Visual & Sound

Perception study

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Eve Air Mobility is working towards a new concept for Urban Air Mobility (UAM) where electric vertical take-off and landing aircraft (eVTOLs)—that are expected to be quieter than many aircraft in the urban environment—will connect people across cities and suburbs. eVTOLs will operate close to communities, thereby introducing new types of sights and sounds. For a lift+cruise eVTOL design configuration, at take-off and landing, a set of rotors will power the eVTOL's vertical lift, while in the cruise phase, the rotors will turn off and the propeller(s) at the back of the aircraft will power horizontal flight. As a result, the sound characteristics of lift+cruise eVTOLs will differ depending on the phase of flight. The sound profile may also differ for distinct eVTOL designs, with varying number and position of propellers.

Communities should be informed and consulted about the types of sights and sounds expected from eVTOL operations. As cities and fleet operators plan for the launch of UAM operations and seek the necessary social license to operate close to communities, it is critical to understand residents' perceptions of this new technology across different environmental settings. Insights from perception studies will help governments and industry tailor their strategies and frameworks for proactive community engagement and consultation.

Eve Air Mobility and the Royal Netherlands Aerospace Centre (NLR) conducted a study to understand community perceptions of an eVTOL visual and sound footprint and the threshold by which perceptions of annoyance arise. Focusing on the areas in and around New York City, Orlando and San Francisco, the study analyzed potential residents' perceptions of eVTOL flights in the context of normal ambient sounds and activities in the urban and suburban environment.

Through the use of virtual reality (VR) and modern technologies for auralization—a technique for creating audible sound data from numerical simulation—we created realistic sights and sounds that mimic an eVTOL operation in different urban and suburban settings. This report presents a summary of the study and the follow-up activities.

Goals

This study aimed to understand residents' perceptions of eVTOL sights and sounds at different phases of flight across different urban and suburban locations. It examined whether an eVTOL acoustic signature created annoyance and compared general perceptions of eVTOL sound to other aircraft sounds in the urban environment. Additionally, the study sought to understand how the sight of the eVTOL aircraft across different settings contributed to people's perceptions of annoyance. Quantitative data analysis was used to rate participants' responses.

Methodology

Multiple combinations of sound and visual samples from different aircraft types, including eVTOLs, helicopters and a turboprop, were prepared and layered over the ambient environment using a virtual reality system. The sound and visual events for each aircraft type were the same for each urban and suburban environment.

Equipment / Tools

A VR environment was created via a pair of VR glasses combined with calibrated headphones and controlled simulation software. The system ensured that the same stimuli were presented to all the participants in a randomized order. Sound events were presented at different sound levels. After each event, participants rated their perceived annoyance.

Scenarios

Data collection was based on scenarios that varied across different urban environments, aircraft types, flight phase, aircraft visibility and sound characteristics. Specifically, each scenario presented visual and aural aircraft events in the context of either a busy urban environment with high background noise or a quieter urban environment with lower ambient noise in proximity to residential neighborhoods. Figure 1 illustrates a summary of the methodology of this study.

