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Implementation of short-term undergraduate psychoacoustics research project involving human subjects.

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Introduction

This work discusses the development and implementation of a five-week undergraduate psychoacoustics research project involving human subjects. It describes the required preparation and scaffolding necessary for undergraduate students with little research experience to complete research involving human subjects in a compressed time frame.

Because of the advance preparation and support provided throughout the program, the students demonstrated a high level of autonomy in completing the project. This sense of ownership resulted in the successful collection, analysis and presentation of the data collected using several different psychoacoustic listening tasks. Because of its careful design, the summer research program described here allowed undergraduate STEM students to gain an appreciation of the importance of human factors in research and engineering design while developing research and professional communication skills. Exposing STEM students to human subjects research early in their studies provides insight which may lead to greater use of human factors in their future engineering and scientific practice.

Overview of the AC^2 summer research program

The AC^2 summer research program is supported by the Collegiate Science & Technology Entry Program, the Louis Stokes Alliance for Minority Participation and the Howard Hughes Medical Institute Inclusive Excellence. The overarching goal of the AC^2 program is to provide academic, financial, and professional support to STEM students from underrepresented backgrounds. The AC^2 summer research program described here is one of the many programs and support structures that are provided to students in the AC^^{2} program throughout the year to meet this goal.

The AC ^{2} summer research opportunity is an intensive five-week program which focuses on development of both technical competences and professional communication skills. Students in the program cohort are grouped in small teams and paired with faculty researchers in a variety of disciplines. While each team works on their individual projects the entire cohort meets regularly to work together to develop the professional and presentation skills necessary to explain their research to a wide audience.

Description of student researchers

The students participating in the AC^2 summer research program were selected from our campus and several community colleges through a competitive application process. They were provided with the opportunity to identify projects of interest, but the final placement was at the discretion of the program organizers. Our wind farm acoustics project was completed by two lower-division undergraduate STEM students: a rising junior involved in AC^2 from our campus who is majoring in organismal biology and a rising sophomore from an AC^2 partner community college who is studying engineering. This was the first time either of these students had participated in an AC^2 summer research program, and the first time they had worked together.

Because the program is designed for lower-division undergraduate students in a wide range of STEM fields, the expectations of the skills that the students would have at the beginning of the project were minimal. The stated requirements were as follows:

- No specific prerequisite technical knowledge required of students.
- Ability to learn computer programs related to audio processing and statistics.
- Students should be organized, able to travel to field sites and able to coordinate test schedules for multiple participants.
- Students should possess critical thinking abilities which will enable them to conduct tests and analyze the results under the supervision of the advisors.

Description of our ongoing research related to wind farm acoustics

The project that these two students participated in was a part of a larger research initiative related to wind farm acoustics. This initiative has three main components:

- Data Collection and characterization using ML/AI: The goal of this portion of the work is to develop Machine learning or artificial intelligence (ML/AI) based methods to identify specific aspects of the acoustic emissions surrounding wind farms. The effective use of ML/AI allows for the collection and classification of large amounts of sound file data, automating the process of isolating wind turbine sounds for further study. [1]
- Perceptual analysis of the psychoacoustics of wind farm noise: Using the collected and classified data, the second goal of the ongoing research is to identify relationships between characteristics of wind farm noise and the perception of these sounds. [2] Recent pilot work focused on the efficacy of paired comparison methods in the assessment of annoyance of wind farm noise. [3]
- Community engagement: The third component of the research is developing community engagement of residents living near wind farms. Through partnership with a faculty member from a neighboring university, the use of a phone app designed for recording their impressions of surrounding sounds allows for engagement of residents in these communities[4]

The student project associated with the AC^2 summer research program involved aspects of the first two components of this research initiative.

Overview of the wind far acoustics summer research project

The students worked with faculty members from Mechanical Engineering and Communication Disorders. The students were taught the principles of field research including outdoor acoustical measurements and psychoacoustic research involving listening studies with human participants. They participated in the data collection, design of the psychoacoustic tests, completion of testing with the participants, and analysis of results.

