frontiers | Frontiers in Built Environment

TYPE Original Research
PUBLISHED 06 September 2023
DOI 10.3389/fbuil.2023.1035592

Check for updates

OPEN ACCESS

EDITED BY
Ali Keyvanfar,
Kennesaw State University, United States

REVIEWED BY
Ahmet Cilek,
Arizona State University, United States
Ping Liu,
Jiangsu University of Science and Technology, China

*CORRESPONDENCE
Eli Samuel Bridge,
ebridge@ou.edu

RECEIVED 02 September 2022
ACCEPTED 22 August 2023
PUBLISHED 06 September 2023

CITATION
Kolbmann CL, Leslie C, Anderson C, Kelly JF, Ross JD, Jervis L, Reedy J and Bridge ES (2023), Perceptions of the crowded sky as assessed through response to aerial infrastructure.
Front. Built Environ. 9:1035592.
doi: 10.3389/fbuil.2023.1035592

Perceptions of the crowded sky as assessed through response to aerial infrastructure

Christina L. Kolbmann[1,2], Carrie Leslie[3], Chris Anderson[4], Jeff F. Kelly[1,2], Jeremy D. Ross[2], Lori Jervis[5], Justin Reedy[4] and Eli Samuel Bridge[2]*

[1]School of Biological Sciences, University of Oklahoma, Norman, OK, United States, [2]Oklahoma Biological Survey, University of Oklahoma, Norman, OK, United States, [3]Department of Sociology, University of Oklahoma, Norman, OK, United States, [4]Department of Communication, University of Oklahoma, Norman, OK, United States, [5]Department of Anthropology, University of Oklahoma, Norman, OK, United States

Ever increasing numbers of wind turbines, communication towers, power lines, and aerial vehicles are clear evidence of our growing reliance on infrastructure in the lower aerosphere. As this infrastructure expands, it is important to understand public perceptions of an increasingly crowded sky. To gauge tolerance for aerial crowding, 251 participants from across the US completed a survey where they rated tolerance for a series of aerial infrastructure images (i.e., towers, turbines, and airborne vehicles) in four landscapes with varying degrees of pre-existing ground-level infrastructure that approximated rural, suburban, and urban settings. We predicted lower tolerance for aerial infrastructure 1) in more natural scenes and 2) among rural residents. In general, participants preferred an open aesthetic with relatively little aerial infrastructure across all landscape types. No clear association was found between infrastructure tolerance and natural scenes nor rural residency, with participants slightly less tolerant of infrastructure in the suburban scene. Tolerance scores were generally similar across age, income levels, and political affiliations. Women indicated less crowding tolerance than men, with this effect driven by a disproportionate number of women with zero tolerance for aerial infrastructure. African Americans and Asians had higher tolerance scores than other racial/ethnic groups, but these trends may have been affected by low sample sizes of non-white participants. Our survey revealed fewer differences in crowding tolerance across demographic groups than might be expected given widely reported political and geographic polarization in the U.S. Attitudes toward aerial infrastructure were varied with few associations with demographic parameters suggesting that public opinion has not yet solidified with regard to this issue, making possible opportunities for consensus building with regard to responsible development of aerial infrastructure.

KEYWORDS

aerial infrastructure, aerosphere, aesthetics, public perception, urban planning and design

1 Introduction

A convergence of technological advances and infrastructure developments have brought us to a new phase of human history—the era of the crowded sky. While the sky was once seen as a limitless expanse, we are continuing to see conflicts arising from concurrent human use of the lower atmosphere for transportation (Kopardekar et al., 2008), communication (Kashyap et al., 2014), solar energy (Sawyer et al., 2022), wind energy (Klæboe and Sundfør, 2016), hunting (Rowland et al., 2021) and drone use (Rule, 2015). Meanwhile, a variety of wildlife requires this airspace as habitat for migration (Peterson et al., 2015), foraging (Remsen and Robinson, 1990), and reproduction (Clark, 2009). Understanding how we can balance demands for space in the lower atmosphere is an emerging problem that can only be met by an interdisciplinary approach which considers the physical properties of the aerosphere, the biological entities that use it, the spatial distribution of relevant resources, and the requirements and perceptions of human societies. This study attempts to provide insights into the last of these elements - human perceptions of the lower atmosphere relative to infrastructure development.

A discussion about anticipated pathways of future development within the lower atmosphere should include some sense of how much aerial infrastructure people regard as tolerable. More specifically, we should understand how various viewpoints might contribute to a balance of economic development, social equity, and environmental health that could be deemed sustainable. Despite the importance of the sky throughout human existence, there is remarkably little research that examines how we currently perceive it. A study of 650 people in 5 urban areas suggests that people, especially urban residents, have only a tenuous awareness of the sky, with most participants expressing concern about the condition of the sky (e.g., cloudy, clear, etc.) while they were unable to accurately describe it during the day or night (Zube and Law, 1984). As the aerosphere is a natural resource in which a variety of constituencies–human and non-human–have interests, we need a better understanding of people's attitudes about its use as well as an understanding of how they use the space.

