Complexity of External Distractors from Small Unmanned Aircraft Systems

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Abstract

The integration of small unmanned aircraft system (sUAS) into the transportation system has presented a unique opportunity to investigate the effects these operations will have on other areas of the system. Specifically, as a potential distraction to terrestrial vehicle operators. The current study investigated the potential of sUAS operations as a perturbation variable on the human attention system. Using methods from a dynamical system perspective evaluation of the potential in the increased complexity sUAS operations might introduce as an external distraction to drivers. The primary measure of this within-subjects research is saccade speeds over time, analyzed with time series analysis. Other metrics recorded included fixation duration, and lane deviations. A majority of participants did not glance at the sUAS longer than two seconds and fixation durations were reduced as a function of altitude. Some of the participants did display increased complexity of saccade movements during encounters with sUAS; however, the majority did not display increased complexity. Participants did not significantly deviate in the driving lanes when encountering a sUAS operation. The findings outlined in the current study suggest that commercial sUAS operations near or over roadways will cause no more risk of distraction than current external distractors present while driving.

Keywords: Distracted Driving, small unmanned aircraft (sUAS), System Dynamics, Time series

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Complexity of External Distractors from Small Unmanned Aircraft

A revolution has gripped the aviation industry not seen since the development of the jet engine or computerization of the flight deck. This new revolution, unmanned aircraft systems (UAS) or “drones”, and has begun to revolutionize law enforcement, commerce, and delivery transportation by providing a new tool not seen before. Systems weighing less than 55 pounds are formally known as small unmanned aircraft systems (sUAS); and the most common systems for commerce use. With any delicate system, the addition of a new transportation method will take time and effort to understand the dynamical effects on the airway and transportation system.

The possibilities for the different uses cases for sUAS are boundless and only withheld by the imagination of visionaries pushing the industry and safety mandated regulation. Many of the use cases require conducting operations over moving vehicles. Current regulatory stature, Code of Federal Regulation (CFR) Part 107.39, prohibit operations over moving vehicles (FAA, 2016). Unless the operators have received a waiver from the Federal Aviation Administration (FAA). Certain operations benefiting from the availability to conduct operations over traffic include law enforcement, local and state authorities, and commercial delivery services.

sUAS Use Cases

Law enforcement are just beginning to incorporate sUAS capabilities into their arsenal of tools. Using sUAS as a traffic monitoring tool can be an improvement over other, more commonly used traffic monitoring techniques, such as patrol officers, camera, and helicopters. An idling patrol car on the side of the road increases emissions, risk of a passing vehicle striking the patrol vehicle, or causing increased congestion on the roadway. Using a helicopter to monitor traffic is extremely expensive, with operational cost between $200 - $600 per hour (AOPA, 2019). Using electric powered sUAS reduces this cost and emissions for traffic monitoring in lieu of standard practices.

The use of sUAS as a tool to inspect roadway infrastructure presents several solutions to current methods. For transportation agencies to inspect bridges, current methods require the closure of the roadway for traffic, while often risking the well-being of an inspector. By using sUAS to do this job it does not risk the well-being of a worker or interrupt traffic flow. Small UAS can assist in the planning of road construction by surveying the site to produce three-dimensional modes, transforming the way delivery of luxury and time critical items.

Commercial delivery services like Amazon, UPS, and Wing Aviation are changing home package delivery around the world. This is an exciting time for package delivery within the sUAS industry. The possibility of being able to deliver time-sensitive medical supply to remote areas are lifesaving**.** The first out-of-line-sight medical supplies carrying Wal-Green's products delivered products using UPS carrier operators in Christiansburg, VA (EnsembleIQ, 2019). Conversely, before sUAS operations can be fully integrated into the transportation system their effects on the rest of the system must be studied to ensure safety as a top priority. A major concern for these operations is the possibility they may present an additional distraction to terrestrial drivers.

The National Highway and Transportation Safety Administration (NHTSA) operationally defines distracted driving as, "Any non-driving activity a person engages in while operating a motor vehicle. Such activities have the potential to distract the person from the primary task of driving and increasing the risk of crashing" (IIHS, 2019, pp. 1-3). NHTSA makes a distinction between internal distractors that are sourced within the vehicle (e.g., cell phone, eating, and selfcare) and external distractors (e.g., staring at an accident while passing, billboards). The scope of the current article will focus on external driving distractors.

Distracted Driving

There are three categories of distracted driving: cognitive (deeply thinking about other situations or activities other than driving), visual (removing the eyes from the road), or manual (removing the hands from the wheel). The probability for an accident increases more than two-fold when extraneous strain in placed on the attentional system; 23% of metropolitan vehicle collisions occur because of a visual distraction (Hurwitz, et al., 2018; Klauer, et al., 2006). Cognitive distractors pull attentional resources from the performance of driving and visual distractions pull sight away from the activity of driving.

External driving distractions are stimuli that are a source of distraction originating outside the vehicle. Roadside distractions, like billboards, pull the driver's sight from the road are visual distractors. Fast moving objects provide increased distractions to focal attention, especially those that violate expectations for the environment (Farkas, 2013; Summer & Egner, 2009), creating a perturbation on the mental effort allocated to driving. Attentional resources are finite and depletes resources for the primary task (Allport, 1989).

Visual distractions are an issue but may also provide a biological indicator for the complexity of mental effort and strain on the finite system. Previous research indicates that more than two seconds of driving without looking at the road doubles the chance of an accident (Klauer, et al., 2006) and meet the criteria for visual distraction. In context, a driver who removes their eyes from the road for two seconds while driving 45 mph covers the approximate size of an American football field (44 yards) without looking at the road. Measuring fixation locations can provide insight into the visual distraction from sUAS but it may be more insightful to measure the attentional system through saccade speeds over time while passing under a sUAS to infer strain on the human system but allocating cognitive resources can also cause a distraction while driving.

People are curious about new technologies, especially, technology that captivated the imagination of the pubic, such as sUAS. If people see a hobbyist flying a sUAS, they will often stop and watch, as they are curious and want to know more about this new technology. Thus, individuals should also be curious about sUAS while driving, creating a pull from equilibrium on the human-in-the-loop (HITL) system. A limited number of studies have considered the issue of distracted driving from sUAS.

The two studies that have looked at such issues have reported sUAS operations with small lateral offsets from the roadways did increase the number of concentrated glances (Hurwitz et al., 2018; Ryan, 2019). Previous studies have evaluated the operational environment and the level of distraction with rural areas having a larger effect than urban settings (Ryan, 2019). Perhaps, rural environments already have less distractors, making the sUAS more noticeable.

Previous literature conducted operations along the roadside with various lateral offsets indicating the further from the roadside the less distraction to drivers. The sUAS was a target for fixation with 38% of participants glancing longer than two seconds (Hurwitz et al., 2018). These studies did not consider operation over traffic for applications at higher operational altitudes. Researchers also conducted flight paths at an altitude of 26 to 60-foot above ground level (AGL) which is much lower than these operations would take place in real world applications, reducing the external validity of the study. Thus, the current study postulated two improvements to this body of literature. First, increasing external validity by measuring altitudes more realistic to sUAS operation over traffic, while excluding the visual operator. Second, an ecological measure of HITL environmental complexity instead of a threshold cutoff statistical approach.

This research investigates if the presence of a sUAS flying over traffic increases the complexity of the environment for HITL factors producing the following hypotheses.

H_1: A majority of the sample will not fixate on a sUAS longer than two seconds.

H_2: Altitude will have a significant effect on fixation duration with participants fixating on the lower altitude longer.

H_3: The complexity of driver scan patterns will increase with encounters of sUAS operations while driving, evident by the dimensional increase in the multifractal spectrum.

H_4: The continuous wavelet transformations will be indicative when the system comes under strain.

H_5: Participants will deviate in their lane near encounters with sUAS.

A more ecological approach conceptualizes vison as a complex perceiver-environmental interaction (Gibson, 1986). Visual perception is a large system with many sub-systems, working under the understanding that the visual system provides insight into the patterns of the system. If these systems are infinite ratioed systems, then patterns become fractal in nature. The possibility exists that traditional cognitive theories may only test context effects, thus as the context becomes more complex so does the whole system as perturbation variables try to bring the system into chaos (Gignoux, 2016). A dynamical system is always between equilibrium and chaos. When a new environmental variable pulls the system toward disorganization (perturbation), the system self-organizes around the variable pulling the system back to equilibrium (attractor). These are patterns of emergence and are signs of a dynamical system

(Gignoux, 2016). The attractor in the system is the task at hand (driving); but can an unfamiliar object (sUAS) operating in the environment create a strong enough perturbation to strain the system, if in fact these operations are causing a distraction to drivers? Fractal analysis can detect these subtle fluctuations in the system.

The more fluctuation in the system (time series data) the more fractal dimensions are present after analyzing the data with a multifractal detrended fluctuation analysis (MFDFA). The number of fractal dimensions may influence the amount of information the perceiver retains from the environment (Farkas, 2013). With the recording of eye movements inference can be made as to the increase in complexity of the human element in the system. As complexity increases, evident by the fractal dimensions, the opportunity for an accident increases.

Multifractal Detrended Fluctuation Analysis

Previous studies in sUAS have been testing environmental acuity and not the increased complexity of a stimulus (i.e., how well the participant notices change in the environment; Farkas, 2013). Different scan pattern approaches have different effects on the collected measurements. A few approaches in traditional cognitive theories have emerged to explain the behaviors observed during visual search but are unable to explain perceiver-environmental interaction.