The project was broken into two parts:

- ***Field work:*** Preparation, sample collection and audio processing of wind farm acoustics data obtained from a wind farm located a two-hour drive from the campus.
- ***Psychoacoustic study:*** Preparation, recruitment, screening, facilitation and statistical processing of annoyance listening studies related to the human perception of specific sounds associated with wind farm noise emissions.

The field work involved a trip near a wind farm where sounds generated from the wind turbines could be collected using an outdoor microphone and sound level meter recording device. The students and advisors met with a local resident who acted as a guide to help identify locations where wind turbine noises could be collected. The students made decisions about where and how to set up the equipment, and they documented the details about the measurement site and weather conditions. This data was collected specifically for use as samples in the psychoacoustic study that the students were helping to plan and were responsible for completing. Upon return to campus, the students downloaded the wind farm noise samples and identified and classified samples that contained only wind farm noise for possible use in the psychoacoustic study.

The psychoacoustic study was conducted on campus in an audiological testing suite. All students in the research program were provided an account with the Collaborative Institutional Training Initiative (CITI) and were required to complete introductory research training prior to beginning the program. Since our students were involved in research with human subjects, they had to complete an additional CITI training module related to social and behavioral sciences research with human participants. The students had to modify the pre-approved protocol to reflect changes to psychoacoustic parameters and test protocols and their specific recruitment procedures and materials. They also were responsible for the selection of the signals to be used in the study and had to make decisions about which, if any, of the wind farm noise samples from their field study should be included. They also determined the order in which the listening tasks would be presented to the participants. The students recruited participants from among their student cohort, ensured that they were scheduled for the required hearing screening, and scheduled their test sessions. Under faculty guidance, they trained the participants and conducted the test sessions. They also received faculty support in analyzing the results and planning how to present them visually and verbally in their poster for the final symposium.

Schedule

To illustrate the condensed timeframe with which the project was designed, an abbreviated weeks by week description of the primary tasks that the students completed is shown here:

Week 1: Introduced to wind farm acoustics and the human perception of sound which involved learning about the equipment and software used to conduct the tests. Completed additional CITI training and submitted modification of the Institutional Review Board (IRB) protocol for approval.
Week 2: Began recruiting and scheduling participants for screening tests. Traveled to wind farm to collect data samples. Prepared for first round of participant tests.
Week 3: Completed first round of participant tests. Further processing of the measured data.
Week 4: Completed second round of participant tests.

Week 5: Completed statistical processing of all data from listening tests, determined what conclusions could be drawn from the results. Prepared poster and presented at symposium.

Required faculty scaffolding for the project

The success of this project in the compressed timeframe was largely due to tools and structures that were in place from previous research, as well as some careful advance planning. Although a completely independent student-led project might have been desirable, this would not have been possible within the time allowed. Prior to bringing the students into the project, the faculty mentors mapped out the details and determined which aspects could be left under control of the students, and which needed to be developed ahead of time by the mentors. The goal was to obtain some useful pilot results while ensuring that the students were not merely collecting data in a fully established protocol. We also identified a limited set of reading materials and presentations that would make the students sufficiently conversant with the topic and the relevant principles of psychoacoustic testing without overwhelming them, while training them to find additional information from credible sources when needed. The experience of visiting the wind farm and experiencing the noise first-hand in the field helped the students to appreciate the real-world human concerns about wind farm noise and underscored the importance of conducting psychoacoustic research. In the discussion below, the steps taken by the faculty and the aspects that were left up to the students are highlighted.

Preparation prior to the project start

Components of the research project which had to be developed in advance of the program included obtaining initial approval from the IRB for the study, confirming that it is "exempt" from full review and has benign behavioral intervention status due to the low level of risk. It also involved the development of psychoacoustics testing software tailored to the types of tests that we were intending to complete, and identification of a preliminary set of test signals which would be used in the event that useful data was not able to be collected during the summer project.

The AC2 summer research program also required student preparation before the start of the project, including completing portions of NIH's CITI training, as well as read basic background information related to the study (provided by the faculty mentors).