To gain insight into human perceptions of aerial infrastructure, we created an online survey wherein participants could actively vary the amount of aerial infrastructure in four different landscape images and indicate what they believed to be acceptable and/or excessive amounts of built environment, such as wind turbines, electrical towers, communications towers, and aerial vehicles (Figure 1). The image selection application was used in conjunction with a more traditional survey instrument that asked participants about their socioeconomic status, political leanings, and attitudes toward nature.

The primary focus of this study was to determine whether people's tolerance of aerial infrastructure is related to their connections with natural, as opposed to artificial, environments. We recruited participants from both rural and urban communities

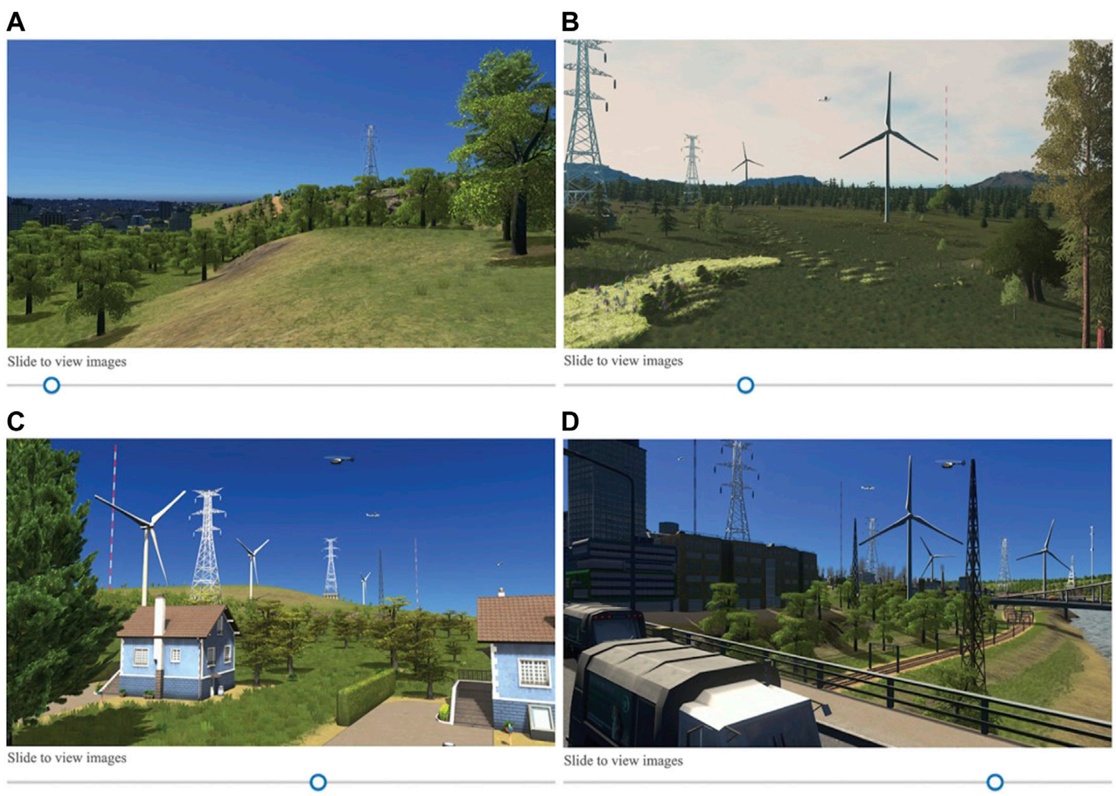

FIGURE 1
Landscape background images used to evaluate tolerance limits for aerial infrastructure. Participants in our survey could move the sliders below each image to increase or decrease the amount of aerial infrastructure in the image. From **(A–D)** we refer to the images as "nature," "park," "suburb," and "urban". Participants were not given labels during the survey.

with the expectation that residents in more rural communities would be less tolerant of aerial infrastructure in general. We also predicted that background images depicting more naturalistic settings would receive lower tolerance scores than landscape images that depicted more built environments. Our survey asked participants whether they saw nature as fragile or robust, and we predicted that lower tolerance scores would be selected by those who regarded nature as fragile. As a secondary focus, we investigated whether tolerance of aerial infrastructure was related to several standard demographic parameters including gender, income, home ownership, age, racial identification, and political affiliation.

Although the depictions of aerial infrastructure in our survey are illustrations rather than real landscapes, this simple tool allowed us to quickly generate novel data on public attitudes about the potential crowding of the sky. This approach can help us establish a baseline of public opinion on a topic which has been relatively under-examined in studies of the public's views on the environment, and this form of preemptively surveying aerial infrastructure tolerance is valuable in informing urban decision-making, expansion planning, and rural industrial development. In addition to testing the predictions described above, we evaluate the potential for our survey approach to contribute meaningfully to plans for future development of the lower atmosphere.

