UAV NOISE IN HUMAN RESOURCES RESEARCH RESPONSE RESEARCH: A FRAMEWORK BASED ON SCOPING REVIEW

Tianjing FENG[1], Jian KANG[1]

[1] *Institute for Environmental Design and Engineering, The Bartlett, University College London, London WC1H 0NN, United Kingdom*

This paper is a revised version of the authors' submitted manuscript that was peer-reviewed by at least two anonymous reviewers.

Abstract

As multirotor UAVs become increasingly used in urban logistics, emergency response, and future low-altitude transport, noise remains a major obstacle to public acceptance. While existing UAV-noise reviews have focused on propagation, source characteristics, psychoacoustic interpretation, and regulatory assessment, less attention has been paid to the methodological design and documentation of human-response experiments themselves. To address this gap, this paper conducts a scoping review of 35 studies. It first examines the acoustic characteristics of UAV noise and then reviews how existing studies design and implement human-response experiments. Based on this synthesis, it proposes a structured framework covering both signal-related and procedural aspects, including source acquisition, metadata control, signal preservation, propagation normalisation, participant screening, playback calibration, trial sequencing, and reporting. By integrating acoustic realism with protocol traceability, the framework aims to improve the rigour, reproducibility, and ecological validity of future psychoacoustic and psychophysiological research on UAV noise.

Keywords: *UAV Noise; Experimental Protocol; Stimulus Design; Acoustic Signature; Psychoacoustics*

1. Introduction

With the rapid growth of the low-altitude economy, drone delivery and Urban Air Mobility (UAM) are increasingly entering urban logistics, transport, and emergency response. As these systems move toward routine operation in densely populated areas, noise has become a key barrier to public acceptance and large-scale deployment[1]. NASA's UAM community-noise research identifies noise as a major constraint and shows that public response depends not only on acoustic exposure but also on contextual and other non-acoustic factors [2]. Within urban soundscapes, UAV noise is superimposed on already dense and heterogeneous acoustic environments, where background noise, built form, and listening context can all shape how it is perceived [3, 4]. Concerns about privacy, safety, and surveillance further interact with annoyance, making low-altitude vehicle noise both an acoustical and socio-psychological issue.

Existing UAV-noise review literature has mainly focused on propagation, source characteristics, psychoacoustic interpretation, and regulatory assessment[5, 6]. By contrast, the methodological design and documentation of UAV-noise human-response experiments—particularly in relation to stimulus construction, reproduction conditions, calibration, contextual control, and reporting—remain insufficiently synthesised.

This paper mainly develops a framework for UAV-noise human-response research. It analyses the signal characteristics of UAV noise and the procedures used in existing experiments, and on this basis proposes a structured framework covering both stimulus design and experimental procedure.

2. Method

We conducted a scoping review of UAV human-response studies to map how UAV noise has been characterised and operationalised in perception experiments, rather than to pool effect sizes. Records were identified through Web of Science, Scopus, and Google Scholar, screened using predefined eligibility criteria, and supplemented by reference tracing and manual inclusion, yielding 35 studies for qualitative synthesis (See Appendix A). Included studies treated UAVs as integrated whole-vehicle acoustic sources and involved controlled human exposure or human-response data; aeronautics-oriented, purely computational, and non-exposure studies were excluded. Data were extracted using an iteratively refined charting form

Corresponding author: *j.kang@ucl.ac.uk.*

covering experimental context, sound sources, stimulus design and presentation, and perceptual or physiological outcomes. UAV-noise characteristics were synthesised through thematic analysis of source properties, operational conditions, propagation context, and signal representation. Experimental protocols were synthesised to derive a more standardised framework that improves comparability across studies and supports the design of more rigorous, scientifically robust experiments.