Scaffolding provided during the project.

During the five weeks of the program, the faculty mentors and the AC² staff worked behind the scenes to provide the necessary support to the student researchers. Scaffolding of the student tasks within the five-week project was structured so that the students would have a role in decision making throughout the process. Examples of the structure provided for all the students by the AC² staff included training at the library in using the resources available for conducting preliminary background research and extensive training and practice in presenting their work with the other students in their cohort. This well-developed structure provided a framework and motivation for completing and disseminating their scientific research in a professional manner.

Participant recruitment was also facilitated by the AC^2 staff who strongly encouraged collaboration between the student researchers and provided opportunities for the other students to participate in the study. Without this pool of motivated participants, the project would have taken much longer.

Student involvement in planning and development of psychoacoustic tests.

The students were able to complete the specialized CITI training module quickly because they had already done a more general CITI training before starting the summer program, as described above. The modifications that were needed in the test protocol were approved rapidly because the basic protocol had already been reviewed for previous pilot work. The testing software (MATLAB GUIs) had been used in prior studies and required little modification. The campus speech and hearing clinic has an established protocol and graduate student support for conducting hearing screenings.

Having all these supports in place allowed the student to have autonomy in multiple aspects of the project. For example, in addition to being given journal articles to read, they were tasked with searching for relevant articles and sharing them. Since they did not have to spend time developing testing software, they had time to modify the IRB protocol, select additional test signals from among their recorded samples, and determine the sequence of the psychoacoustic tasks. Faculty mentors provided oversight throughout the process and performed the statistical analysis while giving the students responsibility for determining how to best display the results visually.

Results of the summer project

The overall student experience from this project was positive. As a result of the advance preparation and support provided throughout the program, the students were able to successfully complete each of the planned tasks. They were also able to use the data collected to draw meaningful conclusions which they clearly presented to a wide audience at the close of the five-week program at the research symposium poster session. Even more importantly than the results of the study, because the structure of the project allowed for continual involvement and decision making at each step, the students acted with a high level of autonomy throughout the program. The sense of ownership that resulted from the successful collection, analysis and presentation of the data helped to increase both their confidence in their own potential as researchers and also in their recognition of the importance of human subjects research in STEM fields.

This example provides a framework for how STEM programs can develop undergraduate research experiences involving human subjects conducted in a compressed time frame. As larger-scale research projects are not available to all undergraduate students, implementing this type of condensed project is critical for providing student with a wholistic view of what must be considered when developing engineering solutions, in accordance with ABET student outcomes 2 and 4. Exposure to human subject research such as the project described here, is critical for future engineers and scientists, as it provides a framework for considering human factors in their future engineering and scientific work.

References

[1] K. L. Hansen, P. Nguyen, G. Micic, B. Lechat, P. Catcheside, & B. Zajamšek (2021). Amplitude modulated wind farm noise relationship with annoyance: A year-long field study. *The Journal of the Acoustical Society of America*, *150*(2), 1198–1208. https://doi.org/10.1121/10.0005849

[2] C. Ioannidou, S. Santurette, & C. H. Jeong (2016). Effect of modulation depth, frequency, and intermittence on wind turbine noise annoyance. *J. Acoust. Soc. Am.*, *139*(3), 1241–1251. https://doi.org/10.1121/1.4944570

[3] H. L. Lai, A. C. Balant, & K. A. Riegel (2024). Empowering residents of communities near wind farms to record and document wind farm noise through the use of a phone app. *The Journal of the Acoustical Society of America*, *155*(3_Supplement), A300-A300.