2 Materials and methods

Our survey was designed using Qualtrics, and can be viewed here: https://osf.io/4gd5e. The survey consisted of 58 questions grouped into three general categories. First, we presented a series of four questions that ask participants to interact with a landscape image using a "slider" immediately below the image (Figure 1). As the participant moved the slider to the right, the landscape became increasingly populated with tall structures and aerial vehicles. Participants were asked to move the slider to the point where they felt that there was too much aerial clutter. The final location of the slider when a participant moved on to the next question was scored as an integer from 0 to 19; henceforth these values are referred to as tolerance scores. Participants were presented four different landscape background images with varying levels of pre-existing ground-level infrastructure, with the presentation order randomized. Images consisted of an open woodland pasture with one cell tower, a park-like scene with a low amount of aerial infrastructure, a low-density suburban scene depicting two residential houses with a moderate amount of infrastructure, and an urban scene with considerable built infrastructure (see Figure 1). Infrastructure added to each scene by the slider included an array of communication towers, electrical towers, wind turbines, airplanes, and drones. The same set of objects was added to each scenario, although the locations of the objects and the order in which they appeared varied among the four scenarios. The background scenes as well as the aerial objects were proportional and realistic, but also clearly artificial and distinguishable from photographs. The backgrounds and arrays of aerial infrastructure were composed using the simulation video game Cities: Skylines (Version 1.12.1, Paradox Interactive AB, Stockholm, Sweden). A rendering of all background images with aerial infrastructure is included in Supplementary Documentation (see Supplementary Figures S1–S4).

Another category of questions participants answered focused on demographic information and environmental concerns. We asked demographic questions about: age, gender, income, racial identification, and political affiliation. In addition, we asked whether participants regarded nature as fragile or robust (on a scale from 1 to 10), and we regarded this response as the respondents 'attitude toward nature.' We also asked respondents which potential problems and benefits associated with increased use of the lower atmosphere were of greatest concern to them and where these environmental concerns ranked among other societal problems. A third category of questions addressed the process of deliberative citizen committees and whether participants would regard these committees as a means of addressing problems or conflicts that relate to overcrowding of the lower atmosphere (data not shown–readers can access the full survey to examine this set of questions).

We disseminated the survey using the survey panel service from Qualtrics. XM, a survey recruitment service which completes specified demographic quotas to achieve as close to a random sampling as possible. All survey respondents were residents of the United States. Respondents were recruited from a variety of sources including frequent-flyer memberships and retail incentive programs. Participants were also compensated by Qualtrics. XM in a variety of ways, and the value of the compensation ranged from approximately 0.7–3 US dollars. To ensure that the images in the survey were viewed in a relatively large format, participants were required to take the survey using a computer as opposed to a phone or tablet. We used preliminary screening options to stipulate a balance among four regions of the United States as well as equal representation from males and females. In addition, we initially stipulated a balance of responses from rural and urban communities (wherein rural communities had <50,000 people); however we had to relax this requirement to reach our target of 250 survey participants. As a result, there are slightly more respondents from urban communities. Our survey and recruitment process were reviewed and approved by the University of Oklahoma Institutional Review Board (IRB number 13439).

Survey data were analyzed using the R Programming Environment (version 4.0.2; R Core Team). We used the 'qualtRics' package (Gin and Silge, 2021) to import data directly from the Qualtrics server. We then filtered data to remove incomplete surveys and responses associated with our own testing of survey functionality. We carried out significance tests were carried out to examine whether tolerance scores were related to several key respondents' characteristics, specifically: 1) rural ***vs*** urban residency, 2) the background images used in the survey, 3) attitude toward nature, 4) political party, 5) gender, 6) race/ethnicity, 7) age, 8) income, and 9) homeownership. With the exception of the age analysis, we used a within-subjects approach (i.e., mixed models with respondent ID as a random factor) in all analyses with the tolerance scores for each of the four background images regarded as a repeated measure. Each of these analyses involved generating a simple null model using the nlme package (Pinheiro et al., 2022), and then generating a corresponding model with the key variables included. We then performed a likelihood ratio test to see if the variable(s) of interest significantly improved the model. Results from these–tests consist of chi-squared statistics an associated p-values. For the analysis age, we generated a mean tolerance score for each participant and simply regressed these means on participant age. Each statistical test involved some degree of data manipulation to divide participants into categories and/or to remove data where there was insufficient representation. A full description of each statistical test along with preliminary data preparation is included in our Supplementary Material, and the associated R code is available here: https://osf.io/d6jhn/. The account below, only summarizes the results. Means are presented with standard deviations unless otherwise indicated. Twenty-four respondents selected 19 (the maximum) for every tolerance score, and 7 respondents selected 0 (the minimum) for every tolerance score. It is possible that these respondents were simply "clicking through" the survey and not providing considered and authentic responses. On the other hand, these people may have been expressing very high or low tolerance for aerial infrastructure. To ensure that this set of responses did not bias our results, we ran all analyses with and without these participants included.