3. Acoustic Characteristics of UAV Noise in Urban Contexts

Multirotor UAV noise has a distinctive source signature that differs from both fixed-wing aircraft and helicopters. At the source, UAV noise is typically rotor- or propeller-dominated, combining deterministic narrowband components with broadband noise. The deterministic component arises from periodic aeroacoustic mechanisms such as thickness and loading noise, producing the characteristic blade-passing-frequency (BPF) fundamental and harmonic structure that is central to source identity[7, 8]. Because multirotor UAVs usually operate at relatively low blade-tip Mach numbers, these harmonics are often less sharply tonal than those of conventional aircraft and may exhibit broader peaks and greater spectral spread [9]. Broadband components, by contrast, are associated with turbulence-related processes such as rotor wakes, boundary-layer effects, atmospheric turbulence, and disturbed-flow re-ingestion. Source characteristics also vary across platforms and operating regimes: rotor configuration, rotor-to-rotor RPM mismatch, platform mass, rotor size, propulsion efficiency, and rotor loading can all alter the emitted spectrum and shift tonal dominance across frequency regions [10, 11]. Different spectral components also play different physical and perceptual roles: lower-frequency harmonic energy tends to propagate farther, whereas higher-frequency broadband content is more directional and may contribute more strongly to perceptual qualities such as harshness, sharpness, and “buzzy” character, including salient energy in the ~100–1000 Hz range and around ~2.5–3 kHz [12, 13]. For this reason, UAV-noise experiments should preserve not only overall SPL, but also the underlying harmonic structure, tonal–broadband balance, and bandwidth integrity of the source signal[14].

These source emissions are then further reshaped during propagation and reproduction, especially in urban contexts. Reflections from the ground, façades, ceilings, and urban canyons can modify both the received spectrum and the temporal envelope, and should therefore be treated as explicit propagation variables rather than uncontrolled background effects [15-17]. Measurement geometry and receiver placement also require clear reporting, including possible ground-effect corrections and recording artefacts [18, 19]. Distance, likewise, should not be represented by gain change alone; geometrical spreading and air absorption are needed to maintain physically plausible attenuation and spectral tilt. Accordingly, credible UAV-noise experiments must preserve propagation realism as well as source realism, so that the reproduced sound remains representative of UAV noise in actual urban listening conditions.

Table 1 Key acoustic characteristics of UAV noise and their experimental relevance

Noise characteristic	Mechanism	Manifestations
Tonality	Periodic Rotor Loading; Thickness Noise	BPF; Harmonics; Tonal Peaks
Broadband content	Rotor Wakes; Turbulence; Disturbed-Flow Re-Ingestion	Broadband Floor; Spectral Spread; Noise Bed
Spectral balance	Narrowband–Broadband Superposition	Low-Frequency Harmonics; High-Frequency Broadband
Platform variability	Scaling Effects; Propulsion-Efficiency Differences	sUAS; Cargo UAV; UAM
Rotor configuration	Rotor Count; Rotor–Rotor Interaction	Quadcopter; Hexacopter; Multi-BPF
RPM dependence	Rotational-Speed Variation	BPF Shift; Harmonic Shift; SPL Change
Temporal variability	Non-Stationary Operation; Control Adjustment	Flyover Envelope; Doppler; Amplitude Modulation
Directivity	Angle-Dependent Radiation; Scattering; Shielding	Elevation Effect; Azimuth Effect; Mode Dependence

4. Framework for UAV-Noise Audio Design and Experiment Design

4.1 Noise Stimuli Processing Workflow

The UAV audio-design protocol begins with disciplined source acquisition and proceeds through a series of quality-control steps aimed at preserving the acoustic identity of drone noise rather than reducing it to a generic loudness stimulus. Recordings should be drawn either from validated open databases or from carefully controlled raw recordings, with replication and randomisation built in from the start. At least three independent takes per condition are desirable, and repeated presentations should be randomised across participants so that take-to-take variability is not obscured[8]. Clips must also be long enough to preserve the temporal structure of the event: for flyovers, the full approach–pass–recede sequence should be retained so that Doppler shift, amplitude modulation, and transient spectral changes remain audible[13], whereas shorter excerpts may be reserved for high-throughput or transient-focused tasks, with duration explicitly justified. In parallel, aircraft metadata should be documented, including payload condition, maximum take-off weight where possible, rotor speed or RPM, and rotor count, since all of these can affect harmonic structure, spectral aggregation, and perceptual character even when the overall level is unchanged[9]. Once source material is accepted, the protocol shifts to preserving the UAV signature itself. Flight mode and phase must be clearly labelled so that each stimulus corresponds to one interpretable state, such as hover, climb, descent, acceleration, or forward flyover. Directivity should also be considered, since single-angle recordings may confound radiation-pattern effects with vehicle or task effects[12]; multi-azimuth or full-directivity sets are therefore preferable when feasible. Signal processing should be minimal and justified, with preservation of the dominant low- to mid-frequency band, the mid-/high-frequency broadband peak, and the blade tones and harmonics that define UAV timbre. Propagation normalisation should go beyond simple gain scaling by accounting for geometric spreading, air absorption, and distance-dependent spectral tilt, while acoustic context should be declared explicitly, such as free field, ground-reflected, façade-reflected, or street-canyon-like[16]. Finally, complete exposure stimuli are assembled through defined event patterns, rendering modes, and optional audiovisual integration. If visual material is included, trajectory congruence, flight-state congruence, synchronisation, and latency checks are all required. The final output is therefore not merely an audio file, but a full stimulus package containing the waveform, metadata sheet, quality-control report, and transformation log. (See Figure 1)

