and design recommendations for drones in inhabited environments [2]. A relevant finding from [2] suggests future work on "Intuitive Comprehension" of drone movements to understand what a drone is trying to convey without other explanation. We defer to these works for a more comprehensive discussion of social uses for drone systems.

2.2 Drone Communication

While a few works have looked into communication of the human to the drone [4][13], we are more interested here in how a drone can communicate to a person who may or may not be using it. There are various ways to explore this problem, but regardless of method, it should inform how the person would naturally interact with and interpret the UAVs' motion.

2.2.1 Lights, Stereo, and Video. Using the right attachments on a UAV can help to bridge communication barriers in a way easier for everyone to immediately understand. Methods such as audio or video can be very direct in their communication by providing verbal speech, written word, or figures that people are used to understanding. A few examples of attachments that can be added to a UAV include: lights[19], video through a projector[11][12][15], and speaker[21].

Unfortunately, adding these to a system comes with a few drawbacks. The main concerns are for system weight limits, battery, and simply that they require additional hardware. This hardware, besides not consistently being present, can be a burden on the system and its performance. The final concern is that they would have a reduced communication range compared to other methods, as they can only communicate as far as they can be seen or heard clearly.

2.2.2 Drone Proxemics. Another method of communication, discussed more extensively in [2], is through proxemics (or the impact of distancing on interactions). While proxemics encompasses more than the comfortable interaction distancing, previous work has explored drone distancing in interactions with vehicles at different heights [7] [20] and as compared to ground vehicles [1]. Generally, participants indicated that drones should interact with them from the social zone rather than personal zone, in contrast with human-human or human-ground robot expectations.

2.2.3 Flight Paths. A few studies have explored the benefits of using the flight paths of a UAV to communicate an intended message.

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

Table 1: Study Questions

Sharma et al.[16] 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. [18] 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.

Duncan et al.[6] explored a set of seven total states, ranging from lost sensor to landing, that they attempted to have matched with common flight paths. They showed that participants had difficulty understanding more technical states, gravitating towards states such as landing instead of lost sensor. Firestone [8] took these seven UAV states and asked participants to design flight paths and characteristics to indicate those states. From this information they were able to create a list of characteristics that each of these flight paths demonstrated.

3 MATERIALS

Throughout this project the videos, participant questionnaires, and questions posed to the participants remained the same. These materials will be described here to reduce repetition in later sections.

3.1 Recruitment and Process

The participants were recruited and participated online via Amazon Mechanical Turk (MTurk). They chose our study based on a short description we provided and to qualify they had to be considered an MTurk "master" as decided by Amazon. All participants are unique and were not allowed to participate in multiple phases. Since the study was run online the study was fully accessible to a broad pool from various locations, ethnicities, genders, ages, and abilities. Participants took roughly 35 minutes on average across all of the tests. The order of the experiment was consistent across participants. They completed demographic questions and NARS on MTurk, then redirected to a Google Form. On the Google Form they viewed each video on an individual page presented with the response options

Figure 2: Design Process

described below. After viewing all videos, they were presented with a closing questionnaire to ask for any remaining comments from the participants.

3.2 Videos

A set of sixteen base motions were created to include the motions from [6], as well as additional videos that corresponded to both the taxonomy and the most popular participant-generated flight paths from [8]. Each video was 30 seconds in length with repetitions of the flight added to reach the desired length of the video, as necessary. Flight paths were all kept around a speed of 0.5 m/s, and the distance covered held constant as much as possible. The motions were captured using a Vicon system. The sixteen motions (shown in Figures 1 and 3) were: 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.

In order to better compare our videos to prior work, we also leveraged the "Exhausted Drone" template speed from [5] 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.

3.3 Questionnaires

The primary questionnaire administered to the participants was the Negative Attitudes towards Robots Scale (NARS) [17]. NARS was selected since people with high NARS have been found to have difficulty in recognizing robot motions in humanoid robots [14] although this was not found with earlier studies with UAVs [6].

3.4 Questions to Understand Responses

As described further in [3], a set of questions was developed to understand participant perception of and anticipated reaction to UAV flight paths. These questions are presented in Table 1 with"type" being the response anticipated from the participant (speech, gesture, or physical).

4 PHASE 1: EXPLORATION

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).

4.1 Free Response Study

Participants were given combination of Speech, Gesture, and Action-based questions. Each participant received 1 or 2 free-response questions chosen from Questions 1 through 6 as shown in Table 1. The questions are categorized such that the "Speech" questions prompted a verbal request or response, "Gesture" were anticipated to provoke anthropomorphic responses, and "Physical" to evoke potential movements. 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.