3 Results

A total of 251 respondents completed surveys. The pool of respondents was slightly female biased with 112 identifying as male, 138 as female, and 1 non-binary. It also had a modest bias toward participants from urban communities (i.e., communities with over 50,000 residents), with 133 urban residents and 118 rural residents. The survey was administered from September 28 to 26 October 2021, nationwide in the United States using the Qualtrics Experience Management service. Although we requested a balance of representation from all regions, without explanation Qualtrics delivered a dataset that was biased toward respondents from the southern United States, with 95 respondents from the south and 48, 56, and 52 from the Northeast, Midwest, and West, respectively. Average response times for the slider questions ranged from 5.1 to 113.1 s, with an average of 25.5 ± 14.0 s. Only two respondents had average response times less than 9 s, suggesting that the vast majority of participants were not randomly choosing tolerance score values. The presentation order of the different landscape background images was randomized, but there was some evidence that the presentation order affected the selection of tolerance levels for aerial infrastructure. We examined the tolerance level means associated with presentation order and found that the first background presented had a slightly higher mean tolerance score (8.43 ± 6.58) than the second (7.62 ± 6.19), third (7.31 ± 6.10), and fourth (7.42 ± 5.95) background images. An ANOVA of tolerance scores across the presentation order was not significant ($F_{3,192} = 1.656$, $p = 0.175$). However, when the tolerance scores from the first background image were compared with the combined scores for all subsequent images combined, there was a significant ANOVA test ($F_{1,179} = 4.657$, $p = 0.0312$). Therefore, we generated a binary variable to indicate which of the four backgrounds was presented first for each respondent (i.e., the first background was coded as a 1 and subsequent backgrounds were coded as 0). We then incorporated this 'first background' factor in all subsequent analysis to control for potential bias associated with image presentation order.

Table 1 summarizes the results of all statistical tests and Figure 2 illustrates effect sizes. We found no evidence that tolerance scores were influenced by urban vs. rural residency, attitude toward nature, age, income, or homeownership. With regard to the background images used in generating tolerance scores, there was a slightly lower mean tolerance score for the low-density suburban background image, and this trend was evident in both the full dataset ($x_3^2 = 19.10$, $p < 0.001$) and the truncated dataset ($x_3^2 = 19.53$, $p < 0.001$) that excluded participants who consistently chose 19 or 0 for all tolerance scores. In comparing tolerance scores among political parties, we found that democrats tended to have lower tolerance scores on average. This potential effect did not reach the level of significance, although it was more pronounced (and nearly significant: $x_3^2 = 6.81$, $p = 0.078$) in the analysis of the truncated data set as opposed to the full dataset. There also appeared to be lower tolerance scores in women (Women: 7.09 ± 5.61; Men: 8.50 ± 5.42; $x_1^2 = 3.96$, $p = 0.048$). However, this difference became less pronounced after removing participants who only chose tolerance values of 19 or 0 (Men: 7.16 ± 4.03; Women: 6.33 ± 4.43; $x_1^2 = 2.09$, $p = 0.15$), which was likely due to the fact that 7 of the 9 participants who selected only 0 for all tolerance score were women. Finally, our analysis of race and ethnicity with regard to tolerance scores was complicated by the fact that 82% of the respondents were white, and representation of each minority group was very limited (Figure 3). Still, there was evidence that African Americans and Asians had higher tolerance scores than some of the other racial and ethnic groups, and this trend held for both the full data set ($x_5^2 = 11.70$, $p = 0.039$) and the truncated data set ($x_5^2 = 14.42$, $p = 0.024$). The results from all statistical tests are more fully presented in Section 1 of the Supplementary Documentation.

4 Discussion

Our main prediction–that lower tolerance for aerial infrastructure would be associated with rural imagery and rural residents–was not strongly supported by any of our analyses. Among the different background scenes, participants tended to indicate lower tolerance scores for the depiction of a suburban residential area. Our expectation was that the more natural settings (the nature and the park scenes) would receive lower tolerance scores than the more human altered settings. While we did not inquire as to the reasoning for various selections such as lower property levels, it is possible that a cluttered skyline is least desirable in a scene that depicts a residential dwelling.

4.1 Assumptions and limitations of the study design

Implicit in our comparison of rural and urban residents is the assumption that the current residential situation of each participant represents their preferences and that these preferences would contribute to their tolerance scores. That is, people who live in rural areas do so because they prefer the countryside, and urban dwellers preferentially choose the more built-up environments of cities. However, it is likely that many of our participants face external constraints, such as economic hardships, family arrangements, or transportation issues, that force them to forego their preferences to

TABLE 1 List of all tests, models, and summarized results from survey data on tolerance of aerial infrastructure. The truncated data set refers to exclusion of survey participants who only chose the minimum or maximum tolerance values in their survey responses. Abbreviations are as follows: TS = tolerance score; first = which background image was presented first; urbRur = Urban vs. Rural resident classification; scene = which of the four background images used in tolerance score questions; natAttCat = categorical classification based on attitude toward nature, party = political party affiliation, race = one of five racial/ethnic categories; income = one of three income categories; homeowner = one of three homeownership categories.