[4] J. Firestone, B. Hoen, J. Rand, D. Elliott, G. Hübner & J. Pohl (2018). Reconsidering barriers to wind power projects: community engagement, developer transparency and place. Journal of Environmental Policy & Planning, 20(3), 370–386. https://doi.org/10.1080/1523908X.2017.1418656

Appendix A: Data collection methods

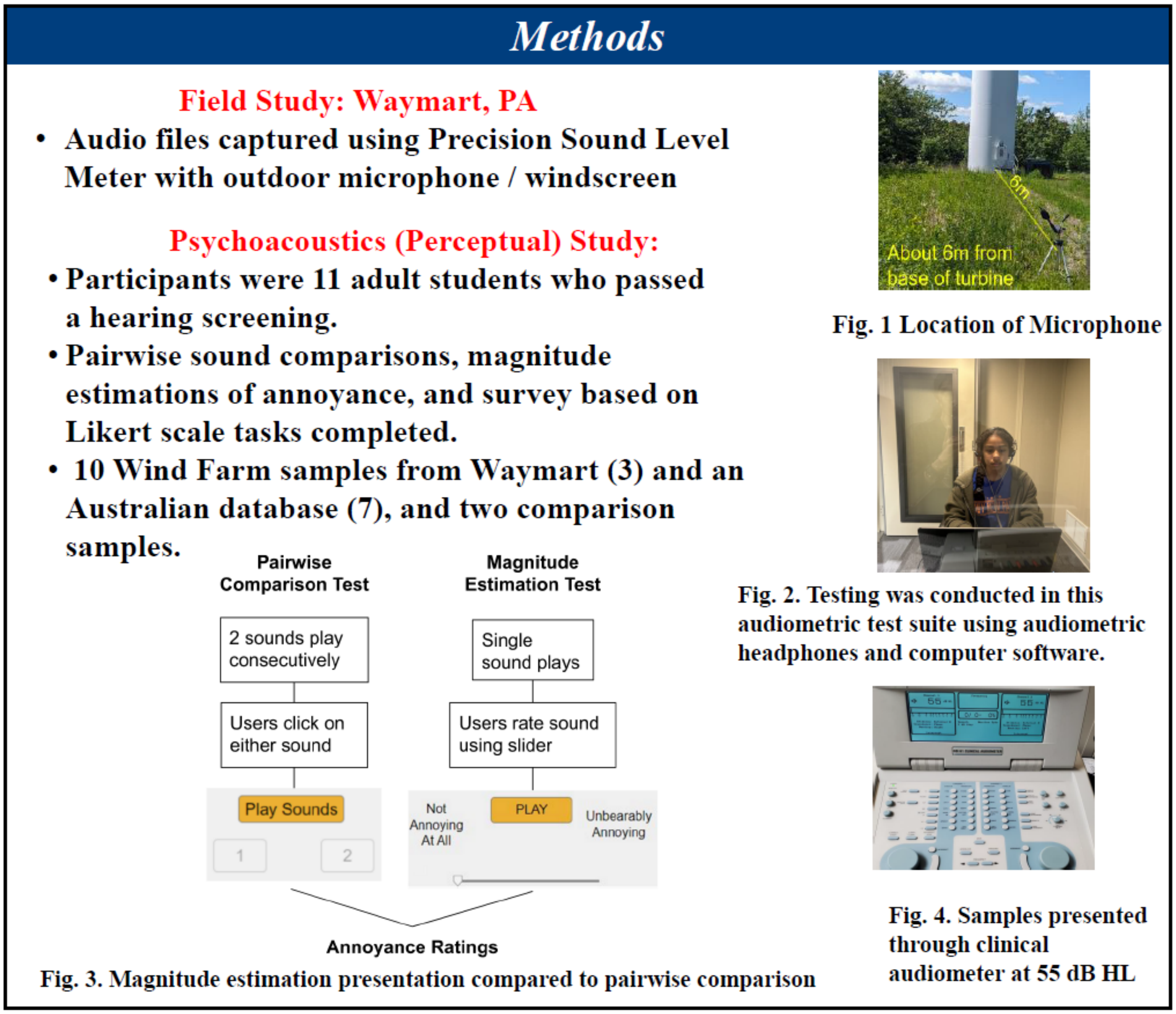

Figure A1: Description of field study and perceptual study data as generated by student researchers for final presentation