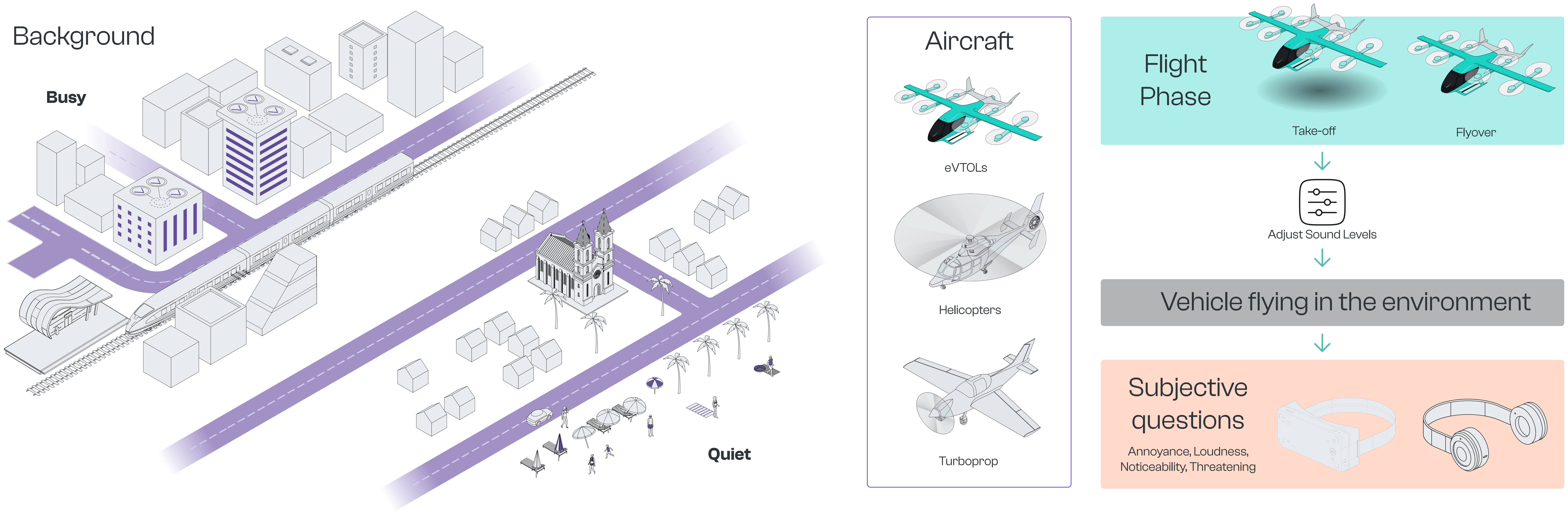


Figure 1: Single event study methodology.

A set of in-situ recordings were done to collect video and audio data of the ambient visual and aural environment. The helicopter and turboprop audios were extracted from an experimental database, while eVTOL sound characteristics were simulated. For eVTOL samples, the auralization process was conducted in two steps: 1) sound source characterization using advanced modeling and 2) flight path and sound propagation to the receptor's position, as shown in Figure 2. Following this process, the main sounds of the vehicle—the lifting and pusher propellers—were synthesized and reproduced. These samples were obtained according to the aircraft design characteristics and the flight phase. Environment only samples, made for both (360°) video and audio in accordance with realistic background sound levels in the selected cities, were also considered to evaluate the feeling of participants about the visual and sound background.