One of the tools available from the non-linear dynamic's toolbox is a method called MFDFA. The analysis is composed of many computational intense calculations to evaluate the roughness of a time series data set. Variations between the data points define roughness in a time series data set and the application of MFDFA must adhere by a few preliminary assumptions before applying the method. These assumptions include whether the time series data is a noise like or random walk, if the data is mono- or multi- fractal, and the data must be non-stationary;

meaning no constant variance or mean is present in the data. The local root-mean-square variations is the quantitative methods to distinguish the type of data. A random walk conversion is necessary if the time series is noise like. A noise time series is the type of data seen from sound frequencies as seen in Figure 1. A monofractal time series has smooth transitions between the large variations and a multifractal has small local fluctuations in-between the large variations (Ihlen, 2012). Figure 2 displays a graph depicting a monofractal or a multifractal time series. Self-similarity fractal shapes are visually appealing, but Fractal Geometry also applies to rough geometric shapes that are not self-similar, for example time series data or the coastline of Brittan (Mandelbrot, 1967).

The current study used the root-square-mean (RMS) approach to finding the multifractal dimensions in the spectrum. If the data has high oscillating behavior then using the RMS approach preserves the integrity of the data (Ihlen, 2012). Measuring saccade speed data will use RMS approach to create the multifractal spectra. Other time series analysis such as ARIMA modeling use RMS approaches for modeling purposes. In a detrending analysis each segment has its own RMS calculation, capturing the variations in each segment instead of the whole time series at once. The logarithmic transformations of the variations and the holder exponent can graphically meet the assumption of multifractality. To meet the criteria for multifractal dimensions the graph of the log-log plot must have a S shape across a linear regression line (Ihlen, 2012). The function of the log dimensions calculation (D) and the holder exponents (h) graphed as a function of the q-sorts provides the multifractal spectra.

The RMS will be used to calculate the holder exponent, in conjunction, a continuous wavelet transformation modius maximums (CWTMM) uses the logarithmic wavelet transformation to find the local minimums and the local maximums (Muzy, et al., 1991). The “m” value will be equal to 2 a recurrence rate of iteration set at two to capture the fluctuations of the system. The q-sort scale the scale should be set to the lowest number of the scale larger ten 10 (rule of thumb) the larger number for the scale should be no less than the 1/10th the size of the timeseries with the appropriate adjustments to ensure equal observations in each segment.

Correlational heat maps of the wavelets can give a good graphical indication when the system came under the influence of a perturbation variable and when the system realigns as seen in figure 3 (Likens, et al., 2014). The multifractal spectrum is a graphical representation of the quotient between the average maxima multiplication and the average scale factor (Muzy, et al., 1991). Thus, A CWTMM will graphically represent the saccade speeds during the scenario to understand when the visual/mental system was influenced by a distracting variable. The comparison of isolated Multifractal spectrum of the complexity of saccade speed are compared within subjects during encounters of typical natural distractors while driving (e.g. pedestrians) and encounters with sUAS flying over traffic.

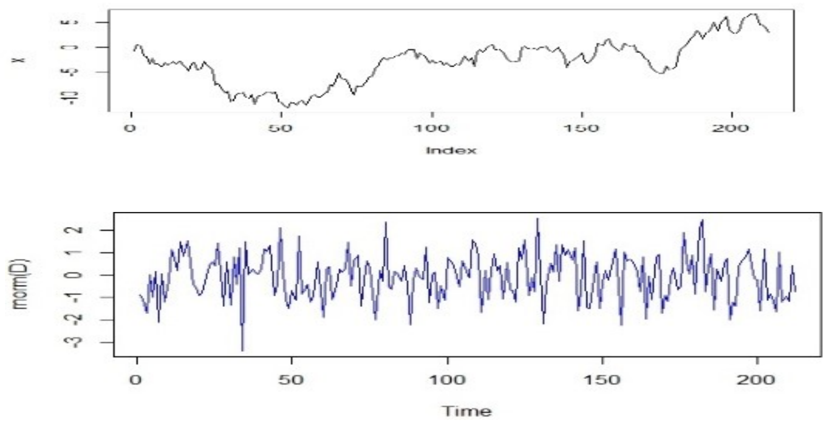


Figure 1. The bottom graph shows an example of a noise like time series. The top graph shows an example of a random walk.

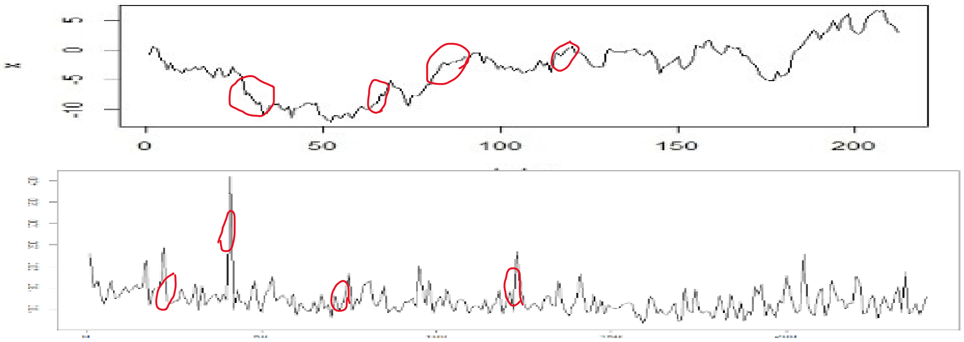
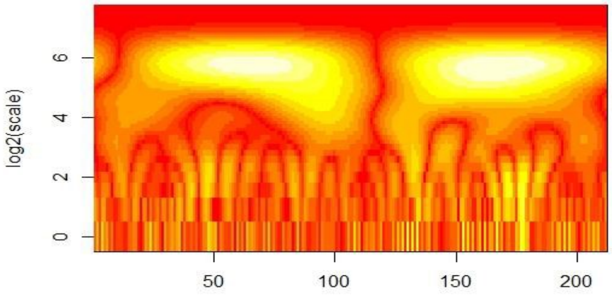


Figure 2. The graph at the top indicates a multifractal time series and the graph on the bottom depicts a monofractal times series. Both graphs have variations with peaks and valleys. The variations between the peaks and valleys defines the difference between the type of fractal data. Data with many variations between the peaks is a multifractal and smooth transactions between the peaks is a monofractal.



` *Figure* 3. A correlational heat map from a continuous wavelet transformation modius maximus. The system has self-similarity in two parts and was disrupted at the middle portion of the graph this is where the system became under the influence of a perturbation variable. In other terms the break indicates the manipulation of the independent variable.

Method

The complexity of saccade speeds over time were recorded during the entire driving scenario through an urban setting and graphed by the wavelet transformations for inference of how the human system has organized around the activity of diving. Furthermore, the complexity during the encounters of sUAS operations and natural stimuli encounters were compared within-subjects to understand if the presence of a sUAS increases the strain on the human visual system.

To evaluate hypothesis number one the time a driver fixates on the sUAS was recorded by eye tracking software and investigate the portion of drivers who had a fixation on the sUAS longer than two seconds. Lane deviations were recorded during the driving scenario by the simulator.

Participants

Participants consisted of a sample of convenient available participants during the current pandemic that were at minimal risk for contracting or spreading COVID-19. Total sample included 20 driving aged adults with a state-issued driver's license. Age ranged from 18 – 56 years old with an average age of 32.8 years (*SD* = 11.73 years). Years of driving experience ranged from 1 to 39 years with an average of 15.7 years (*SD* = 11.89 years). All participants had normal or corrected to normal vision, as indicated by the eye exam required to obtain a state-issued driver's license, participants provided a valid and current driver license before beginning the study.

Materials

The research was conducted using Python CARLA library for the software of driving simulator. The typical use for the library is to test autonomous vehicle algorithms, but the author adopted the code to work as a manual driving simulation an operated on an Alienware computer and displayed on a 50 ultra-high-definition monitor. Smart Eye wearable glasses collected and record eye tracking data.

Simulator equipment

A gaming simulation driving setup provided a cockpit for the participant for all driving scenarios (*see* Figure 4). The simulator cockpit was constructed from wood and a seat from a Mazda RX-8. The whole base measured 55 inches long and placed on wheel casters setting at a height of nine inches. An addition smaller base of nine inches tall provided a mounting platform for the seat. The bottom of the seat was 18 inches off the ground. One of the issues to creating a realistic simulation is the visual perception of a target in the simulation is perceived to be at the same distance as the target would be in real life. Since the target on the screen is much closer to the participant in the simulator than the target would be in real life the use of visual angle provides the same retinal image as the object would at the distance seen in reality (Levin & Haber, 1993). When a person looks at an object, the image is projected onto the retina. To simulate distance the image on the retina must be the same size in the simulator as the project image would be when observing the object in a real environment.

Biological evidence supports objects seen at the same visual angle elicits similar responses in the visual cortex (Murray, et al., 2006). Thus, by calculating the visual angle of the image between the line of light entering the retina; the size of the retinal image becomes a ratio (*see* Figure 5*).* To accurately simulate a sUAS at the altitude of 100-foot and 150-foot AGL the sUAS will need to be placed at 385 foot in front of the vehicle to not be obstructed by the roof of the vehicle. A five-foot wide delivery drone, the size of the current Amazon delivery drone will be the primary model used in the simulation (D'Onfro, 2019). A sUAS at 150-foot AGL, placed

385 foot in front of the vehicle provides a relative distance of 406 foot creating a visual angle of 2.984 degrees.