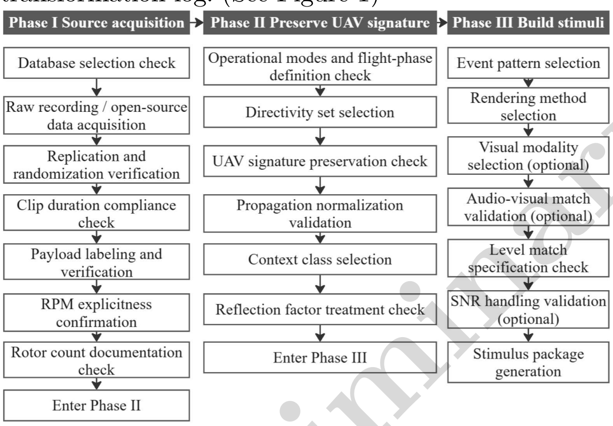

Figure 1 UAV Noise Stimulus Design Workflow: Recommended Practices and Common Pitfalls

4.2 Perception Experiment Design Workflow

The perception-study protocol begins only after the stimulus package is complete and fully traceable. The first stage is input validation and subject preparation, including stimulus integrity checks, participant screening, sample-size planning, background documentation, and hearing-threshold assessment consistent with normal hearing [20]. The test environment—whether a lab, treated room, home setup, or field site—should be documented and controlled, including room treatment, background SPL, and spectral conditions [21]. A baseline condition should be defined explicitly, and key acoustic metrics such as loudness, tonality, and sharpness should be reported with transparent calculation settings.

The next stage concerns playback, sequencing, and reporting. Playback conditions should be calibrated and documented, and the trial design should specify trimming, fade treatment, and breaks to avoid artefacts and fatigue. Stimulus order should be randomised, familiarisation trials provided, and process logs retained. Each stimulus should also be linked to a stable identifier with key metadata, including flight mode, RPM, signal-to-noise ratio, and acoustic context. This makes the experiment a traceable exposure protocol rather than a simple listening test.

Psychoacoustic studies commonly explain UAV/UAM annoyance using sound-quality attributes such as loudness, tonality, roughness, sharpness, and modulation rather than SPL alone. Existing studies highlight roughness and tonality as important predictors, while loudness and level-based metrics remain strongly associated with annoyance [19]. Recent work further introduces masking, detectability, and physiological indicators, suggesting a broader but still developing assessment framework [22, 23]. (See Figure 2)

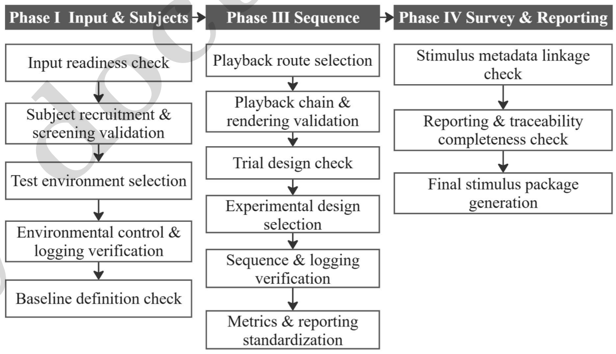

Figure 2 UAV Noise Perception Experiment Design Workflow: Recommended Practices and Common Pitfalls

5. Conclusion

This paper has reviewed the acoustic characteristics of UAV noise and highlighted their implications for human-response research. Compared with conventional environmental and aircraft noise, UAV noise is marked by tonal–broadband interactions, blade-passing-frequency harmonics, platform- and rotor-dependent spectral variation, and sensitivity to flight state, propagation context, and signal representation. These features make it difficult to interpret annoyance or perceptual outcomes using level-based metrics alone. Accordingly, the paper proposes a structured experimental framework covering stimulus acquisition, metadata control, signal processing, propagation normalisation, playback calibration, participant screening, sequence design, and reporting. The main contribution is not a new acoustic metric, but a protocol-oriented foundation for improving the rigour, reproducibility, and ecological validity of UAV-noise studies.