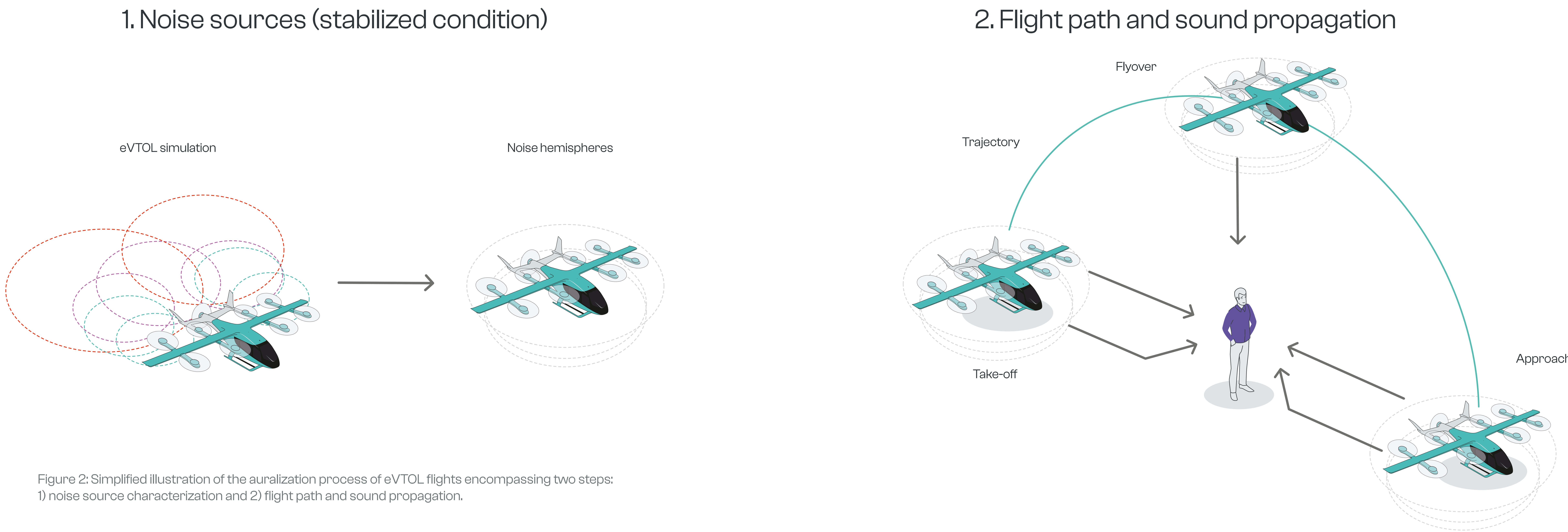
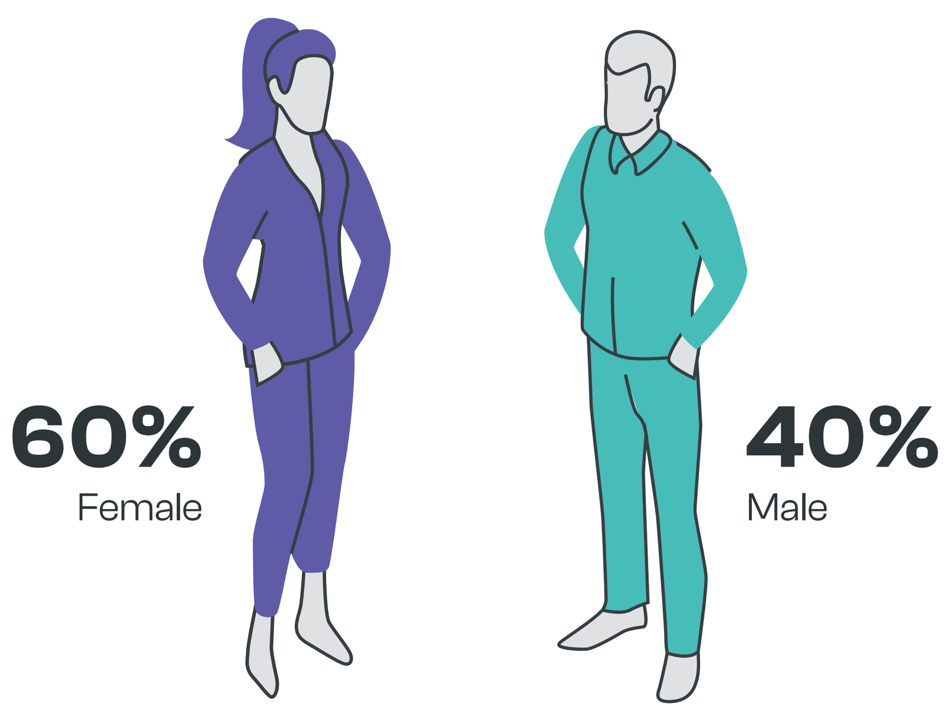


Figure 2: Simplified illustration of the auralization process of eVTOL flights encompassing two steps: 1) noise source characterization and 2) flight path and sound propagation.

Participants

The study sought to recruit participants who reflected the community's demographic diversity. Over 100 participants aged 18 to 65 were selected based on broad demographic requirements including but not exclusive to age, gender, residential locations and education levels. The aim was to recruit a representative sample of the local population. The study was conducted in New York City, Orlando and San Francisco. Gender and the number of participants per city are shown in Figure 3.