In the simulator the image on the screen will be four-foot from the participant's eye, resulting in the size of the sUAS on the screen to be 2.5 inches for sUAS at the 100-ft altitude and 1.5 inches in the 150-foot encounters. As seen in *Figure 6,* an example of a sUAS operation during the driving scenario at an altitude of 100-foot.

The Simulator collected data on the participant driving behavior such as, lane deviation and steering wheel inputs. Smart Eye wearable glasses collected scan behaviors from participants as they drive the scenario. The simulator software was program using the Python CARLA driving simulator library.

Figure 4. The driving simulation component will provide a similar experience to operating a motor vehicle.

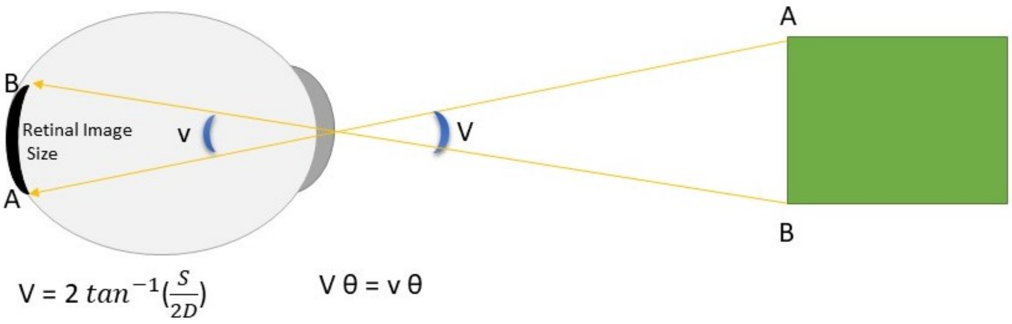


Figure 5. The figure displays a diagram of visual angle as a eye views an objectand the formula for a visual angle calculation.

Figure 6. A screen shot of a third person view during a sUAS operating over the vehicle.

Procedure

The participants were provided informed consent, immediately following the participant's arrival at the study location. A verbal briefing introduction was provided by script to the participants (*see* Appendix B). After the briefing, the participant drove a 5-minute driving scenario to assimilate to the simulator. During the training scenario the participant performed all the driving maneuvers required to drive the study scenario, such as stopping at stop lights, yielding to other traffic, and following driving directions. The training simulation did not include the sUAS the participant would later see in the study but did include other cars and pedestrians. Before the commencement of the study the participant had opportunity to take a short break. The participants drove an approximate 15-minute driving scenario through an urban setting. The participants were instructed to drive as they usually would, following traffic laws. The driving path was predetermined for the participants and indicated to the driver by following voice commands simulating an in-car GPS system.

During the driving scenario the participant encountered a total of four sUAS operations; two at 100-foot AGL, and two at 150-foot AGL. The driving simulator will consist of various intersections where the driver will have to interact with other traffic, traffic lights and pedestrians. While the participants are driving visual patterns were recorded to see where the participant is gazing and driving performance was recorded (driving lane deviation). At the conclusion of the driving simulator the participants filled out a post-test questionnaire asking their thoughts on sUAS and sUAS operations near roadways (*see* Appendix A).

Results

Eye Tracking

Fixation Duration

Eye tracking software collected glance behavior during the driving simulation. To evaluate hypothesis number one: A majority of the sample will fixate on the sUAS longer than two seconds. Three participants (15%) glanced at a sUAS longer than two seconds, did so when the sUAS was at the lower altitude (100 AGL). The average time participants glanced at sUAS in the 100 ft AGL condition across both encounters was 1.13 seconds (*SD* = 0.53). No participants glanced at the sUAS at 150 AGL longer than two seconds with seven participants (35%)

glancing at the higher altitude sUAS across nine encounters, the average time for those encounters were 0.6 seconds (*SD* = 0.3). A majority of participants did not glance at a sUAS encounter longer than two seconds (N = 15; 75%).

When comparing lower to higher encounters, the lower altitude encounters had significantly longer fixation durations (F (1, 19) = 58.90, $p < 0.0001$, $\eta^2 = .76$). Background cluster did not have a significant effect on glance behavior of the participants (F (1, 19) = 0.5, $p = 0.83$).

Complexity of Saccade Speeds

Saccade speeds were recorded and compiled during the driving simulation. To evaluate hypothesis number three: The complexity of driver scan patterns will increase with encounters of sUAS operations while driving, evident by the dimensional increase in the multifractal spectrum. Three participants (15%) displayed pattern of increased complexity while driving near a sUAS encounter with four displaying a slight increase (20%), totally seven participants with any increase in complexity measure (35%). Figure 7 displays the multifractal spectra from participant 10 who showed the most increase in complexity of saccade speeds. The majority of the participants did not display behavior considered to be distracted driving but when examining individual complexity, the multifractal spectra does show an increased strain on the system during encounters with a sUAS. Figure 8 displays continuous wavelet for participant 10, indicating the visual system was placed under stain from a perturbation of the sUAS during the three encounters of sUAS (*see* Appendix (F) Multifractal Spectra graphs).

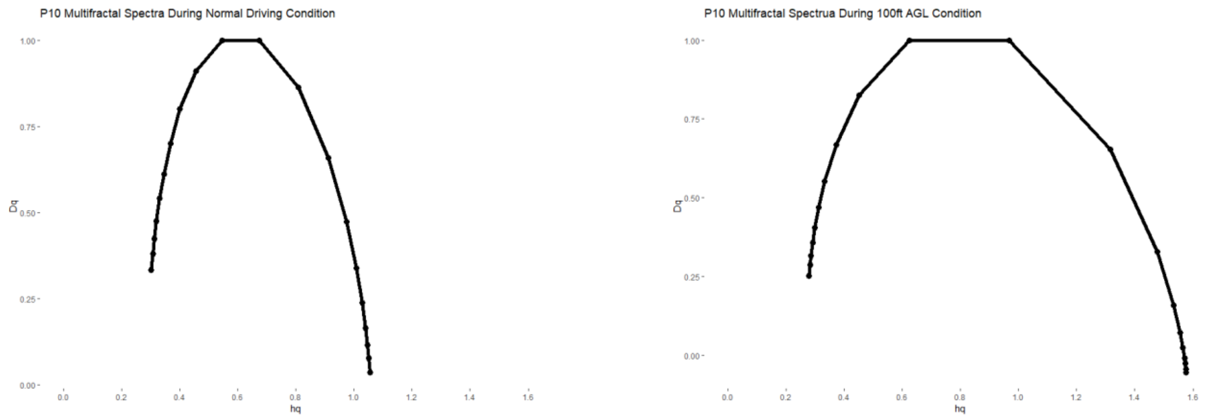


Figure 7. Comparision of the multifractal spectra for saccade speeds between normal driving condition and while passing a sUAS for participant number 10.

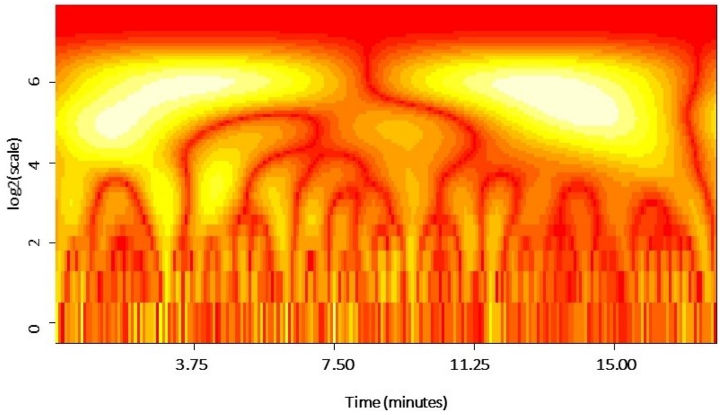


Figure 8. CWTMM wavelet during participant number 10 driving scenario.

Driving Performance

Lane deviations were recorded throughout the driving scenario to understand if drivers deviated in their lane during encounters with a sUAS present. No driver crossed the centerline during the driving scenario, participant four deviated the most (2.56 feet). The deviation was caused by a pedestrian crossing the road in a non-crosswalk location. The scenario was not programed into the simulation and may have been a glitch in the application programming interface (API). Extreme lane deviation was not an issue near sUAS encounters; however, three participants did exhibit deviation near the lower altitude sUAS encounters (*see* Figure 9).