Analysis and model (R code)	Full dataset results	Truncated data set results
Null TS ~ first + (1|id)	not a test	not a test
urban vs. rural residents TS ~ urbRur + first + (1|id)	no effect $x_1^2 = 0.012$, $p = 0.91$	no effect $x_1^2 = 0.54$, $p = 0.46$
Background Image TS ~ scene + first + (1|id)	slightly lower mean TS score for the low-density suburban background $x_3^2 = 19.10$, $p < 0.001$	lower mean TS score for the low-density suburban background $x_3^2 = 19.53$, $p < 0.001$
Attitude toward nature TS ~ natAttCat + first + (1|id)	no effect $x_2^2 = 0.1.96$, $p = 0.37$	no effect $x_2^2 = 3.32$, $p = 0.19$
Political party TS ~ party + first + (1|id)	no effect $x_3^2 = 0.72$, $p = 0.87$	higher TS among democrats (nearly significant) $x_3^2 = 6.81$, $p = 0.078$
Gender TS ~ gender + first + (1|id)	lower TS in women $x_1^2 = 3.96$, $p = 0.048$	lower TS in women, but not significant $x_1^2 = 2.09$, $p = 0.15$
Race/ethnicity TS ~ race + first + (1|id)	African Americans and Asians tended to have higher TS scores. $x_5^2 = 11.70$, $p = 0.039$	African Americans and Asians tended to have higher TS scores. $x_5^2 = 14.42$, $p = 0.024$
Age TS ~ age	no effect $R^2 = 0.0045$, $p = 0.29$	no effect $R^2 = 0.0023$ $p = 0.48$
Income TS ~ income + first + (1|id)	no effect $x_2^2 = 1.82$, $p = 0.40$	no effect $x_2^2 = 1.27$, $p = 0.53$
Homeownership tolerance ~ homeOwner + first + (1|id)	no effect $x_2^2 = 1.83$, $p = 0.40$	no effect $x_2^2 = 1.29$, $p = 0.52$

live in more urban or rural settings. Previous studies suggest wind turbine noise is a burden for rural landowners (Pedersen and Waye, 2004; Rogers et al., 2006; Harrison, 2011; Van Renterghem et al., 2013; Schmidt and Klokker, 2014), on the other hand extending cellular network capabilities from more towers is beneficial for rural or underserved communities (Cassidy, 2013). Unfortunately, we did not ask participants to state their preferred living situation. Making it unclear whether those preferring rural residency would be more opposed to aerial infrastructure than those who prefer urban environments.

The slider images in our survey provided a simple means of revealing attitudes toward built infrastructure, but this approach clearly has limitations with regard to real world applications. Dynamic graphics controlled by sliders have been previously used to assess participants' perceptions of body esthetics (Springer et al., 2011; Ralph-Nearman et al., 2019), simulated environments (Khadka and Banic, 2019; Stephens and Smith, 2022), and self-ideal dietary portion sizes (Embling et al., 2021), but to our knowledge this was the first attempt to deploy this method to gauge reactions to aerial crowding. This use of slider scales can lead to higher participant dropout when using static pictures (Funke et al., 2011), but our survey used dynamic frames. Online surveys do not always incentivize honest, unrushed responses (Martins and Lavradio, 2020), and our survey is likely not an exception. Also, there was some indication in our data that the presentation order of the images influenced tolerance scores. Several studies have shown that perceptual inertia, or "hysteresis" can influence how users interact with graphical interfaces that involve decision making (Wienese et al., 2000; Brady and Oliva, 2012; Martin et al., 2015). For example, subjects tasked with indicating transitions among different types of on-screen images can display marked changes in the timing of their responses as testing progressed (Poltoratski and Tong, 2014). The notion of hysteresis could very much help to explain why the first image's score was consistently higher than subsequent image's scores.

4.2 Implications of expanding aerial infrastructure

The aesthetics of aerial infrastructure has been a focus of controversy in national and global planning efforts (Al-Hinkawi and Ramdan, 2016; Haruna et al., 2018). Although aesthetics are clearly an issue that we must address as our communications, energy, and transportation technologies advance, we are unaware of previous attempts to assess tolerance of aerial infrastructure in

10.3389/fbuil.2023.1035592

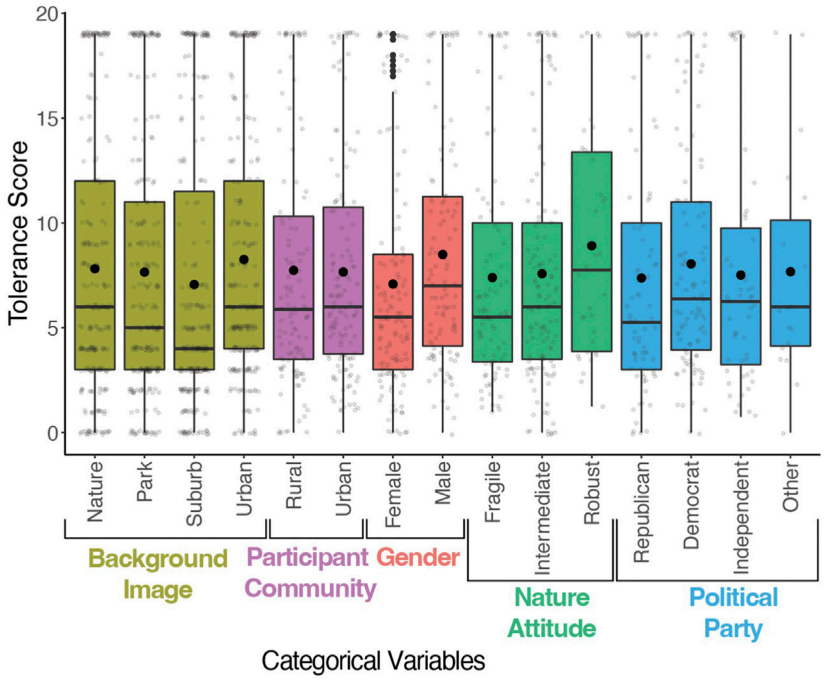

FIGURE 2
Boxplots of aerial infrastructure tolerance scores in relation to several categorical responses in our survey. The lines within each box are medians, and the solid dots are means. The transparent dots show the actual data with jitter added to better illustrate variation. Note that the first four boxplots on the left correspond to separate responses to each of the four background images. For all of the other boxplots, we used the mean tolerance score for each individual across the four background images.