Gender distribution



Participants per city

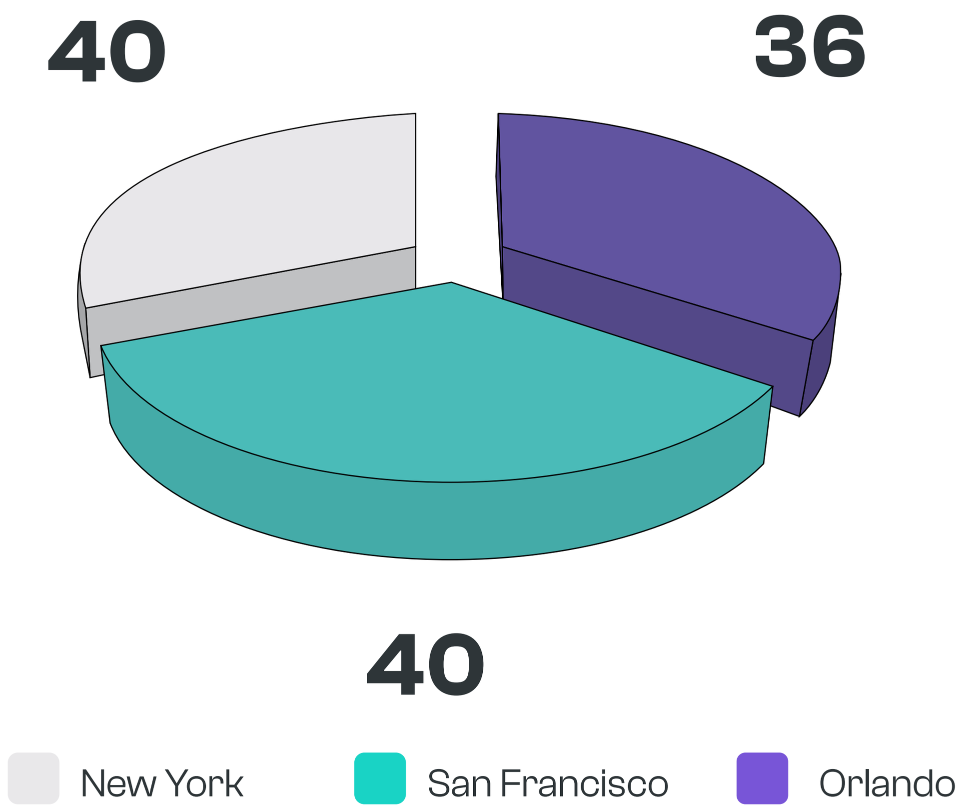


Figure 3: Gender distribution and participants per city

Data Collection

Participants were briefed about the study and given instructions before data collection. The preparation process included a pre-survey questionnaire that assessed individual noise sensitivity. During the test, they rated the scenarios by using an 11-point Likert Scale, with 0 being 'Not at all' and 10 being 'Extremely', answering how strongly the aircraft events affected them in terms of annoyance, noticeability, threat, and loudness in the context of the urban or suburban environment. Figure 4 shows the study execution in one of the test sites.

Figure 4: Study execution in New York City, NY.

Results

The results of a first perception study are presented here to assess community response to eVTOL sights and sounds. Results presented herein are part of a preliminary assessment of the community perceptions of eVTOL sights and sounds. A more thorough understanding of this topic will require data from real operations and practical implementation of the technology.

General response to eVTOL sound

Overall, annoyance scores for eVTOL flyovers were low considering the sound level expected from these aircraft.

Participants expressed more annoyance at eVTOL take-off events - where they are 330ft away from the flight event - when compared to eVTOL flyovers at 1000ft above ground level (AGL). This is not surprising when considering the higher reference A-weighted sound pressure level for the take-off phase, and proximity of the vehicle to the observer during take-off scenarios. Figure 5 presents the boxplots of responses considering flyovers and take-offs when observer is in a quiet environment. The median scores are represented by the black lines.