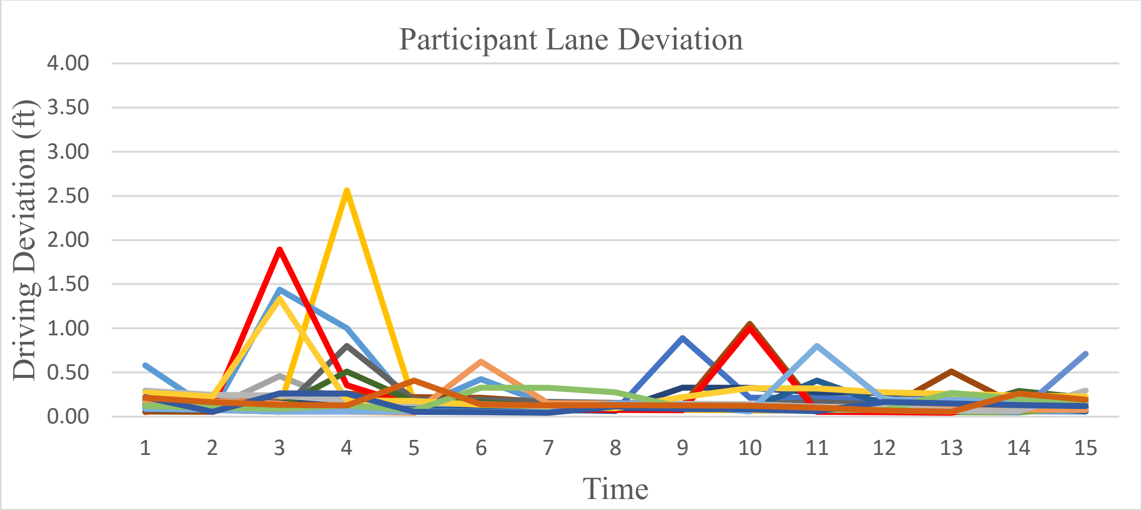


Figure 9. Lane deviation for all participants during the driving simulation. Survey Results

Survey Results

Each participant provided feedback from a post-study survey (*see* ***Error! Reference source not found.***). Six participants out of the 20 (30%) have seen a sUAS in flight. These participants scores on a five-point Likert scale as to how curious they were in the sUAS average 3.67 (*SD* = 1.21). A single participant reported they had seen a sUAS near a roadway and indicated a three as to how curious they were about the sUAS while driving. When asked to rate if sUAS should be allowed near roadways on average participants reported 3.15 (*SD* = 1.04) on a five-point Likert scale. When asked if they would feel comfortable driving under a crossing sUAS the participants answered an average of 3.05 (*SD* = 1.00) on a five-point Likert scale. When asked if the recent advancement in drone technology excites the participants, they report on average 2.80 (*SD* = 1.11) on a five-point Likert scale. Some of the participants reported strong feeling on the subject but on average the participants in the study were indifferent to the sUAS operation near roadways.

Discussion

Other researchers are considering the effects sUAS will have on existing terrestrial driving operators. As mentioned earlier, Ryan (2019) and Hurwitz et al., (2018) tested experimentally the effects of sUAS operation over vehicle. However, their research considered operations at much lower altitudes than sUAS operation will take place in a real-world scenario. This is also a recommendation that came from an FAA report that interviewed professional sUAS operators, the operations should take place at the highest possible safe altitude (Thompson et al., 2020). The current research expanded on this research by applying a dynamical system perspective in the analysis methods and increasing external validity by expanding on the more real-world altitudes sUAS operations will take place.

The research provides some conclusions and adds to the limited body of research on the possible strain sUAS may pose on the existing transportation system. Conclusions based on the current study suggest that sUAS will not cause a significant distraction to most drivers. Furthermore, a recommendation provided from these results suggest that the higher the altitude a sUAS operates, the less of a distraction the sUAS will impose on drivers. These finding are in line with a recent technical report by the FAA's William J. Hughes Technical Center which also provided similar recommendations (Thompson et al., 2020). The empirical evidence provided through this study supports the recommendation and provides an additional layer of empirical research related to this matter.

Using a MFDFA as a measure of complexity to understand the strain placed on the attentional system provides more individualistic understanding of each driver rather than using standard parametric methods that aggregate data and sum away individuality. For example, participant number 10 displayed great increase in the complexity of saccade patterns while encountering the lower attitude sUAS in the environment. Participant Number 19 also displayed a major increase in the spectra width when comparing between a sUAS encounter and normal conditions. Participant Number 17 displayed the narrowest spectra with no change between normal driving conditions and encountering a sUAS. Participant Number 12 displayed the most unique shaped spectra, specifically the spectrum during no sUAS condition. This observation may provide the strongest evidence to the presence of an attractor creating complexity and showing the vast difference between randomness and complexity. With complexity, patterns emerge, usually around an attractor. Randomness does not show underling pattern and the spectrum does not display patterns of complexity (i.e., a narrow width spectrum). The spectrum generated from Participant Number 12's encounter with a sUAS becomes more organized into complex patterns indicating patterns of emergence and organization around an attractor, this might be the best example of random saccade patterns and complex saccade patterns.

Parametric statistics indicate no significant effect on drivers from sUAS near roadways, especially as altitude increases. However, using MFDFA as a measure of complexity the spectra indicate some drivers will have additional strain placed on the attentional system. The additional strain observed from the spectrum of the participant's saccade patterns do not seem to deplete resources to the point of significantly increasing the risk of an accident. Conversely, these examples provide insight as to how saccade patterns organize around an unexpected object in the environment. Additionally, the low percentage of drivers who did experience increased strain on the attentional system lends evidence to support sUAS will not increase the risk of an accident to levels beyond what other lawful external distractors present, such as digital billboards.

The gaze patterns observed during the study lend support to the negative relationship between attentional strain and sUAS altitude. Lending further support sUAS will cause less distraction at higher altitudes. A recommendation to reduce possible distractions from sUAS to drivers is to operate the sUAS as close to the 400-foot limit as is feasible. The higher the altitude, the less sUAS operation may cause a distraction to drivers. Safety is rarely based on zero risk solution but an acceptable risk level of comparing the benefit to risk ratio. The civil applications may be more beneficial to society than the risk proposed. The evidence suggest sUAS operations over moving vehicles will pose no more than minimal risk to terrestrial drivers. This research suggests sUAS will not pose extraneous strain on the existing terrestrial transportation system, although additional research is required. For instance, future research should investigate what potential risk may be associated with a failure condition. What is the risk of damage to persons or property if a sUAS has an emergency situation and what safety measures could reduce the associated risk? From available literature and evidence from this study the author concludes sUAS operation should be allowed near roadways with precautions, such as flying at higher altitudes with additional fail-safe systems, and when possible warn drivers a sUAS operation is being conducted in the area.

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Appendix (A) Survey

Survey Question

Please answer or rate the following on a one to five scale, one indicating completely disagree/never to five completely agree/always.

1) How old are you?
2) How long many years have you had a state issued license?
3) Have you ever seen a drone flying in person before?
    a. If yes, I was curious about what the drone was doing?

       ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

    b. If yes, I was curious enough about the drone to watch it fly.

       ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

4) Have you seen a drone fly near a roadway?
    a. If yes, I was curious about the purpose of the drone.

       ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

    b. If yes, I tried to watch the drone flying.

       ○ 1 ○ 2 ○ 3 ○ 4 ○ 5

5) Do you believe drones should be allowed to fly near active roadways?

○	○	○	○	○
1	2	3	4	5

6) Would you feel comfortable driving under a drone as it was crossing the roadway?

○	○	○	○	○
1	2	3	4	5

7) Does the recent advancement in drone technology excite you about future implications of the technology?

○	○	○	○	○
1	2	3	4	5

Appendix (B) Introduction Script

Welcome to the study, thank you for participating today. Before beginning, please take a copy of the information I am about to read to you verbally. The information provides my contact information as well as the UCO IRB if you have any questions or concerns about today's study. Today you will be driving in a simulation of a typical urban environment. The total time for the research study will last no longer than 60 minutes. As you drive, various measures will be recorded. Such as the location you are looking on the screen, lane deviations, and speed variations. We will start with an eight-minute driving scenario for you to get use to using the controls and physics of the simulator. After the training scenario you may use have a break a short break before starting the study driving scenario. The study will last about 15 - 20 minutes to drive the complete scenario.

As you drive through the city, please drive as you usually would, following all traffic laws and watching for pedestrians. For this reason, you are encouraged to view as much of the frontward facing environment from the driving seat.

At the conclusion, of the driving scenario you will be provided a survey that will ask you questions related to your age, driving experience, and objects you may have seen during the driving scenario. As well as your opinion related to roadway laws. I would like to remind you that you may withdraw from the study at any time without penalty; however, class credit will be granted based on the amount of the study completed. Your continued participation indicates consent to participant in the study.

If you decide to proceed with participating in the study, please note all the data will be associated with a participant ID and not connected to you. All information collected during the study is confidential, data presented in an article or presentation will be presented in aggregated form. Further participation is indication of consent and agreeing to participate in research as part of an authorized research program of the University of Central Oklahoma, under the supervision of Dr. Mickie Vanhoy. The purpose of this study is to examine the effects of environmental situation on the effect of eye movements. During the study eye tracking software will record your glance behavior and the location of your gaze. If you have any questions about this study, I may contact Mickie Vanhoy, Ph.D.,mvanhoy@uco.edu, or Theodore Mofle tmofle@uco.edu. I may also contact the Research Administrator at experimentrak@uco.edu. If I have any questions about my rights as a research participant, I may contact the Chair of the UCO Institutional Review Board by phone, at (405) 974-5479 or by email at irb@uco.edu.

I would like to remind you while continued participation is indication of consent this includes not only consent to participant but also consent to have eye movement recorded. In no way will your eye movement data be able to identify you. The data from the current study will be kept on a password protected computer and kept for the duration of the project, including the document write-up, approximately one year from the conclusion of the data collection portion of study. Further participation involuntary and you may remove yourself from the study at any time, without penalty. If you do not have any question at this time let’s begin the training scenario.