References

[1] M. M. Costagliola-Ray, L. Lieber, W. A. M. Nimmo-Smith, E. A. Masden, P. Caplat, J. Wilson, and N. J. O'hanlon: "To fly or not to fly? Comparing vantage point and uncrewed aerial vehicle surveys for assessments of seabird abundance and fine-scale distribution", Environmental Impact Assessment Review, vol. 97, pp. 106906, 2022

[2] M. M. Connors: 'Factors that Influence Community's Acceptance of Noise: An Introduction for Urban Air Mobility', NASA Ames Research Center, 2019

[3] J. Kang: 'Urban sound planning-A soundscape approach'. Acoustics 2019, Sound Decisions: Moving Forward with Acoustics-Proceedings of the Annual Conference of the Australian Acoustical Society, 2019, pp. 11

[4] M. Ba, and J. Kang: "Effect of a fragrant tree on the perception of traffic noise", Building and Environment, vol. 156, pp. 147-155, 2019

[5] B. Schaffer, R. Pieren, K. Heutschi, J. M. Wunderli, and S. Becker: "Drone Noise Emission Characteristics and Noise Effects on Humans-A Systematic Review", Int J Environ Res Public Health, vol. 18, no. (11), 2021

[6] A. J. Torija, and C. Clark: "A Psychoacoustic Approach to Building Knowledge about Human Response to Noise of Unmanned Aerial Vehicles", Int J Environ Res Public Health, vol. 18, no. (2), 2021

[7] J. Schmal, D. W. Herrin, and D. F. Comesaña: 'Quadcopter Sound Characterization using a UAV Test Stand'. INTER-NOISE and NOISE-CON Congress and Conference Proceedings, 2023, pp. 6214-6223

[8] H. H. Hubbard: 'Aeroacoustics of flight vehicles: Theory and practice.', NASA, 1991

[9] R. Cabell, R. McSwain, and F. Grosveld: 'Measured Noise from Small Unmanned Aerial Vehicles'. NOISE-CON, Providence, Rhode Island, United States, 2016

[10] I.-C. Ardelean, D. Usov, A. Filippone, B. Parslew, and P. Hollingsworth: "Unmanned Wingless Rotorcraft Scaling", Journal of Aircraft, vol. 60, no. (5), pp. 1553-1563, 2023

[11] G.-Y. Kim, D.-G. Won, Y.-H. Kim, S.-E. Jeon, S.-H. Kim, and S.-S. Lee: 'Investigation of physiological responses on drone noise in a laboratory condition'. INTER-NOISE and NOISE-CON 2023, pp. 1116-1121

[12] Y. J. Go, and J. S. Choi: "An Investigation of Multi-rotor Drone Noise Based on the Acoustic Hemisphere in an Actual Environment", International Journal of Aeronautical and Space Sciences, vol. 25, no. (2), pp. 420-434, 2024

[13] N. S. Zawodny, N. A. Pettingill, and C. S. Thurman: 'Identification and Reduction of Interactional Noise of a Quadcopter in Hover and Forward Flight Conditions'. Inter-Noise 2022, Glasgow, UK, 2023

[14] C. Ramos-Romero, N. Green, A. J. Torija, and C. Asensio: "On-field noise measurements and acoustic characterisation of multi-rotor small unmanned aerial systems", Aerospace Science and Technology, vol. 141, 2023

[15] F. Škultéty, E. Bujna, M. Janovec, and B. Kandera: "Noise Impact Assessment of UAS Operation in Urbanised Areas: Field Measurements and a Simulation", Drones, vol. 7, no. (5), 2023

[16] V. Didkovskyi, O. Korzhyk, S. Kozeruk, A. Kozak, R. Kostiuk, and S. Liakhevych: 'Noise Measurement of the Multicopter UAV'. 2019 IEEE 5th International Conference Actual Problems of Unmanned Aerial Vehicles Developments (APUAVD), Kiev, Ukraine, 2019, pp. 67-70