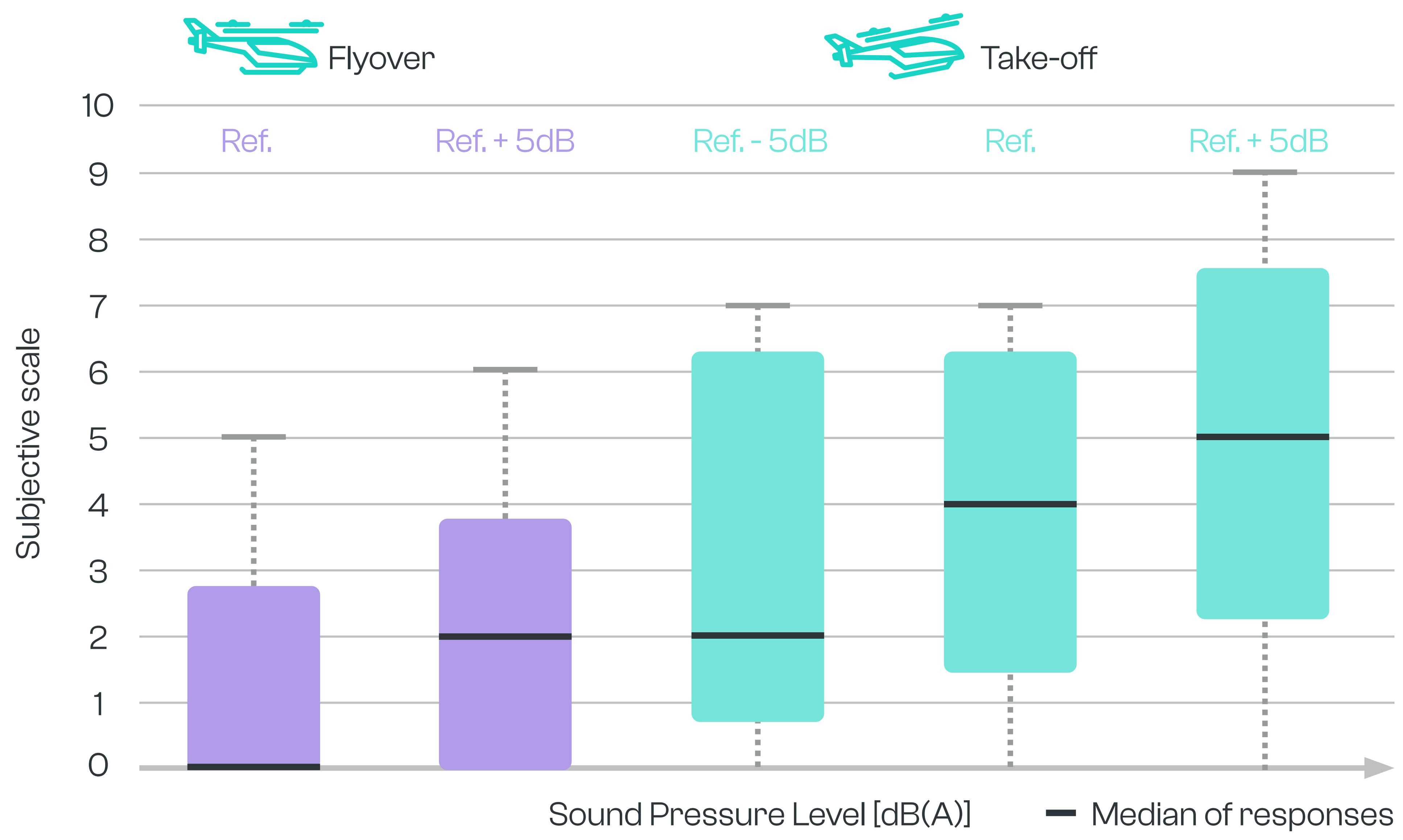


Figure 5: Boxplots of responses considering eVTOL sound in a quiet environment in all the studied cities.
Median scores are represented by the black lines.
Box limits indicate the range of the central 50% of answers, with a central line marking the median value.

In general, lower annoyance was reported for eVTOL flyovers and take-offs when compared to helicopters flying at the same altitude. Figure 6 shows a 'highly annoyed' (HA) trend for helicopters and eVTOLs. The x-axis indicates the A-weighted Sound Pressure Level, while the green and purple boxes represent the operating noise level range for both technologies. For determining HA threshold, the 11-point Likert scale is especially well-suited as the highest three scores related to the 72% threshold value. This represents the percentage of people that would be highly annoyed when experimenting with the flight event.