4.2 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 drones. The wording that proved 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 [3], but the responses were collapsed here and viewed as a single set moving forward based on the fact that responses were relatively consistent and seemingly more related to the flight path rather than the question.

5 PHASE 2: REFINEMENT

5.1 Free Response Analysis

5.1.1 Frequency Analysis. The responses of these 80 participants 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). Which 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 5.1.2. 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).

5.1.2 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

5.1.3 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 [10] amongst their categorization.

When sorting the responses into categories by video, a few results emerged that both raters agreed upon.

- 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"

5.1.4 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.

6 PHASE 3: CONFIRMATION

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 1, which were selected in Phase 2, based upon the responses in Phase 1, to elicit participant perceptions of robot communication and anticipated response. The majority of the results that follow will be based on the responses from Phase 3 (unless otherwise mentioned).

7 RESULTS

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 2 (excluding yaw in the Say column and the 8.2 rows) reports significant results.

7.1 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

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

Table 2: 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 8.2 refers to rotated flight paths with results only discussed in Section 8.2

Figure 3: Flight paths not included in Figure 1 (from top left to bottom right: undulate, left-right, U-shape, hover, vertical circle, up-down/descend, front-back, yaw, and descend and shift)

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 2.

7.2 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 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 8.2, "Follow it" only appeared within the movements that were confined to the X axis or XY 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.

7.3 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.

7.4 NARS

The states can be sorted into 3 main different categories: Positive ("To Follow It/ Move Towards", "Yes", "Welcome", "Help", "Follow it", "Help it"), Neutral ("Landing", "Delivery", "Watch it", "Investigate") and Negative (DNF, "No", "Caution", "Move Away"). Using this categorization, people with negative NARS scores were more likely to pick negative states (M:13), and less likely to pick positive responses (M:9) than those with a positive NARS score (M:10 and M:11, respectively). Both picked a neutral option around 12 times on average.

8 ADDITIONAL EXPLORATORY STUDIES

Throughout this process, opportunities were presented to gain additional knowledge and ensure that we were not missing information while investigating these flight paths specifically with regards to the states we were labelling and the axes of motion in the flight paths. Small proto-studies were run at these points to collect information and inform the larger studies. These additional investigations did not fit nicely in the narrative above, so they will be reported here for completeness.

8.1 State Elicitation

One proto-study we ran between Phases 2 and 3 was to try to elicit states for forced choice responses by asking an additional sixteen participants for 3-5 states. Eight were asked for states they believed a drone should convey while the other 8 for information they believed a drone should be able to communicate to people not involved in the drone operations. This question was posed either at beginning or the end of the study to see if the participants were more likely to just use the states we gave them if we put it at the end and if they would be more creative if placed at the beginning. The placement did not seem to have much effect overall. Both the beginning and end placement had each of the participants communicate at least one of the states or labels that were already being included in the forced choice responses. The quality of these responses was poor and they were not further analyzed for inclusion.

8.2 Axis Investigation

An additional proto-study, upon seeing the results of Phase 3, was to understand the impact of the primary axis of motion on the participant responses. On an initial analysis of the first 32 participants who responded to Questions 1 and 6 posed for the sixteen videos described earlier, it appeared that any motion moving mainly 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. 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 4.

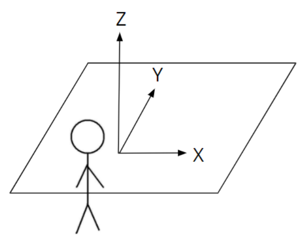

Figure 4: Direction of axes relative to person

Figure Description Figure 4 shows a stick person facing the x-z plane. The x-axis moves left-right, the y-axis moves front-back, and the z-axis moves up-down in relation to the stick figure.

Based on the small set of responses to this proto-study, we did not find support for this observation. A majority of the responses were still DNF, while the "Move Away" category was less represented than in the earlier study. It did appear that simplicity of path was still a priority because complexity added to the simple front-back motion (with additional movement along the Z axis) inspired the change to a DNF action.

A deviation from the set was observed with the horizontal figure 8 receiving "Follow it" as a tie for one of two popular responses. While this proto was quite small so only limited conclusions should be drawn, it is interesting that this tie may be due to the relatively similar distancing maintained in both the front-back and the turned variant of the horizontal figure 8 when approaching the person, with only a slight decrease in the width of the motion from the initial video or due to a lack of motion on the Z axis, which was distinct from the other motions in the set.

9 DISCUSSION

This work describes an iterative design and refinement process to better understand how people will respond to UAVs, how they anticipate these vehicles will communicate, and underlying commonalities based on the axis or plane of motion. The limitations, implications, recommendations, and our reflections on this work will be presented in this section.