Researcher Contact Information:
Theodore Mofle
tmofle@uco.edu
405-549-1849
IRB contact Information:
IRB@UCO.edu
405-974-5479

Appendix (C) R Code for Spectrum

```
library(wmtsa)

library(MFDFA)

library(ggplot2)

library(readr)

library(tidyverse)


View(rt12)

ts.UAS12 <- as.ts(X12_UAS)

ts.noUAS12 <- as.ts(X21_noUAS)




ts.x<- ts(pup12)

class(ts.x)

plot(ts.x)

x_cwt <- (wmtsa::wavCWT(ts.x, scale.range = deltat(ts.x) *

                          c(1, length(ts.x)), n.scale = 100,

wavelet = "gaussian2" , shift=5, variance=1))

class(x_cwt)

plot(x_cwt)

x_tree <- wmtsa::wavCWTTree(x_cwt, n.octave.min = 1, tolerance =

0, type = "maxima")

plot(x_tree)
```

```
linchirp <- wmtsa::make.signal("linchirp")

x_holder <- wmtsa::holderSpectrum(x_tree, n.scale.min = 3, fit

=) # fit can equal lmsreg

print(x_holder)




ts.x<- ts(pupn12)

class(ts.x)

plot(ts.x)

cusps <- function(x) -0.2*abs(x-1)^0.5 - 0.5* abs (x-15)^0.3 +

0.00346 * x+1.34

x<- seq(-5,20,length = 240)

y<- signalSeries(cusps(x), x)

x_cwt <- (wmtsa::wavCWT(ts.x, scale.range = deltat(ts.x) *

                          c(1, length(ts.x)), n.scale = 100,

wavelet = "gaussian2" , shift=5, variance=1))

class(x_cwt)

plot(x_cwt)

x_tree <- wmtsa::wavCWTTree(x_cwt, n.octave.min = 1, tolerance =

0, type = "maxima")

plot(x_tree)

linchirp <- wmtsa::make.signal("linchirp")

x_holder <- wmtsa::holderSpectrum(x_tree, n.scale.min = 3, fit

=) # fit can equal lmsreg
```

```
print(x_holder)

x1.holder<- holderSpectrum (x_tree)

plot (x,y, xlab = "time", ylab = "linchirp")




ts.UAS12<-as.ts(UAS12)

scale=10:100

q<--10:10

m<-1


UAS12<-read.csv("12_UAS.csv")

ts.UAS12 <- as.ts(UAS12)


noUAS12 <- read.csv("12_noUAS.csv")

ts.noUAS12 <- as.ts(noUAS12)


MFDFAUAS12<-MFDFA(ts.UAS12, scale, m, q)

plot(MFDFAUAS12$spec)


MFDFAnoUAS12<-MFDFA(ts.noUAS12, scale, m, q)

plot(MFDFAnoUAS12$spec)


ts.noUAS12 <- as.ts(noUAS12)
```

```
MFDFAnoUAS12<-MFDFA(ts.noUAS12, scale, m, q)
plot(MFDFAnoUAS12$spec)


ggplot(data = MFDFAnoUAS12[["spec"]], mapping = aes (x = hq, y =
Dq)) +
  geom_point(size = 3) +
  geom_path(mapping = aes(x = hq, y = Dq), data
=MFDFAnoUAS12[["spec"]], size = 2) +
  scale_x_continuous(breaks = seq (0,1.6, by = 0.2), limits =
c(0,1.6))+
  theme(panel.background = element_blank()) +
  labs(title = "P12 Multifractal Spectrum for No sUAS
Condition")


ggplot(data = MFDFAUAS12[["spec"]], mapping = aes (x = hq, y =
Dq)) +
  geom_point(size = 3) +
  geom_path(mapping = aes(x = hq, y = Dq), data
=MFDFAUAS12[["spec"]], size = 2) +
  scale_x_continuous(breaks = seq (0,1.6, by = 0.2), limits =
c(0,1.6))+
  theme(panel.background = element_blank()) +
  labs(title = "P12 Multifractal Spectrum for 100 Condition")
```

Appendix (D) IRB Approval Letter

UNIVERSITY OF
Central Oklahoma

November 23, 2020 IRB Application #: 2020-071

Proposal Title: Complexity of External Distractions from Small

Unmanned AircraftType of Review: Initial Review-Expedited

Investigator(s):

Theodore Mofle
Mickie Vanhoy,
Ph.D.

Dear Mr. Mofle and Dr. Vanhoy:

Re: Application for IRB Review of Research Involving Human Subjects

We have received your materials for your application. The UCO IRB has determined that the above named application is APPROVED BY EXPEDITED REVIEW. The Board has provided expedited review under 45 CFR46.110, for research involving no more that minimal risk and research Category 7.

Date of Approval: November 19, 2020

If applicable, informed consent (and HIPAA authorization) must be obtained from subjects or their legally authorized representatives and documented prior to research involvement. A stamped, approved copy of the informed consent form will be made available to you. The IRB-approved consent form and process must be used, where applicable. Any modification to the procedures and/or consent form must be approved prior to incorporationinto the study. At the completion of the study, please submit a closure request form to close your file.

It is the responsibility of the investigators to promptly report to the IRB any serious or unexpected adverse events orunanticipated problems that may be a risk to the subjects.

Please let us know if the IRB or Office of Research Integrity and Compliance can be of any further assistance toyour research efforts. Never hesitate to contact us.

Sincerely,

MPowers

Melissa Powers, Ph.D.
Chair, Institutional
Review BoardUniversity
of Central Oklahoma 100
N. University Dr.
Edmond, OK 73034
405-974-5497
irb@uco.edu

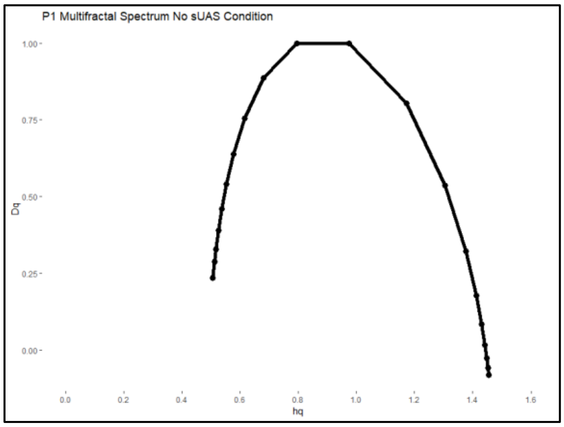
Office of Research Integrity and Compliance

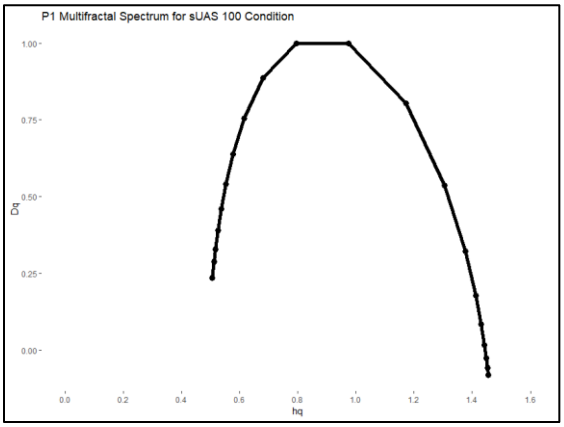
100 North University Drive / Edmond, OK
73034Phone (405) 974-5497 Fax (405) 974-
3818

Appendix (F) Multifractal Spectra

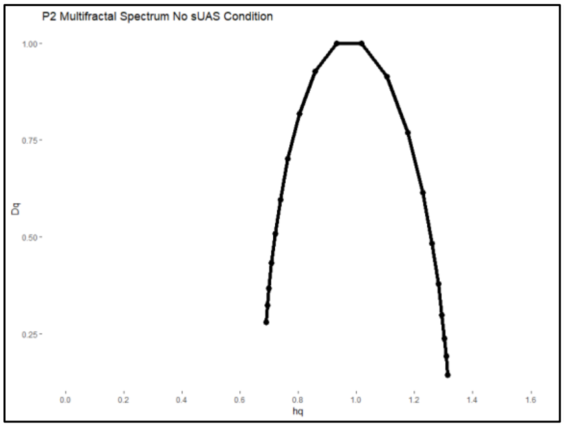
Full participant data sets and syntax are provided at tmofle.github.io.