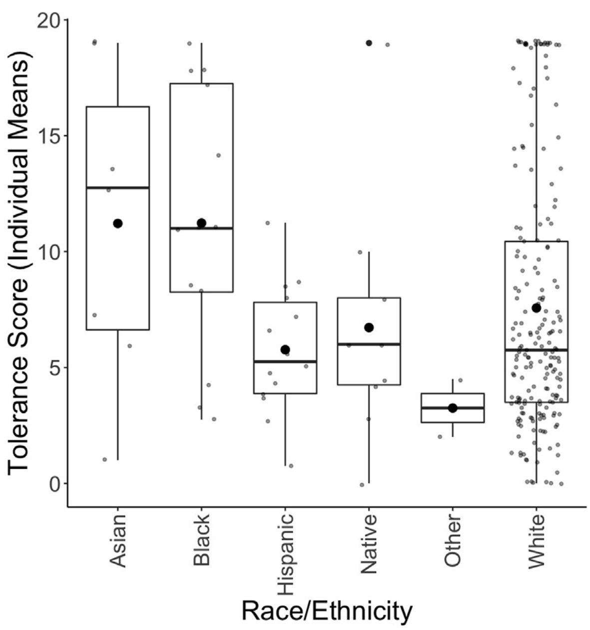

FIGURE 3
Tolerance scores across race and ethnicity categories of all survey participants. The lines within each box are medians, and the solid dots are means. The transparent dots show the actual data with jitter added to better illustrate variation.

a manner similar to our survey (i.e., in a hypothetical context). Several studies have assessed overall skyline aesthetics (Karimimoshaver and Winkemann, 2018), preferred type of skylines (Gholami et al., 2019; Karimimoshaver et al., 2021), infrastructure altering landscape indices (Sklenicka and Zouhar, 2018), and urban landmark visual appeal (Zhao et al., 2020), but these studies did not include varying levels of infrastructure. The most similar study asked visitors of Nairobi National Park in Kenya how their place attachment and genius loci (spirit of a place) changed with local urban growth and wind farm expansion (Nordman and Mutinda, 2016). Another study used eye-tracking technology to determine value of landscapes comparing hotels to culturally significant buildings like temples (Guo et al., 2021). Our study is the first to use imagery to discern tolerance thresholds in various landscapes for aerial infrastructure gradients.

With diminishing airspace availability, urban planners must consider public perceptions of increasingly crowded skies. There are bound to be many perspectives among academic disciplines which may pertain to the perceived or anticipated impacts of human alterations of the lower atmosphere, including: 1) physical infrastructure such as communication towers, tall buildings, and wind-powered turbines; 2) transportation such as airplanes, unmanned aerial systems or “drones”, blimps, and rockets; 3) airborne emissions including particulates, greenhouse gases, and other pollutants (e.g., ozone, hydrogen sulfide); and 4) artificial lighting by roadway or other infrastructure installations. It may also reflect different priorities in terms of sustainable use or ethical valuation. Various parties may not be on the same page in terms of sharing concerns within the system or even be able to recognize each other's motivations and reasoning.

5 Conclusion

Most participants selected tolerance thresholds indicating mid-level acceptance of aerial infrastructure. There were groups of people who selected tolerance scores that were on the extreme ends of the scale, suggesting that while most respondents preferred a relatively uncrowded aesthetic, a relatively small number of respondents may have had strong reactions toward the degree of aerial infrastructure crowding. While previous research strongly points to polarized attitudes toward public concerns, such as climate change (Jaffe, 2018), agriculture (Rasheed et al., 2022), and urbanization (Wilkenson, 2019), this study did not find associations between tolerance scores and political affiliation. It may be that the degree to which the sky should be dedicated to built infrastructure and transportation does not likely rank very high among the daily concerns of average people. This fact would suggest that there is still time for discussions that include everyday citizens about regulation of the use of the aerosphere. We argue that the time for these discussions is at hand given the rapid pace of development in the lower atmosphere These discussions must include human and non-human impacts, as the lower atmosphere is not merely a space for humans to populate with airplanes and communications towers but also a habitat for millions of other species that are struggling to cope with human induced changes to the aerial and terrestrial environments. This awareness along with a better understanding of human perceptions of cell towers, wind turbines, and drone usage will help urban planners use the lower atmosphere in a responsible manner that balances public needs with the unique ecology and aesthetics of the sky.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/d6jhn/.