At take-off, a difference was found between similar flights in quieter and louder environments. Operations in louder backgrounds presented a trend of lower annoyance scores.

The HA plot considers take-off in both background scenarios is presented in Figure 7.

Flyover @ 1000ft AGL

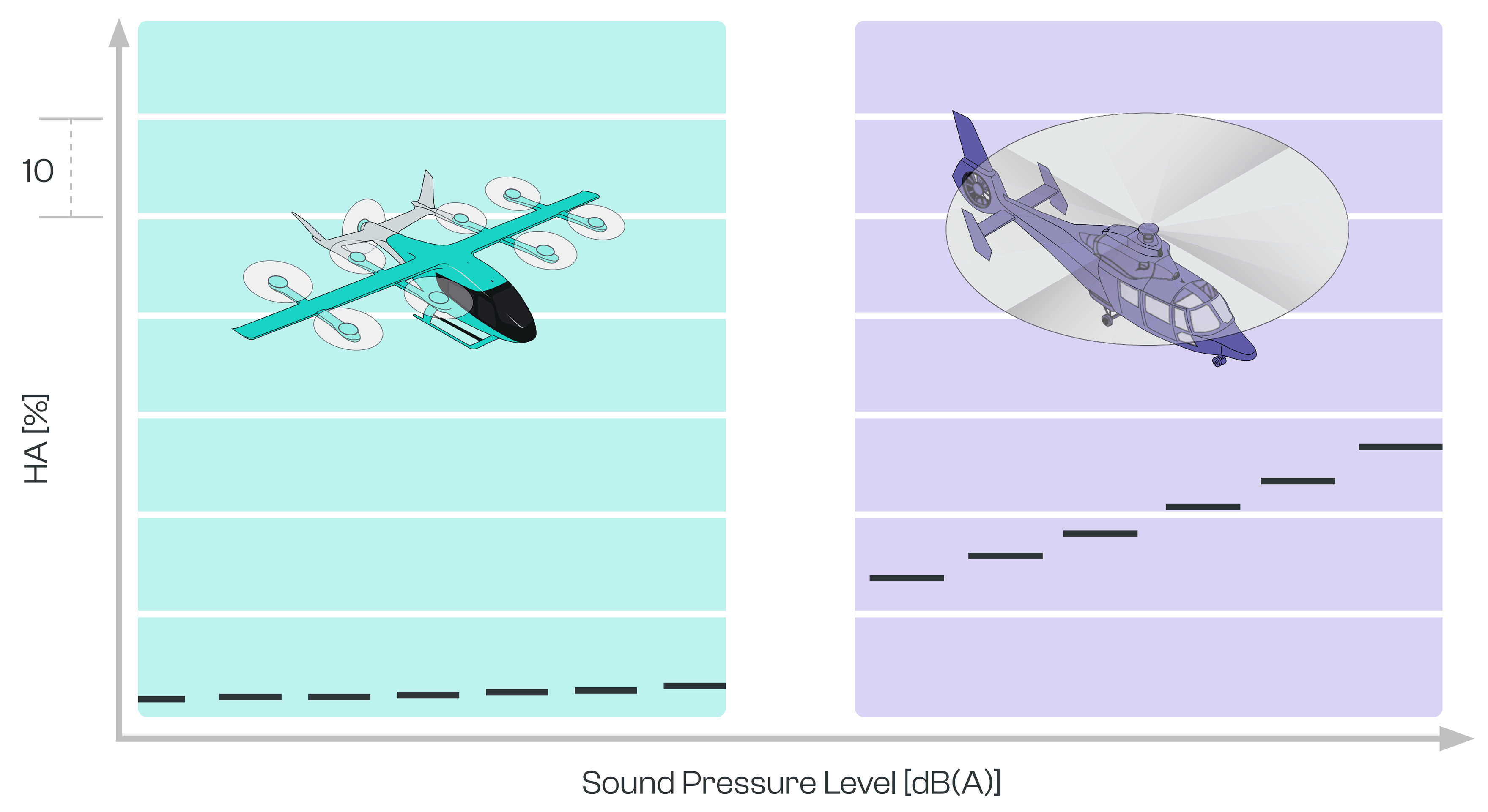


Figure 6: HA trends in a quiet environment for eVTOL and helicopter flyovers operating on their expected sound level range.