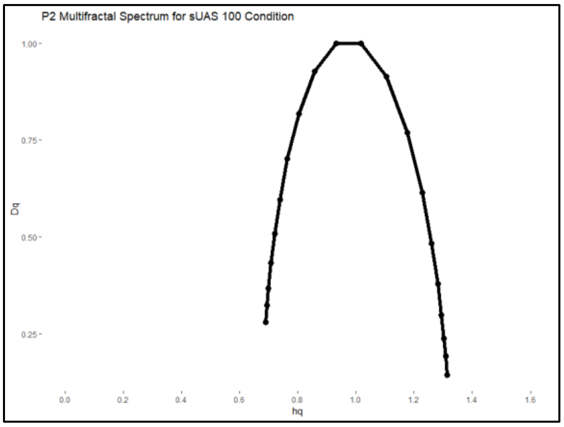
Participant 1





Participant 2





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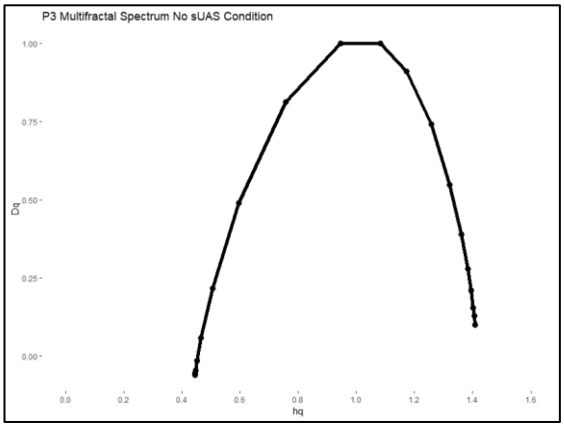
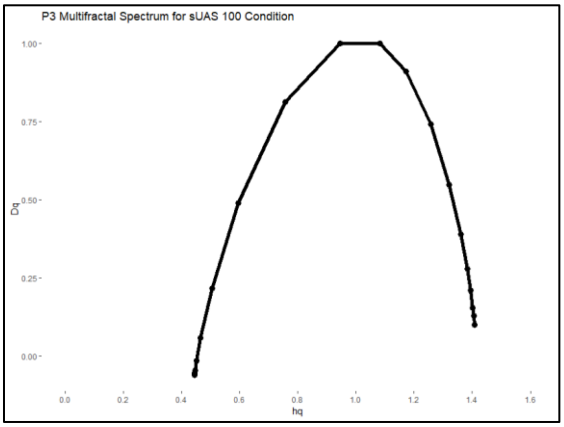
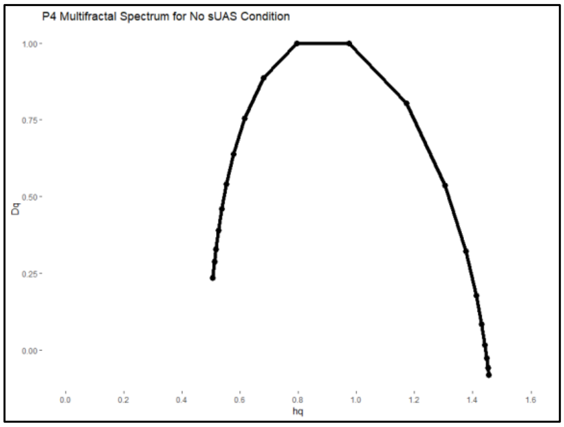
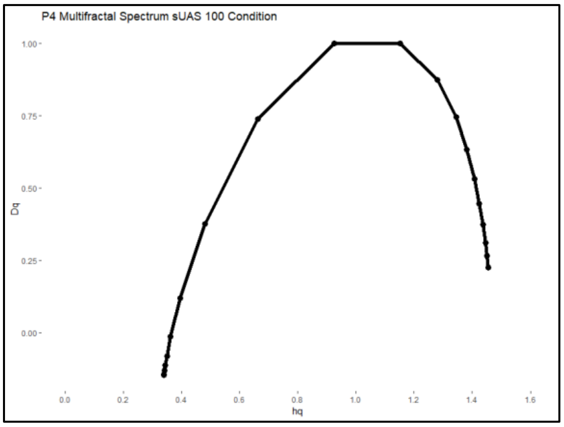


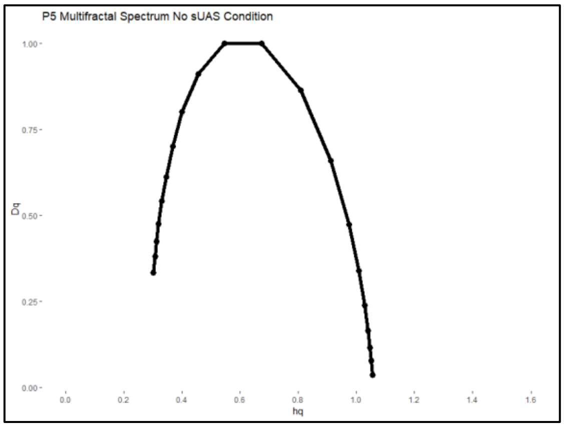


Participant 4


P4 Multifractal Spectrum for No sUAS Condition


P4 Multifractal Spectrum sUAS 100 Condition

Participant 5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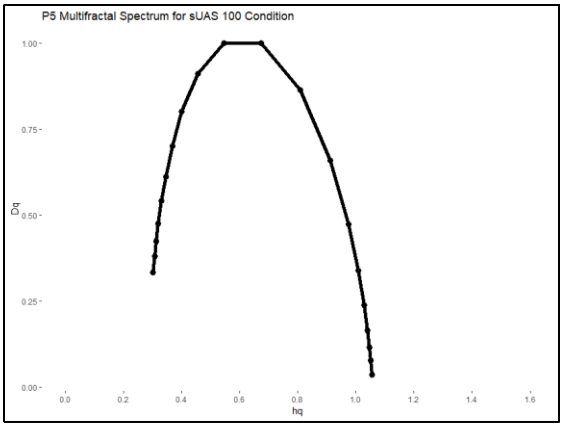
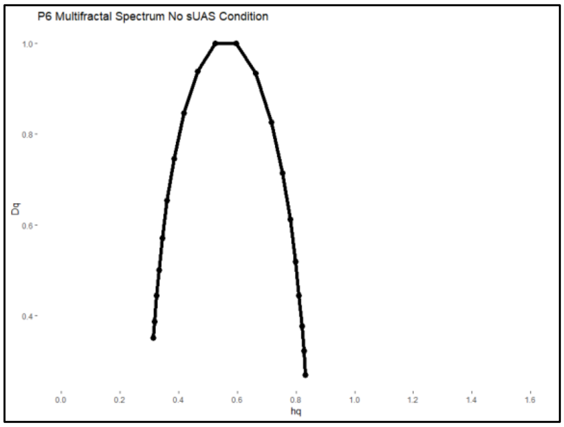

P5 Multifractal Spectrum for sUAS 100 Condition

Participant 6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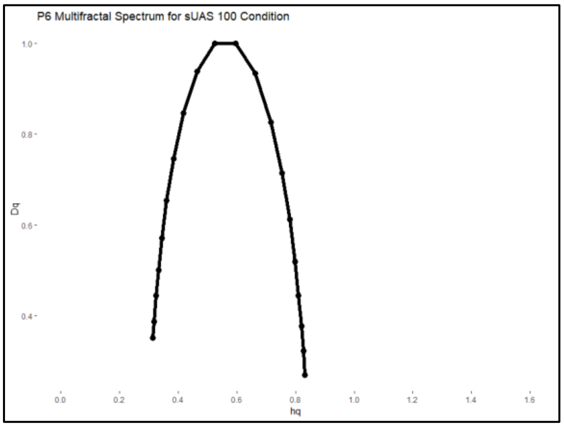
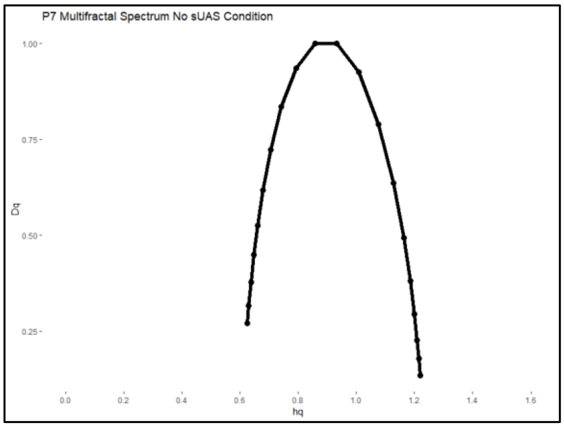
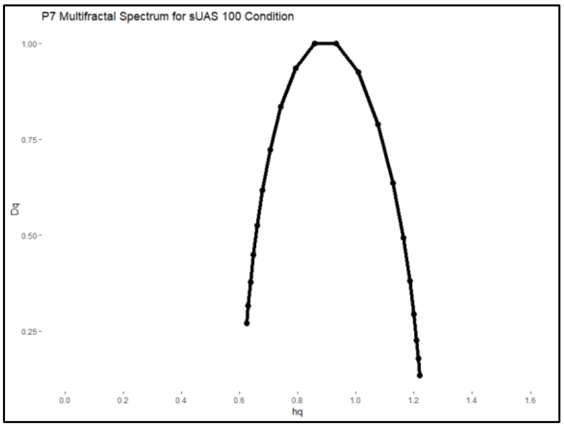
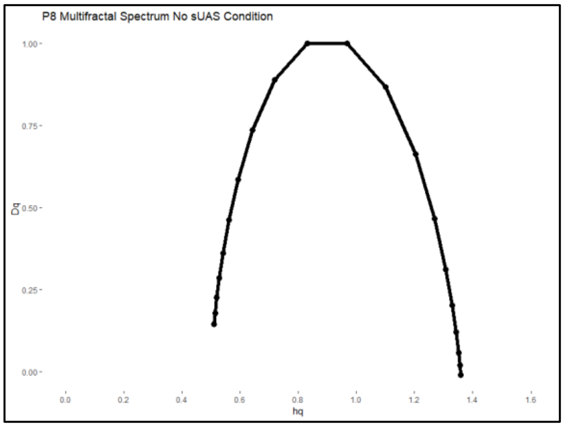

P6 Multifractal Spectrum for sUAS 100 Condition

Participant 7


P7 Multifractal Spectrum No sUAS Condition


P7 Multifractal Spectrum for sUAS 100 Condition

Participant 8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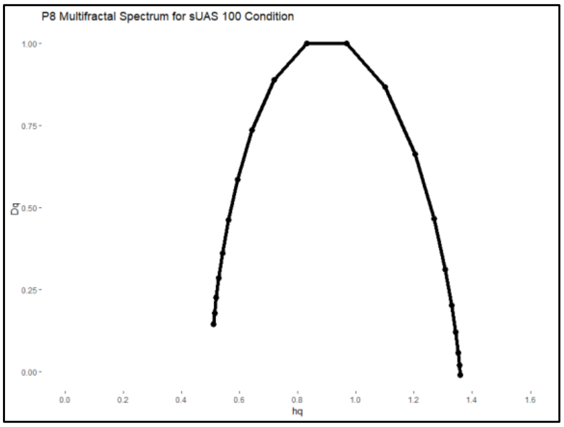
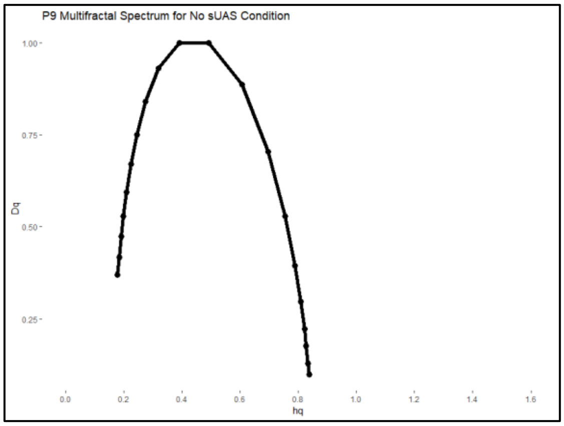