Ethics statement

The studies involving human participants were reviewed and approved by University of Oklahoma Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CL, CA, JDR, LJ, JR, and EB conceived of the survey and wrote the survey questions. EB analyzed survey results. CK, JK, EB, and JDR drafted the manuscript, which was edited by CL, JDR, LJ, and JR. All authors contributed to the article and approved the submitted version.

Funding

This project was supported by the National Science foundation with award 1545261 from the National Research Trainee program and award 1840230 from the Emerging Frontiers program. This was supported by the Plans Institute and the Oklahoma Biological Survey.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fbuil.2023.1035592/full#supplementary-material

References

Al-Hinkawi, W., and Ramdan, A. "Aesthetic values of the future cities," in Proceedings of the 2nd International Conference on Architecture, Structure and Civil Engineering, London, UK, March 2016.

Brady, T. F., and Oliva, A. (2012). Spatial frequency integration during active perception: perceptual hysteresis when an object recedes. *Front. Psychol.* 3, 462. doi:10.3389/fpsyg.2012.00462

Cassidy, M. (2013). Introducing project loon: balloon-powered internet access. https://blog.google/alphabet/introducing-project-loon/.

Clark, C. J. (2009). Courtship dives of Anna's hummingbird offer insights into flight performance limits. *Proc. R. Soc. B Biol. Sci.* 276 (1670), 3047–3052. doi:10.1098/rspb.2009.0508

Embling, R., Lee, M. D., Price, M., and Wilkinson, L. L. (2021). Testing an online measure of portion size selection: A pilot study concerned with the measurement of ideal portion size. *Pilot Feasibility Stud.* 177, 177. doi:10.1186/s40814-021-00908-x

Funke, F., Reips, U. D., and Thomas, R. K. (2011). Sliders for the smart: type of rating scale on the web interacts with educational level. *Soc. Sci. Comput. Rev.* 29, 221–231. doi:10.1177/0894439310376896

Gholami, S., Karimimoshaver, M., and Samavatekbatan, A. (2019). Assessing the impact of natural skylines on residents' preferences for built skylines. *J. Archit. Plan. Res.* 36 (3), 215–228.

Guo, S., Sun, W., Chen, W., Zhang, J., and Liu, P. (2021). Impact of artificial elements on mountain landscape perception: an eye-tracking study. *Land* 10 (10), 1102–1118. doi:10.3390/land10101102

Harrison, J. P. (2011). Wind turbine noise. *Bull. Sci. Technol. Soc.* 31 (4), 256–261. doi:10.1177/0270467611412549

Haruna, A. I., Oppong, R. A., and Marful, A. B. (2018). Exploring eco-aesthetics for urban green infrastructure development and building resilient cities: A theoretical overview. *Cogent Soc. Sci.* 4 (1), 1478492. doi:10.1080/23311886.2018.1478492

Jaffe, C. (2018). Melting the polarization around climate change politics. *Georget. Environ. Law Rev.* 30 (455), 455–497. URL: https://www.law.georgetown.edu/environmental-law-review/wp- content/uploads/sites/18/2018/07/melting-_GT-GELR180017.pdf.

Karimimoshaver, M., Parsamanesh, M., Aram, F., and Mosavi, A. (2021). The impact of the city skyline on pleasantness; state of the art and a case study. *Heliyon* 7 (5), e07009–9. doi:10.1016/j.heliyon.2021.e07009

Karimimoshaver, M., and Winkemann, P. (2018). A framework for assessing tall buildings' impact on the city skyline: aesthetic, visibility, and meaning dimensions. *Environ. Impact Assess. Rev.* 73, 164–176. doi:10.1016/j.eiar.2018.08.007

Kashyap, R., Bhuvan, M. S., Chamarti, S., Bhat, P., Jothish, M., and Annappa, K. "Algorithmic approach for strategic cell tower placement," in Proceedings of the 2014 5th International Conference on Intelligent Systems. Modelling and Simulation, Langkawi, Malaysia, January 2014. doi:10.1109/isms.2014.112

Khadka, R., and Banic, A. (2019). KnobCollector: custom device controller for dynamic real-time subjective data collection in virtual reality. *Lect. Notes Comput. Sci.* 84, 84–95. doi:10.1007/978-3-030-21607-8_7

Klæboe, R., and Sundfør, H. (2016). Windmill noise annoyance, visual aesthetics, and attitudes towards renewable energy sources. *Int. J. Environ. Res. Public Health* 13 (8), 746. doi:10.3390/ijerph13080746

Kopardekar, P., Bilimoria, K. D., and Sridhar, B. (2008). Airspace configuration concepts for the next generation air transportation system. *Air Traffic Control Q.* 16 (4), 313–336. doi:10.2514/atcq.16.4.313

Martin, J.-R., Kösem, A., and van Wassenhove, V. (2015). Hysteresis in audiovisual synchrony perception. *PLOS ONE* 10 (3), e0119365. doi:10.1371/journal.pone.0119365

Martins, J., and Lavradio, L. (2020). Rushing to the end: participants' perceptions of demotivating aspects of online surveys. *Análise Psicológica* 38 (2), 241–256. doi:10.14417/ap.1674