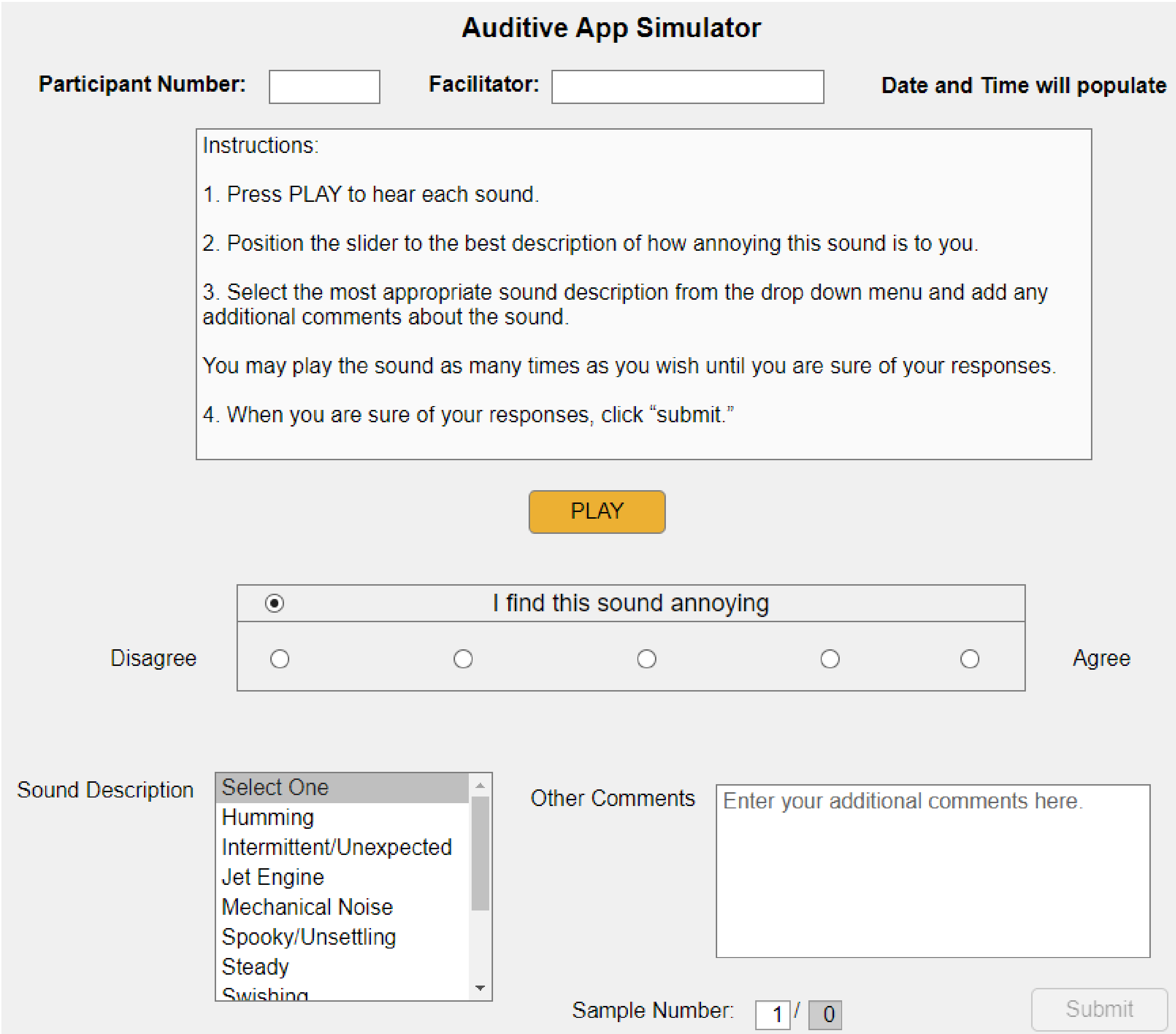

Figure A2: Example user interface relating to perceptions of wind farm sounds (developed by authors using MATLAB)

Appendix B: Example data

Field research Data:

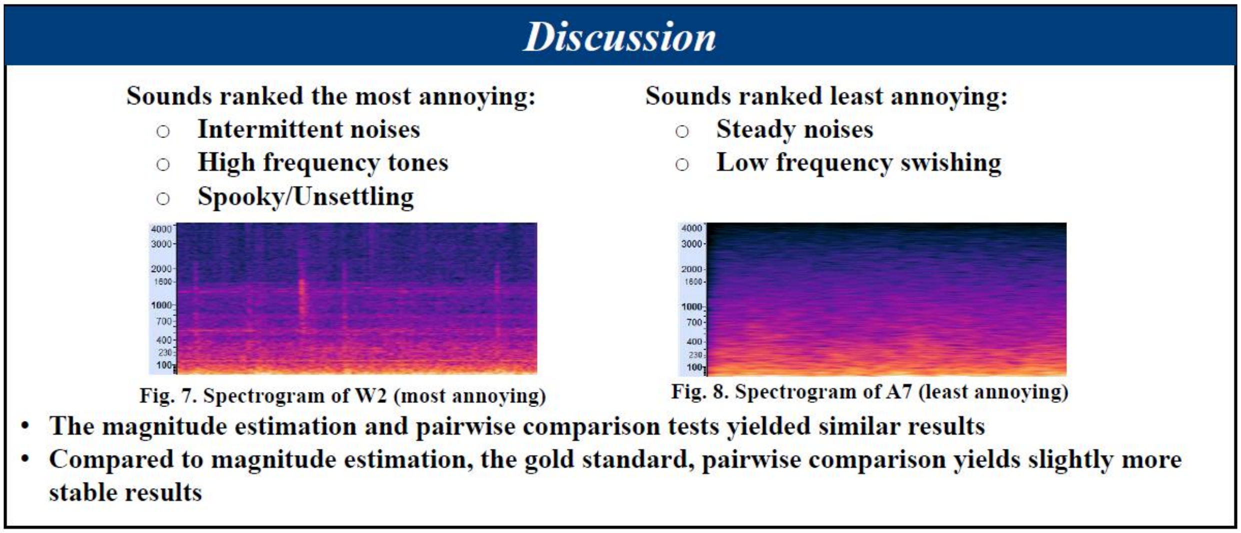

Figure B1: Sound files collected near wind farm were parsed into 10 second samples, and displayed as spectrograms (W2) for comparison with publicly available database files (A7). Example spectrograms selected by student researchers for final presentation.

Raw data from listening studies:

```
11-Jun-2024 10:46:53, Heaven, 4, H1_1083_20s_EQ_25dB_SonesdBA_Su24_fade.wav,9
11-Jun-2024 10:46:53, Heaven, 4, H1_1671_20s_EQ_25dB_SonesdBA_Su24_fade.wav,0
11-Jun-2024 10:46:53, Heaven, 4, RuralTraffic_20s_EQ_25dB_SonesdBA_Su24_fade.wav,29
11-Jun-2024 14:44:45, Samantha, 3, H1_2353_20s_EQ_25dB_SonesdBA_Su24_fade.wav,44
11-Jun-2024 14:44:45, Samantha, 3, H1_1670_20s_EQ_25dB_SonesdBA_Su24_fade.wav,78
11-Jun-2024 14:44:45, Samantha, 3, W_19_053_20s_EQ_25dB_SonesdBA_Su24_fade.wav,83
11-Jun-2024 14:44:45, Samantha, 3, H1_0679_20s_EQ_25dB_SonesdBA_Su24_fade.wav,60
11-Jun-2024 14:44:45, Samantha, 3, W_21_349_20s_EQ_25dB_SonesdBA_Su24_fade.wav,51
11-Jun-2024 14:44:45, Samantha, 3, Speech noise8192_20s_EQ_25dB_SonesdBA_Su24_fade.wav,91
```