[17] T. Feng, and S. Lu: 'FDTD-based simulation and optimization of open plan offices involving novel acoustic lattices and retroreflectors'. Proceedings of Building Simulation 2025: 19th Conference of IBPSA, 2025

[18] W. L. Willshire Jr, and P. A. Nystrom: 'Investigation of effects of microphone position and orientation on near-ground noise measurements', NASA, 1982

[19] C. T. J. Hui, M. J. Kingan, Y. Hioka, G. Schmid, G. Dodd, K. N. Dirks, S. Edlin, S. Mascarenhas, and Y.-M. Shim: "Quantification of the Psychoacoustic Effect of Noise from Small Unmanned Aerial Vehicles", International Journal of Environmental Research and Public Health, vol. 18, no. (17), 2021

[20] J. Callanan, P. Ghassemi, J. DiMartino, M. Dhameliya, C. Stocking, M. Nouh, and S. Chowdhury: "Ergonomic impact of multi-rotor unmanned aerial vehicle noise in warehouse environments", Journal of Intelligent & Robotic Systems, vol. 100, no. (3), pp. 1309-1323, 2020

[21] K. B. Evensen, L. H. Hauge, and T. Gjestland: 'Directional perception and its influence on noise annoyance from unmanned aerial vehicles'. INTER-NOISE and NOISE-CON Congress and Conference Proceedings, 2024, pp. 5017-5023

[22] X. Wang, B. Wu, R. Xie, and T. Wu: 'Testing and research on acoustic characteristics of low small slow drones'. Proceedings of SPIE - The International Society for Optical Engineering, 2024

[23] S. Hara, Y. Hayashi, Y. Mitsukura, and H. Kamide: "Applicability of Kansei analyzer for noise-induced stress assessment— toward social acceptability survey of flying cars—", Technical Journal of Advanced Mobility, vol. 2, no. (3), pp. 31-41, 2021

[24] S. Hara, K. Takahara, and Y. Mitsukura: 'Stress Evaluation Using EEG for Novel Air Mobilities'. IEEE 11th Global Conference on Consumer Electronics (GCCE), 2022, pp. 72-73

[25] S.-E. Jeon, G.-Y. Kim, D.-G. Won, Y.-H. Kim, S.-H. Kim, and S.-S. Lee: "Subjective responses on drone noise with immersive reproduction tool", INTER-NOISE and NOISE-CON Congress and Conference Proceedings, vol. 268, no. (6), pp. 2302-2307, 2023

[26] D. Y. Gwak, D. Han, and S. Lee: "Sound quality factors influencing annoyance from hovering UAV", Journal of sound and vibration, vol. 489, pp. 115651, 2020

[27] R. Wang, Y. Liu, W. Fei, A. G. Feleke, and L. Bi: 'Acoustic Target Recognition Method Based on EEG Signals', in Editor (Ed.)^(Eds.): 'Book Acoustic Target Recognition Method Based on EEG Signals' (IEEE, 2022, edn.), pp. 4437-4441

[28] A. Thomas, D. Hiller, A. L. Maldonado, L. McLeod, C. Sharp, and J. Woodcock: "Exploring the public perception of sound of medical delivery drones in

Scotland. An online listening test approach", INTER-NOISE and NOISE-CON Congress and Conference Proceedings, vol. 268, no. (3), pp. 5618-5625, 2023

[29] D. R. Begault: 'Psychoacoustic Measures for UAM noise in the Context of Ambient Sound', in Editor (Ed.)^(Eds.): 'Book Psychoacoustic Measures for UAM noise in the Context of Ambient Sound' (2023, edn.), pp.

[30] S. Krishnamurthy, S. Rizzi, R. Biziorek, J. Czech, J. Berg, D. Tannler, D. Bean, A. Ayrapetyan, A. Nguyen, and J. Wivagg: 'Remotely administered psychoacoustic test for sUAS noise to gauge feasibility of remote UAM noise study', in Editor (Ed.)^(Eds.): 'Book Remotely administered psychoacoustic test for sUAS noise to gauge feasibility of remote UAM noise study' (Institute of Noise Control Engineering, 2023, edn.), pp. 780-793