Nordman, E., and Mutinda, J. (2016). Biodiversity and wind energy in Kenya: revealing landscape and wind turbine perceptions in the world's wildlife capital. *Energy Res. Soc. Sci.* 19, 108–118. doi:10.1016/j.erss.2016.05.020

Pedersen, E., and Waye, K. P. (2004). Perception and annoyance due to wind turbine noise—A dose– response relationship. *J. Acoust. Soc. Am.* 116 (6), 3460–3470. doi:10.1121/1.1815091

Peterson, A. C., Niemi, G. J., and Johnson, D. H. (2015). Patterns in diurnal airspace use by migratory landbirds along an ecological barrier. *Ecol. Appl.* 25 (3), 673–684. doi:10.1890/14-0277.1

Pinheiro, J., Bates, D., DebRoy, S., and Sarkar, D.R Core Team (2022). nlme: linear and nonlinear mixed effects models. R package version 3.1-155. URL: https://CRAN.R-project.org/package=nlme.

Poltoratski, S., and Tong, F. (2014). Hysteresis in the dynamic perception of scenes and objects. *J. Exp. Psychol. General* 143 (5), 1875–1892. doi:10.1037/a0037365

R Core Team (2018). *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing.

Ralph-Nearman, C., Arevian, A., Puhl, M., Kumar, R., Villaroman, D., Suthana, N., et al. (2019). A novel mobile tool (somatomap) to assess body image perception pilot tested with fashion models and nonmodels: cross-sectional study. *JMIR Ment. Health* 6 (10), e14115. doi:10.2196/14115

Rasheed, S., Venkatesh, P., Singh, D. R., Renjini, R. V., Jha, G. K., and Sharma, D. K. (2022). Public intervention for conservation of paddy ecosystems—an empirical evidence from Kerala, India. *Natl. Acad. Sci. Lett.* 45, 287–289. doi:10.1007/s40009-022-01120-y

Remsen, J. V., and Robinson, S. K. (1990). A classification scheme for foraging behavior of birds in terrestrial habitats. *Stud. avian Biol.* 13 (1), 144–160.

Rogers, A. L., Manwell, J. F., and Wright, S. (2006). *Wind turbine acoustic noise.* Golden, Co, USA: Renewable Energy Research Laboratory.

Rowland, M. M., Nielson, R. M., Wisdom, M. J., Johnson, B. K., Findholt, S., Clark, D., et al. (2021). Influence of landscape characteristics on hunter space use and success. *J. Wildl. Manag.* 85 (7), 1394–1409. doi:10.1002/jwmg.22107

Rule, T. A. (2015). Airspace in an age of drones. *Bul. Rev.* 95, 155.

Sawyer, H., Korfanta, N. M., Kauffman, M. J., Robb, B. S., Telander, A. C., and Mattson, T. (2022). Trade-offs between utility-scale solar development and ungulates on western rangelands. *Front. Ecol. Environ.* 20, 345–351. doi:10.1002/fee.2498

Schmidt, J. H., and Klokker, M. (2014). Health effects related to wind turbine noise exposure: A systematic Review. *PLoS ONE* 9, e114183. doi:10.1371/journal.pone.0114183

Sklenicka, P., and Zouhar, J. (2018). Predicting the visual impact of onshore wind farms via landscape indices: A method for objectivizing planning and decision processes. *Appl. Energy* 209, 445–454. doi:10.1016/j.apenergy.2017.11.027

Springer, N. C., Chang, C., Fields, H. W., Beck, M., Firestone, A. R., Rosenstiel, S., et al. (2011). Smile esthetics from the layperson's perspective. *Am. J. Orthod. Dentofac. Orthop.* 139 (1), 91–101. doi:10.1016/j.ajodo.2010.06.019

Stephens, R., and Smith, M. (2022). Effect of speed on flow and enjoyment for driving and rollercoasters. *Transp. Res. Part F Traffic Psychol. Behav.* 85, 276–286. doi:10.1016/j.trf.2022.02.001

Van Renterghem, T., Bockstael, A., De Weirt, V., and Booteldooren, D. (2013). Annoyance, detection and recognition of wind turbine noise. *Sci. Total Environ.* 456-457, 333–345. doi:10.1016/j.scitotenv.2013.03.095

Wienese, M., La Heij, W., van der Heijden, A. H. C., and Shiffrin, R. M. (2000). Perceptual inertia: spatial attention and warning foreperiod? *Psychol. Res.* 64 (2), 93–104. doi:10.1007/s004260000026

Wilkinson, Will. (2019). The density divide: urbanization, polarization, and populist backlash. URL: https://www.niskanencenter.org/wp- content/uploads/2019/09/Wilkinson-Density-Divide-Final.pdf.

Zhao, M., Zhang, J., and Cai, J. (2020). Visual preference evaluation on urban landmarks in the process of urbanization: A case study of Shanghai oriental pearl radio and tv tower. *J. Asian Archit. Build. Eng.* 20, 493–501. doi:10.1080/13467581.2020.1799800

Zube, E. H., and Law, C. (1984). Perceptions of the sky in five metropolitan areas. *Urban Ecol.* 8 (3), 199–208. doi:10.1016/0304-4009(84)90035-4