Figure B2: Example raw data from magnitude estimation annoyance studies: participants listened to a 20 second sound file and gave it a 0 – 100 slider value based on how annoying the sound was (last number in line).

```
10-Jun-2024 11:17:53, Samantha, 1, 7 , 12 , 7
10-Jun-2024 11:17:53, Samantha, 1, 8 , 11 , 11
10-Jun-2024 11:17:53, Samantha, 1, 2 , 6 , 6
10-Jun-2024 11:17:53, Samantha, 1, 2 , 9 , 9
10-Jun-2024 11:17:53, Samantha, 1, 2 , 7 , 2
10-Jun-2024 11:17:53, Samantha, 1, 6 , 7 , 7
10-Jun-2024 11:17:53, Samantha, 1, 4 , 11 , 11
10-Jun-2024 11:17:53, Samantha, 1, 10 , 11 , 11
10-Jun-2024 11:17:53, Samantha, 1, 9 , 12 , 12
10-Jun-2024 11:17:53, Samantha, 1, 1 , 4 , 4
10-Jun-2024 11:17:53, Samantha, 1, 9 , 10 , 9
10-Jun-2024 14:10:37, Samantha, 3, 6 , 10 , 6
10-Jun-2024 14:10:37, Samantha, 3, 8 , 12 , 8
```

Figure B3: Example raw data from pairwise comparison studies: participants heard two sounds and ranked which was more annoying (last number in line)

```
10-Jun-2024 12:59:13, Heaven, 2, H1_1671_EQ_25dB_SonesdBA_Su24_fade.wav,1,Thumping,Sounds like rain with someone walking over metal or dumping something
10-Jun-2024 12:59:13, Heaven, 2, W_17_016_EQ_25dB_SonesdBA_Su24_fade.wav,4,Mechanical Noise, I hear a lot of clanking being from possible debris
10-Jun-2024 12:59:13, Heaven, 2, H1_1670_EQ_25dB_SonesdBA_Su24_fade.wav,1,Whooshing,Just sounds like strong wind
10-Jun-2024 12:59:13, Heaven, 2, Speech noise8192_EQ_25dB_SonesdBA_Su24_fade.wav,1,Steady,
10-Jun-2024 12:59:13, Heaven, 2, H1_0793_EQ_25dB_SonesdBA_Su24_fade.wav,0,Spooky/Unsettling, Sounds as if something is on the verge of collapsing
10-Jun-2024 12:59:13, Heaven, 2, W_21_349_EQ_25dB_SonesdBA_Su24_fade.wav,1,Swishing,
10-Jun-2024 12:59:13, Heaven, 2, H1_1083_EQ_25dB_SonesdBA_Su24_fade.wav,1,Whooshing, I think something is gaining speed or possibly flying
10-Jun-2024 12:59:13, Heaven, 2, RuralTraffic10s_EQ_25dB_SonesdBA_Su24_fade.wav,2,Jet Engine,
10-Jun-2024 12:59:13, Heaven, 2, W_19_053_EQ_25dB_SonesdBA_Su24_fade.wav,0,Thumping,Something sounds lose and is clanking against its self
10-Jun-2024 12:59:13, Heaven, 2, H1_2810_EQ_25dB_SonesdBA_Su24_fade.wav,1,Whooshing,
10-Jun-2024 12:59:13, Heaven, 2, H1_0679_EQ_25dB_SonesdBA_Su24_fade.wav,1,Spooky/Unsettling, The wind is creating an echo that sounds strange
10-Jun-2024 14:00:55, , 3, W_17_016_EQ_25dB_SonesdBA_Su24_fade.wav,2,Mechanical Noise,
10-Jun-2024 14:00:55, , 3, H1_2353_EQ_25dB_SonesdBA_Su24_fade.wav,3,Whooshing,
10-Jun-2024 14:00:55, , 3, H1_2810_EQ_25dB_SonesdBA_Su24_fade.wav,4,Whooshing,
10-Jun-2024 14:00:55, , 3, W_19_053_EQ_25dB_SonesdBA_Su24_fade.wav,5,Intermittent/Unexpected,
10-Jun-2024 14:00:55, , 3, Speech noise8192_EQ_25dB_SonesdBA_Su24_fade.wav,5,Whooshing,
10-Jun-2024 14:00:55, , 3, H1_0679_EQ_25dB_SonesdBA_Su24_fade.wav,4,Spooky/Unsettling,
10-Jun-2024 14:00:55, , 3, H1_1671_EQ_25dB_SonesdBA_Su24_fade.wav,5,Mechanical Noise,
10-Jun-2024 14:00:55, , 3, H1_1670_EQ_25dB_SonesdBA_Su24_fade.wav,4,Whooshing,
10-Jun-2024 14:00:55, , 3, W_21_349_EQ_25dB_SonesdBA_Su24_fade.wav,3,Humming,mix of whoosh and hum in background
10-Jun-2024 14:00:55, , 3, H1_1083_EQ_25dB_SonesdBA_Su24_fade.wav,4,Whooshing,
10-Jun-2024 14:00:55, , 3, RuralTraffic10s_EQ_25dB_SonesdBA_Su24_fade.wav,4,Jet Engine,
10-Jun-2024 14:00:55, , 3, H1_0793_EQ_25dB_SonesdBA_Su24_fade.wav,4,Spooky/Unsettling,
```