P8 Multifractal Spectrum for sUAS 100 Condition

Participant 9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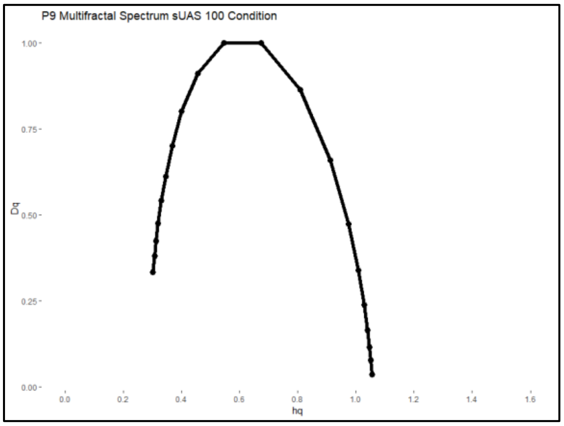
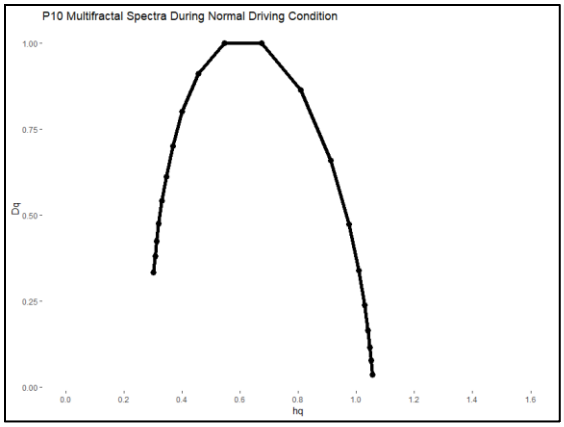
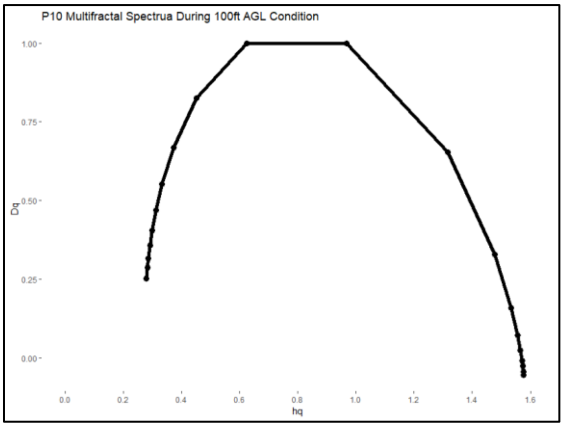
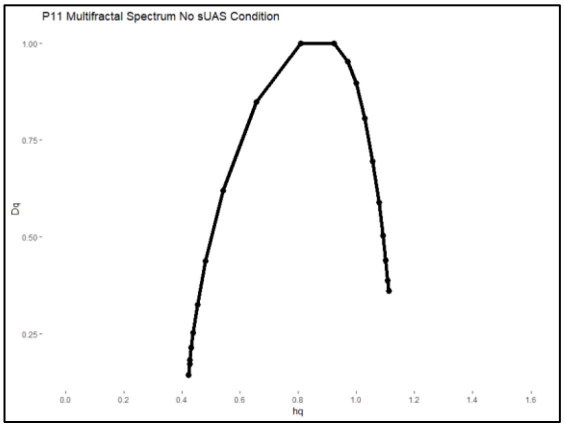