Take-off @330ft | busy vs quiet

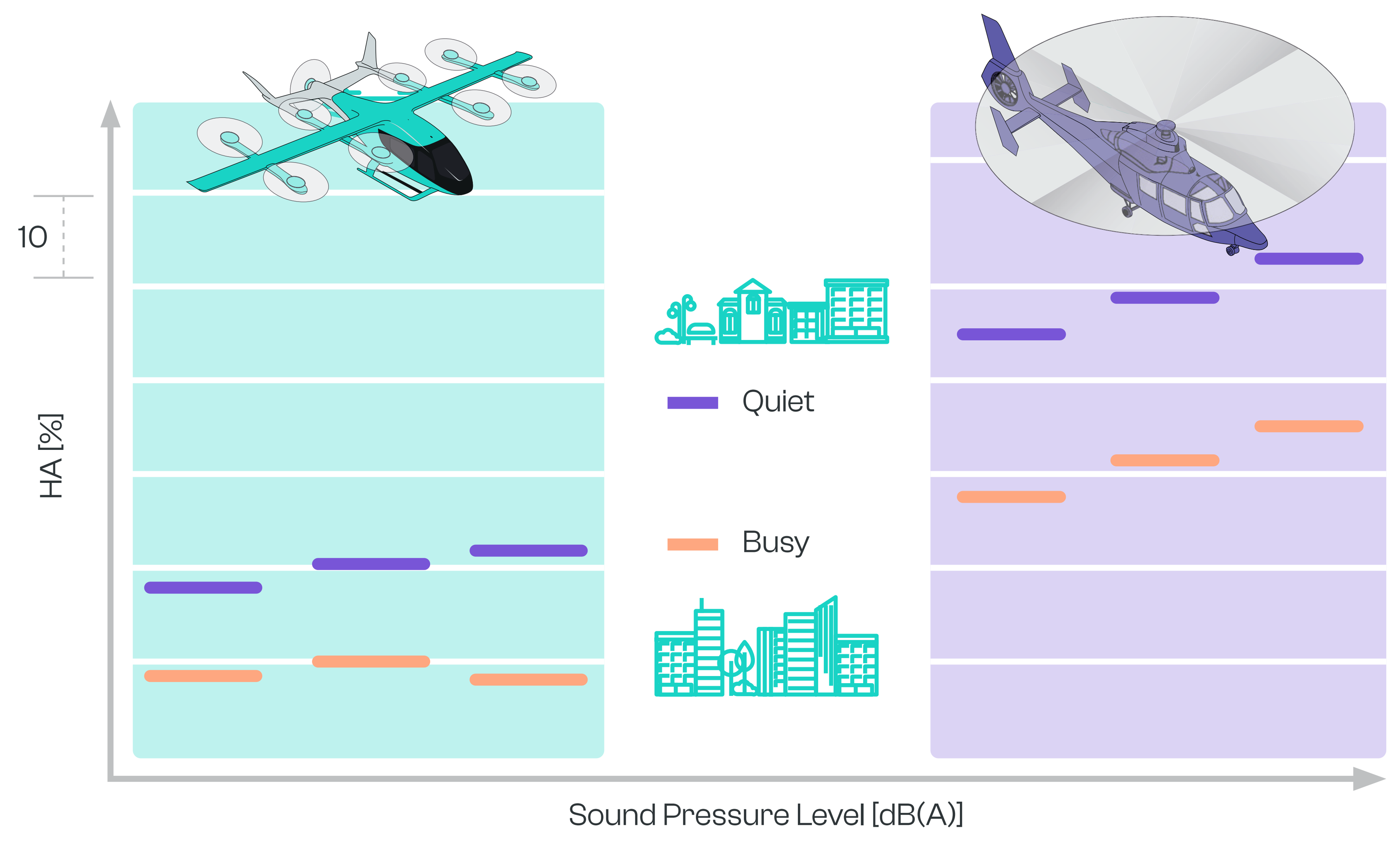


Figure 7: HA values considers different environments for eVTOL and helicopter take-offs operating on their expected sound level range.