9.1 Limitations

A significant limitation of this work is that all of the motions were presented to the participants remotely through video. This may have impacted their ability to provide a true reaction to how they would respond.Video is an effective preliminary method of gathering information about how people would expect to respond, but is not fully effective for seeing how they may actually respond. Since there were minimal restrictions to who could participate, it's possible that many of the participants have never interacted with a UAV before. This could potentially create a gap between their expected reaction and actual reaction. Also due to the use of video, we are unable to effectively explore the effect of varying drones in size and sound.

Extending this work as an in-person study could be interesting to compare the results, but would necessarily limit our participant pool, and accessibility. In addition to questions on perception, we did not verify that participants had their sound enabled, even though there was a reminder at the top of every page. It is also highly probable that the sound level varied for those who did have their sound on. Because sound can have a significant impact on presence, fear, and interest in the machine, sound perception would be an additional reason an in-person study may be useful.

Another ongoing extension of this work is to explore the effect of varying perception of a person to a drone. It was briefly explored in axis exploration, but current methods were ineffective at understanding at what perspective, or position, a person no longer interprets the motion the same way. One method that may prove effective for that work would be VR, but this is outside the scope of this work.

A restriction of our system was that the controller does not precisely control the altitude of the UAV, so the paths were slightly varied due to battery levels. This could be a possible concern, as not all of the motions could be held at exactly the same center height position. The biggest concern related to this is the height difference between the left-right and the front-back paths, which ended up being about .25m apart on the z-axis.

9.2 Implications

This research explored how people would perceive varied UAV flight paths, including: perceived communication and physical response. This work presents important practical implications for UAV developers and future researchers to provide safe and knowledgeable interactions. 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, are likely to follow vehicles with large motions in the Y axis and without motion in the Z axis, perceive direct changes in altitude as landing and believe movement across the X axis (with or without movement in the Z axis) to be blocking a path.

When comparing the results presented here to the findings of Firestone [8], we can see that it is mostly confirmatory towards the taxonomy they presented. This work also supports that landing is best communicated using direct, decreasing motions using throttle. Additionally, to attract attention or signal an area of interest the UAV should use a simple motion with stable altitude.

In comparison to Duncan et al. [6], the results here only loosely support the findings presented. One of the motions of interest that they present, spiral, they found to overwhelmingly point to meaning landing. While "Landing" does appear as a popular response for the spiral flight path in the forced choice here, it's not as convincing a conclusion.

While this work presents similar trends (and sometimes mixed results) with respect to previous work, it also builds on that work through involving the participants in creating the labels and leverages the earlier findings as a starting point for exploration.

9.3 Recommendations

Complex motions are likely to result in participant intention to move away from the UAV and/ or area. If you need them to stay and watch what the drone is doing, it's best to minimize the amount of motion or simplify the motion for improved reception.

Participants report being most likely to follow vehicles with large motions along the Y axis, but only in the absence of altitude changes. For "Landing", most motions moving down along the z-axis were associated with some type of landing, but had higher agreement with simpler motions, such as descend and shift, diagonal descend, and straight descend. Responses also suggested that participants were likely to associate motions of a UAV with gestures of humans such as nodding for up-down or a cross for plus.

It is recommended that future studies differentiate within some of the categories that were combined here for simplicity and continue the exploration of perception based on axis/plane of motion, particularly when augmented with speed or size changes. One specific category that would be interesting to investigate by understanding the individual components would be "Do Not Follow/ Do Not Pass/ Restricted/ Go Away". While this combination gave us a general sense of action, it could potentially have been more informative as separate states since it was, in general, the most popular response.

9.4 Reflection

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 a large 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.

Central findings from this work inform how motions are perceived across states that people believe an aerial vehicle may try to communicate and give a sense that people, in general, anticipate that aerial vehicles are much more likely to block an area or need room to land than previous work may have indicated. This is in contrast to the communicative uses of these systems in popular media, but those systems are generally also outfitted with audio or light communications to generate anthropomorphic perception.

10 CONCLUSION

This work presents an exploration into how participants would respond physically, as well as their perception of the messages contained in aerial vehicle flight paths. This work suggests that NARS can be a significant indicator of how a person is likely to react and whether they are more likely to expect a negative message to be conveyed. In terms of specific motions, this work presents a few additional findings. It indicates that landing is conveyed by direct movements with an altitude change. People are most likely to follow a path that comes towards them before retreating (as long as it does not contain an altitude change). Participants are more likely to watch or move away from paths with either no lateral movement or with large altitude changes. Flights across an area are likely to cause participants to avoid the vehicle or that area (regardless of altitude).

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