Figure B4: Example raw data from Auditive App pilot: participants listened to a 10 second sound file and responded using prompts similar to those on the Auditive phone app.

Processed data:

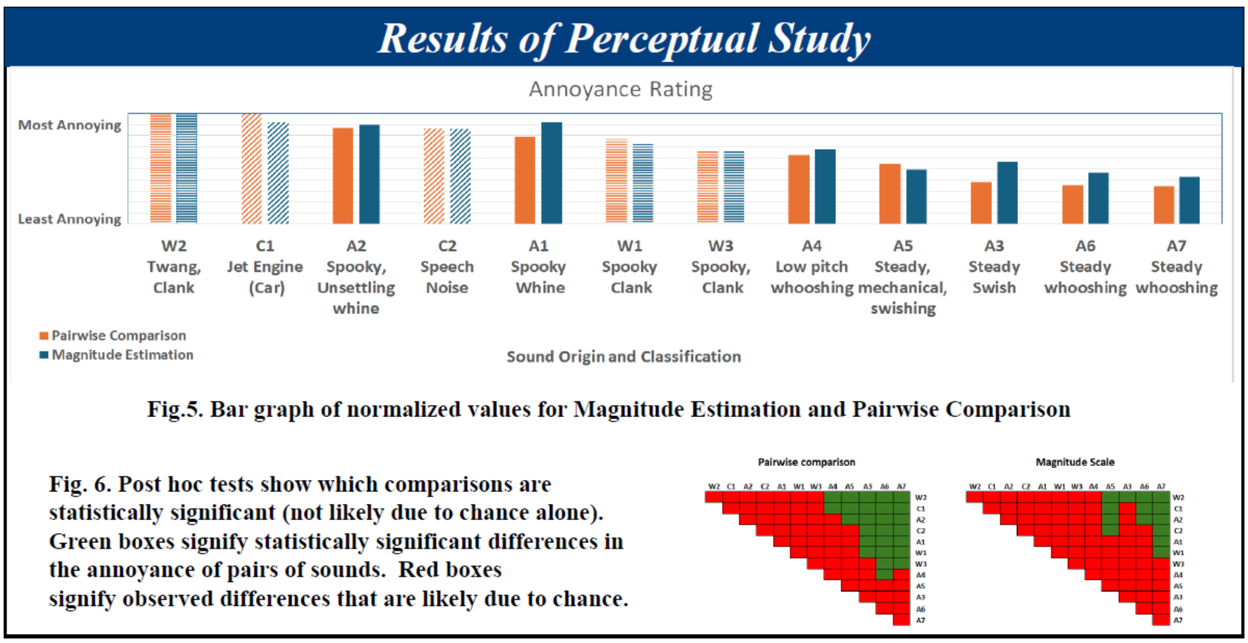

Figure B5: Processed data from the perceptual study as presented by the students. Included both Annoyance ratings calculated from both types of perceptual studies (pairwise comparison and magnitude estimation annoyance studies).