[31] M. Boucher, M. Rafaelof, D. Begault, A. Christian, S. Krishnamurthy, and S. Rizzi: 'A Psychoacoustic Test for Urban Air Mobility Vehicle Sound Quality'. INTER-NOISE and NOISE-CON Congress and Conference Proceedings, 2023, pp. 794-807

[32] S. A. Rizzi, D. L. Palumbo, J. Rathsam, A. W. Christian, and M. Rafaelof: 'Annoyance to noise produced by a distributed electric propulsion high-lift system', in Editor (Ed.)^(Eds.): 'Book Annoyance to noise produced by a distributed electric propulsion high-lift system' (2017, edn.), pp. 4050

[33] A. W. Christian, and R. Cabell: 'Initial investigation into the psychoacoustic properties of small unmanned aerial system noise', in Editor (Ed.)^(Eds.): 'Book Initial investigation into the psychoacoustic properties of small unmanned aerial system noise' (2017, edn.), pp. 4051

[34] N. Sieben, R. Aalmoes, and V. J. M. C. Vos: 'A Deeper Understanding in the Psychoacoustic Characterization of Drone Noise'. Proceedings of the 10th Convention of the European Acoustics Association Forum Acusticum 2023, 2024, pp. 1015-1021

[35] R. Aalmoes, and N. Sieben: 'Visual and audio perception study on drone aircraft and similar sounds in an Urban Air Mobility setting'. INTER-NOISE and NOISE-CON Congress and Conference Proceedings, 2021, pp. 2510-2521

[36] R. Aalmoes, B. d. Bruijn, and N. Sieben: 'The influence of contextual non-auditory factors on drone sound perception'. Inter-noise and noise-con congress and conference proceedings, 2023, pp. 773-779

[37] M. J. B. Lotinga, M. C. Green, and A. J. Torija: "Human perception and response to sound from unmanned aircraft systems within ambient acoustic environments", NPJ acoustics, vol. 1, no. (1), pp. 2-2, 2025

[38] N. Green, C. Ramos-Romero, and A. J. Torija: 'Comparison of the noise perception of conventional aircraft and Unmanned Aircraft Systems'. INTER-NOISE and NOISE-CON Congress and Conference Proceedings, 2024, pp. 7419-7430

[39] A. J. T. Martinez, and Z. Li: 'Metrics for assessing the perception of drone noise', in Editor (Ed.)^(Eds.): 'Book Metrics for assessing the perception of drone noise' (2020, edn.), pp. 3163-3168

[40] A. J. Torija, Z. Li, and P. Chaitanya: "Psychoacoustic modelling of rotor noise", The Journal of the Acoustical Society of America, vol. 151, no. (3), pp. 1804-1815, 2022

[41] N. Green, A. J. Torija Martinez, and C. Ramos-Romero: "Perception of noise from unmanned aircraft systems: Efficacy of metrics for indoor and outdoor listener positions", Journal of the Acoustical Society of America, vol. 155, no. (2), pp. 915-929, 2024

[42] N. Green, C. Ramos-Romero, and A. Torija Martinez: 'Advances in the Measurement and Human Response to Noise of Unmanned Aircraft Systems'. SAE Technical Paper Series, 2023

[43] A. J. Torija, Z. Li, and R. H. Self: "Effects of a hovering unmanned aerial vehicle on urban soundscapes perception", Transportation Research Part D: Transport and Environment, vol. 78, pp. 102195, 2020

[44] R. K. Nicholls, T. M. AJ, N. Green, and C. R. Romero: "Assessment of drone noise impact on urban soundscapes", 2022

[45] M. C. Green, M. J. B. Lotinga, and A. J. Torija: "Shaping future soundscapes: Affective impact of unmanned aircraft systems noise in urban environments", Journal Of The Acoustical Society Of America, vol. 158, no. (4), pp. 2763-2778, 2025

[46] R. K. Nicholls, and A. J. Torija Martinez: 'An investigation into human response to unmanned aerial vehicle noise', in Editor (Ed.)^(Eds.): 'Book An investigation into human response to unmanned aerial vehicle noise' (2021, edn.), pp.