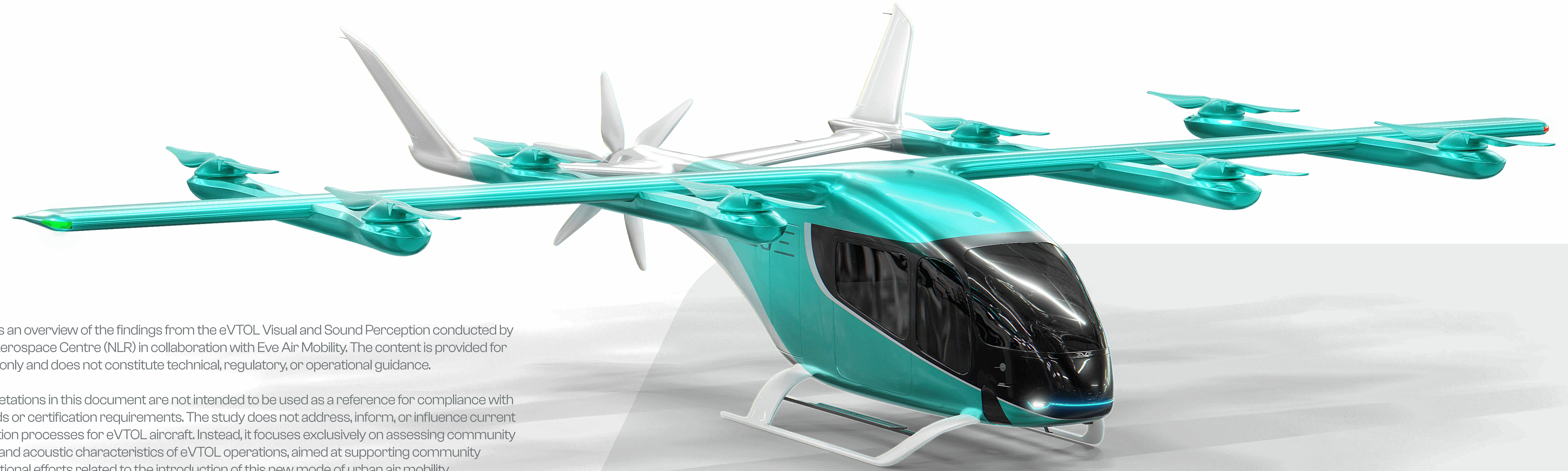
Visual Impact of eVTOLs on Perceptions of Annoyance

During flyover events, there were no differences in aural annoyance ratings with or without the sight of eVTOLs overhead. However, higher annoyance scores were found when the aircraft was visible during take-off.

A higher level of annoyance was reported when participants could see an eVTOL taking off compared to when they only heard it.

Concluding remarks

This study has provided useful insights into the perceptions of eVTOL sights and sounds in urban and suburban environments. The results show there were low levels of annoyance from eVTOL sounds when compared to helicopters in the context of local ambient sights and sounds. In terms of visual annoyance, there was an increase of annoyance when the eVTOL was visible during take-off. Insights about community perceptions of eVTOL sights and sounds will be useful to governments and industry as they begin planning the ecosystem for UAM operations. Community engagement and consultation must be a key part of these plans and are critical to the successful launch and scale of UAM. Data about eVTOL sight and sound perceptions in the context of the local environment will enable to understand how communities are likely to respond to the new sights and sounds from this new technology. Subsequently, governments and communities will be better informed as they evaluate how to best benefit from UAM while minimizing any negative effects.



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