P9 Multifractal Spectrum sUAS 100 Condition

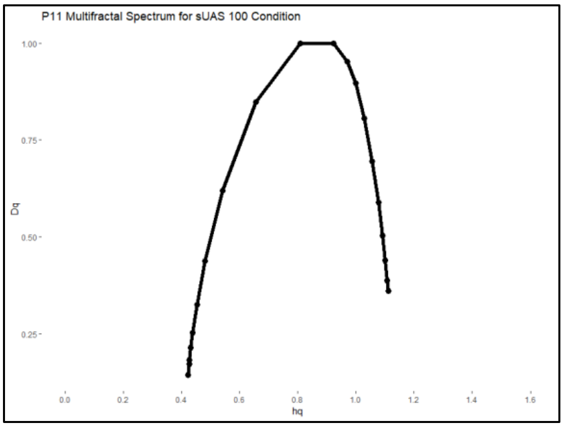
Participant 10


P10 Multifractal Spectra During Normal Driving Condition

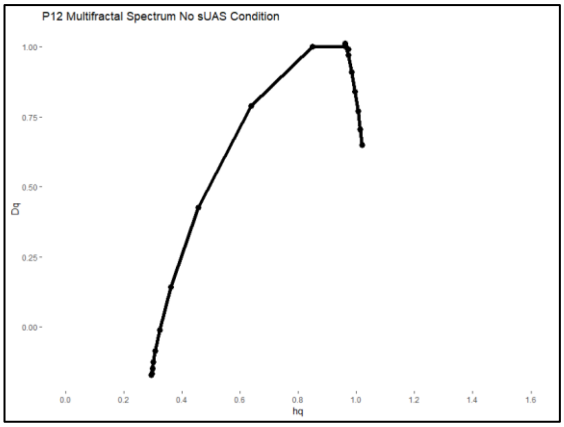

P10 Multifractal Spectrua During 100ft AGL Condition

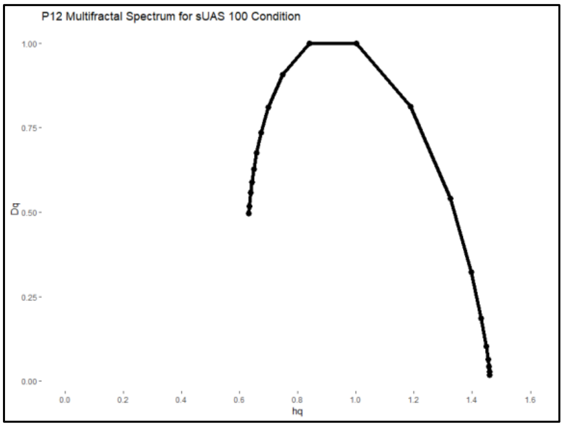
Participant 11


P11 Multifractal Spectrum No sUAS Condition

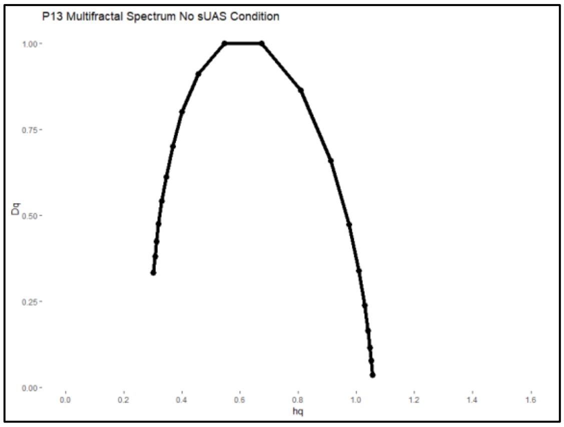

P11 Multifractal Spectrum for sUAS 100 Condition

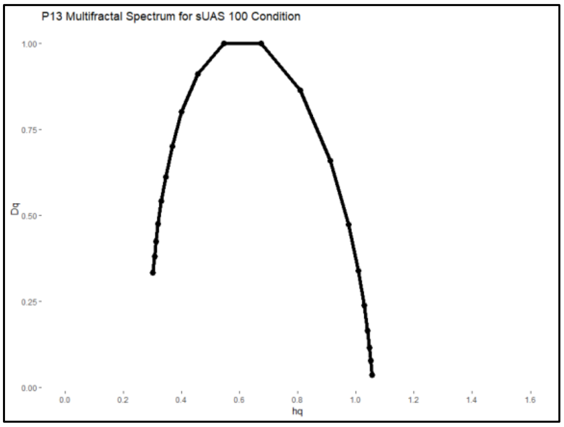
Participant 12


P12 Multifractal Spectrum No sUAS Condition

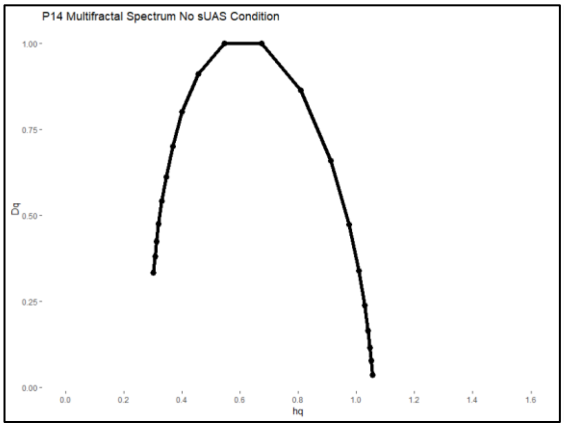

P12 Multifractal Spectrum for sUAS 100 Condition

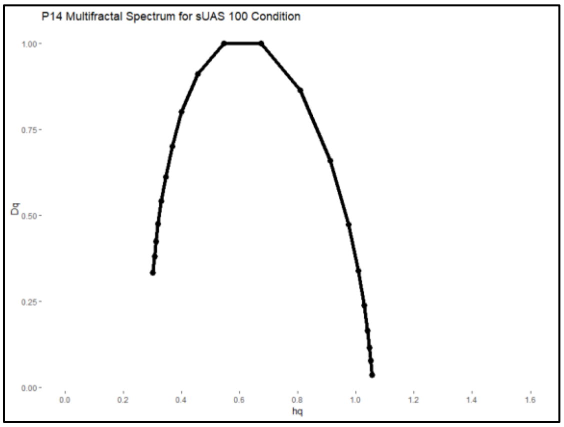
Participant 13



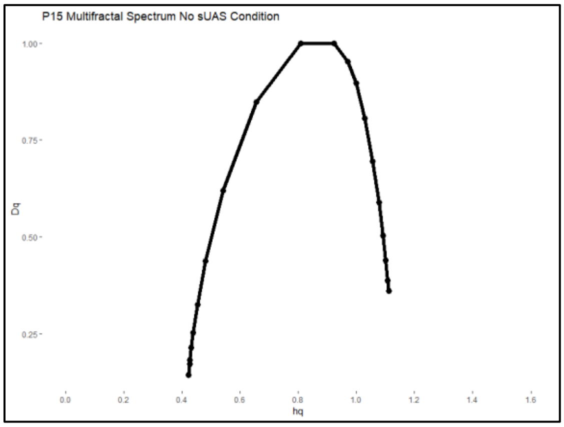


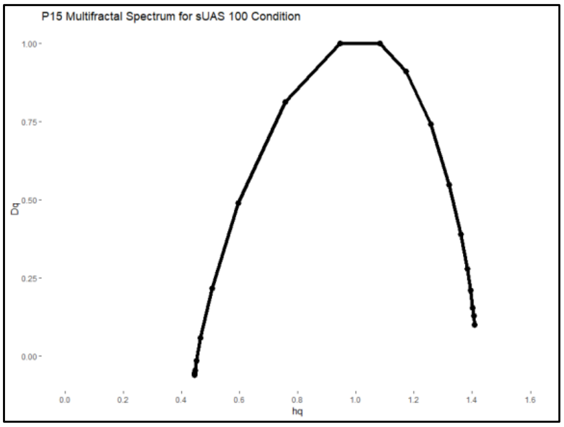
Participant 14



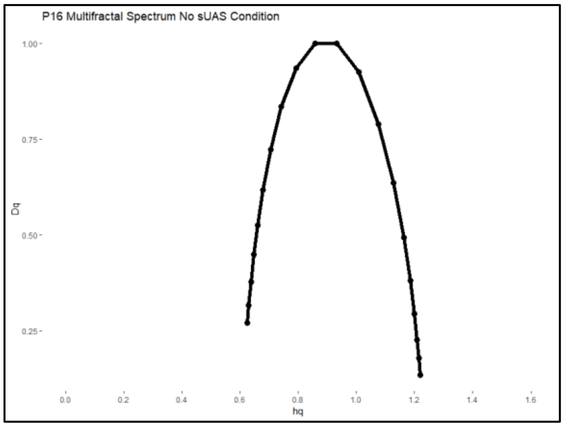


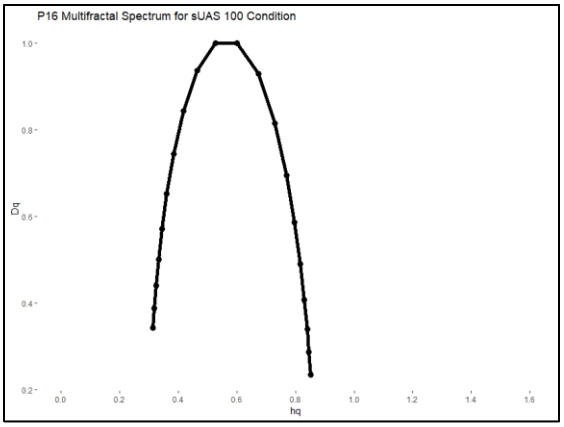
Participant 15



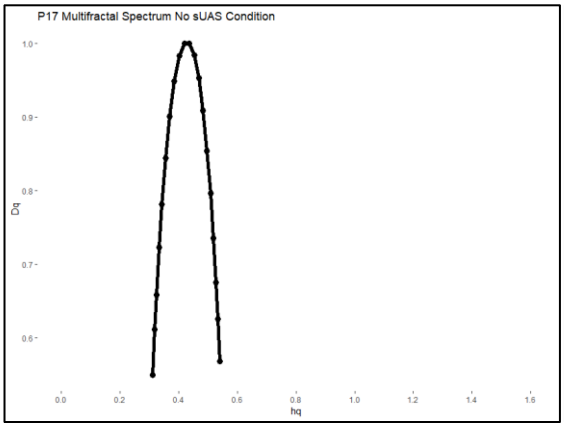


Participant 16


P16 Multifractal Spectrum No sUAS Condition


P16 Multifractal Spectrum for sUAS 100 Condition

Participant 17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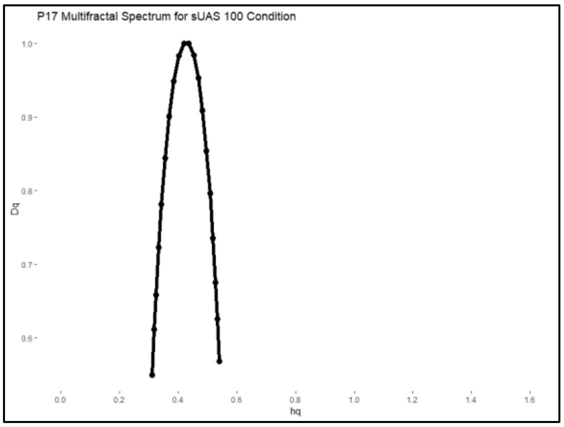
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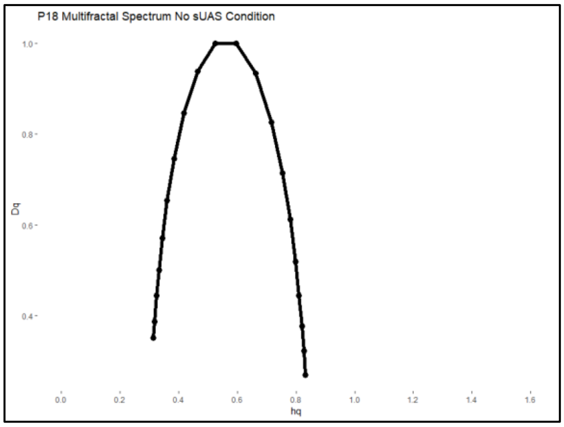
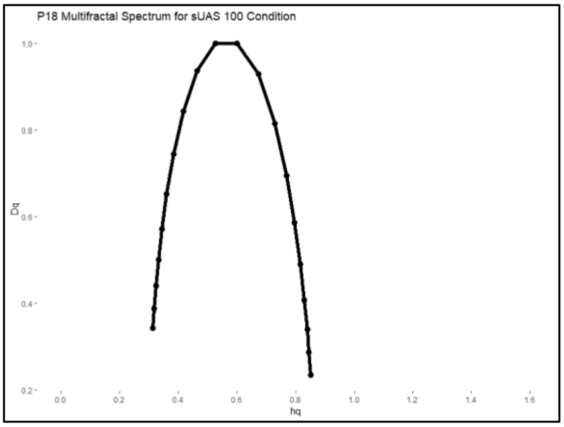
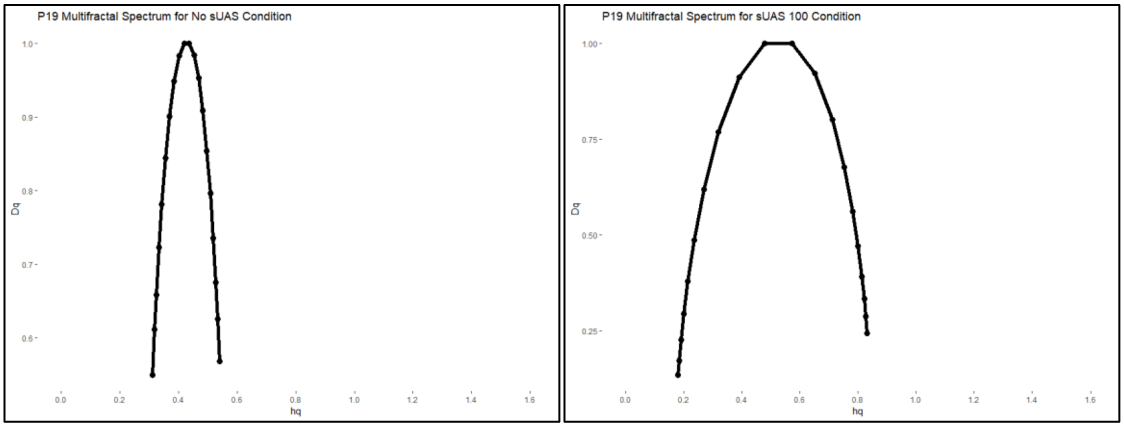
Participant 18


P18 Multifractal Spectrum No sUAS Condition


P18 Multifractal Spectrum for sUAS 100 Condition

Participant 19



Participant 20