[47] A. J. Torija, and R. K. Nicholls: "Investigation of Metrics for Assessing Human Response to Drone Noise", International Journal Of Environmental Research And Public Health, vol. 19, no. (6), 2022

[48] R. König, L. Babetto, A. Gerlach, J. Fels, and E. Stumpf: "Prediction of perceived annoyance caused by an electric drone noise through its technical, operational, and psychoacoustic parameters", Journal of the Acoustical Society of America, vol. 156, no. (3), pp. 1929-1941, 2024

[49] M. Stolz, and T. Laudien: 'Assessing Social Acceptance of Urban Air Mobility using Virtual Reality'. 2022 IEEE/AIAA 41st Digital Avionics Systems Conference (DASC), 2022, pp. 1-9

[50] J. Ivosevic, E. Ganic, A. Petosic, and T. Radisic: "Comparative UAV Noise-Impact Assessments through Survey and Noise Measurements", International Journal Of Environmental Research And Public Health, vol. 18, no. (12), 2021

[51] S. W. Huber, P. Wellig, K. Heutschi, K. U. Stein, and R. Schleijpen: 'Determination of the detection threshold of human observers in acoustic drone detection'. Target and Background Signatures V, 2019

[52] C. Kawai, J. Jaggi, F. Georgiou, J. Meister, R. Pieren, and B. Schaffer: "Short-term noise annoyance towards drones and other transportation noise sources: A laboratory study", Journal of the Acoustical Society of America, vol. 157, no. (1), pp. 288-288, 2025

[53] R. M. Martinez, R. M. Y. Villanueva, B. v. d. Hoff, and J. S. Pockelé: 'Human response to the flyover noise of different types of drones recorded in field measurements'. Quiet Drones 2024, 2024

Appendix

NO	Study	Subjects	Location	Source	Duration	Stimuli length	Visual	Questionaire
1	Hara et al. (2022)	11	Large-screen projector room	Industrial drone	/	18 s	Screen-CG animation	/
2	Hara et al. (2021)	5	/	Helicopter; Alarm; Adjusted-heli; rotor	/	15 s	Screen-CG animation	/
3	Kim et al. (2023)	4	Soundproof booth	DJI Spark 2; DJI M30	/	30s	VR (Oculus Quest II)	/
4	Jeon et al. (2023)	11	Soundproof booth	DJI Spark 2; F550; DJI M30; Phantom 3; AGRAS T40	/	10s	VR (Oculus Quest II)	/
5	Gwak et al. (2020)	50 (Exp1) + 25 (Exp2)	Anechoic room	Small JJRC H12W; DJI F450; DJI S1000; Civil aircraft	/	7 s	/	/
6	Wang et al. (2022)	4	/	DJI Tello; BG: Natural Wind 3.4–7.9 m/s	/	30 s	/	/
7	Thomas et al. (2023)		Online	Fixed-Wing UAV (4 VTOL rotors + 2 pusher)			2D animation	/
8	Evensen et al. (2024)	17	Auralization lab	Single UAV	/	5 s	Lights dimmed	/
9	Begault (2023)	/	NASA larc NAF auralization room	Concept UAM	/	/	/	/
10	Krishnamurthy et al. (2023)	48	Online	UAV (SUI, Dax-8, Phantom 2, VPV); Ground vehicles (Subaru, Step Van, Box Truck, Utility Van); Numerically Auralized Quadcopter & DEP aircraft	51 min	≈12–52 s	/	Pre: Demographics, Hearing, ZIP Code, Expertise; Post: Volume Change, Difficulties
11	Boucher et al. (2023)	40	Exterior Effects Room	Concept UAM	/	4.6s		Post: WNSS
12	Rizzi et al. (2017)	32	Exterior Effects Room	DEP high-lift system (auralized; sounds via NP×DF×subclass); Real prop/rotor aircraft	/	6 s	/	Post/Pre: Hearing exam
13	Christian and Cabell (2017)	38	Exterior Effects Room	Dax8; Stingray500; Phantom2; SUI; 4 road vehicles; Quadcopter/DEP aural	1h	≈8–48 s	/	/
14	Sieben et al. (2024)	/	NLR VCNS (VR)	MK Quadro XL; Gryphon GD-40X; Light heli; Lawnmower	45min	/	VR (Oculus Rift)	Post: Drone Attitude; Demographics; WNSS
15	Aalmoes and Sieben (2021)	30	NLR VCNS (VR)	MK Quadro XL 2.5 kg; Gryphon GD-40X 40 kg; light heli 1100 kg; Lawnmower	45min	/	VR (Oculus Rift)	Post: Drone Attitude; Demographics; WNSS
16	Aalmoes et al. (2023)	26	NLR VCNS (VR)	Drone1 quad; Drone2 octo; Drone3 hexa		<60 s	VR (Oculus Rift)	Post: WNSS; Demographics; Sight/Hearing; Drone Familiarity; Interview
17	Hui et al. (2021)	37	Anechoic chamber	DJI Mavic 2; DJI Matrice 210 V2; DJI Phantom 3; DJI Tello	40min	10 s	/	/
18	Lotinga et al. (2025)	41exp1; 42exp2	Listening room	Yuneec H520E; DJI Matrice 300; Malloy T150 X8	60–90 min	Exp1: 25 s; Exp2: 75 s	/	Pre: PANAS, hearing status Post: SF-WNSS, AAM attitude, area of residence & soundscape, demographics, feedback
19	Green et al. (2024)	41	Listening room	UAV (DJI M300; Malloy T150; Yuneec H520e); AC (B737-8 Max; B787-9; A320)	/	12 s	/	/
20	Martinez and Li (2020)	30	Small anechoic chamber	DJI Phantom 3; A320/A320neo; heli; car; motorbike/moped; B767, B787;	40 min	/	/	/
21	Torija et al. (2022)	29 (33 recruited)	Lab room	Single & contra-rotating propellers (14/16/18 in)	30 min	3 s	/	/
22	Green et al. (2024)	/	Listening room	GD28X; DJI M200; Yunceec	/	12 s	/	Pre: Demographics
23	Green et al. (2023)	30	Listening room	GD28X; DJI M200; Yunceec	/	/	/	Pre: Demographics
24	Torija et al. (2020)	30	Small anechoic chamber	DJI Phantom 3	1h20m	15 s	VR (Oculus Rift S)	/
25	Nicholls et al. (2022)	/	Online	Inspire; Matrice 600; Mavic; Matrice 200; GD28X	40 min	10 s	/	/
26	Green et al. (2025)	110	Outdoor park soundwalk	DJI Mavic 3	/	1 min	In-situ park view	Participants Demographics
27	Nicholls and Torija Martinez (2021)	/	Online	Inspire, Intel Falcon, Matrice 600, Matrice 200, Mavic, Phantom 3, Yuneec Typhoon, Gryphon GD28X	20 min	4 s	/	Pre: Age; Frequency Sensitivity
28	Torija and Nicholls (2022)	49	Online	Inspire, Intel Falcon, Matrice 600, Matrice 200, Mavic, Phantom 3, Yuneec Typhoon, Gryphon GD28X	20 min	4 s	/	/
29	König et al. (2024)	578	Online (global)	eVTOL “Rubina X8”	35 min	8 s	Context photo	Pre: Demographics, Short WNSS
30	Stolz and Laudien (2022)	47	Outdoor; under tent	5 UAV(Alpha 800 (heli), DeX ProX8, Phantom 4, MK Okto XL, PX-31); Volocopter 2X air taxi	/	1 min all, except air taxi (2 min)	VR (HTC Vive Pro HMD)	Pre: Attitude, Concerns; Post: Attitude Change, Concerns, Demographics
31	Ivosevic et al. (2021)	31	Outdoor meadow	Small Commercial Quadrotor; Custom Hexarotor	2h	/	Real UAV	Post: Demographics, Reasons Pro/Contra Uavs, Overall Benefit Judgment
32	Huber et al. (2019)	19	Quiet non-soundproofed room	DJI Phantom2	1h	2 s	/	/
33	Kawai et al. (2025)	36	Laboratory listening experiment	DJI Mavic 2 Pro; DJI Matrice 300 RTK; heli; Civil Jet; Propeller aircraft; Car	45–55 min	24 s	/	Post: Drone Knowledge/Attitude/Practice; Demographics
34	Martinez et al. (2024)	57	PALILA booth (TU Delft)	UAV (DJI Mini 2; DJI Mavic 3; Autel EVO II; DJI Phantom 3; DJI Phantom 4; DJI M300; Dronevolt H20); eVTOL(Atmos Marlyn; Avy Aera 3)	25 min	20 s	/	Pre: Demographics, Hearing, Well-Being; Post: Post-Exp Questionnaire
35	Callanan et al. (2020)	28	Workshop	DJI Phantom 4; 3DR Iris+	1h	80s	/	/