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INDOOR AND OUTDOOR NOISE PERCEPTION OF COMMUNITIES NEAR SCHIPHOL AIRPORT

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ABSTRACT

A large airport can have a negative environmental and health-related impact on neighbouring communities, due to aircraft induced noise exposure and air pollution. The impact of aviation on neighbouring communities could be mitigated by different methods of home insulation, a solution often provided by airports. A survey was conducted for residents living nearby Amsterdam Airport Schiphol to study the relation between aircraft annoyance and perception to aviation and home insulation. A comparison is also made to other typical noise sources residents experience both inside and outside of their home, such as noise from neighbours, road traffic noise, industry noise, and home appliances. Initial results show no relation between the amount of isolation methods someone applied in their home and aircraft annoyance. However, a positive relation was found between more isolation methods applied at someone's home and aviation perception. Furthermore, residents experience more annoyance from aircraft noise than industry noise and the noise of home appliances. This difference was not found between aircraft noise and road noise, or noise from neighbours. Further analyses revealed that residents living in areas with aircraft noise exposure above 45dB Lden experience more aircraft annoyance than residents exposed to less than 45dB Lden.

Keywords: *aircraft noise, noise annoyance, indoor noise, airport noise.*

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1. INTRODUCTION

A large airport can have a negative environmental and health-related impact on neighbouring communities, due to aircraft induced noise exposure and air pollution. Studies around airports [1-3] show that people's health and overall quality of life is affected by the aircraft noise due to aircraft landing and taking off. For this reason, the World Health Organization (WHO) has set up European guidelines [4] to reduce adverse health effects for persons affected by aircraft noise. The impact of aviation on neighbouring communities could be mitigated by different measures as outlined by the "balanced approach" [5], a methodology by the International Civil Aviation Organization (ICAO), and adopted by European regulations. It contains four steps that should be applied to reduce the impact of aircraft noise. The first step is reduction of noise at the source, i.e. making aircraft more silent. The second step is optimizing aircraft operations to reduce noise annoyance. The third step is related to mitigation measures for land-use. One of the measures in this step is home insulation, a solution often provided by airports, and sometimes also part of national law, such as in the Netherlands for housing within 60 Lden noise contours [6]. Only if these three steps of balanced approach do not result in the desired result, measures to reduce the number of operations at the airport should be implemented. This is a step that may have economic consequences for the airport and the region.

Even though home isolation is offered as a solution for residents exposed to more than 60 dB Lden, the WHO recommendations suggest that for aircraft noise, outdoor Lden should remain below 45 dB to minimize adverse health effects, while nighttime levels should not exceed 40 dB Lnight [4], as Aircraft noise at night disrupts sleep architecture, leading to reduced sleep efficiency and increased awakenings [7]. Given that indoor noise levels are

typically lower than outdoor levels, with large ranges between 10 and 28dB(A) reductions [8], depending on open or closed windows, these recommendations translate to lower indoor Lden thresholds. Furthermore, prolonged exposure to indoor aircraft noise has been linked to multiple adverse health outcomes. Chronic noise exposure, including aircraft noise, has been associated with increased risks of hypertension and ischemic heart disease [9] and even has cognitive impacts on children exposed to aircraft noise [10].

To understand aircraft noise annoyance, it is often compared to other transportation noise, e.g. road and rail traffic noise [11-12]. Aircraft noise can relate differently to other common noise sources residents are exposed to, such as industrial and neighbourhood noise. Industrial noise and general neighbourhood noise (e.g., loud music, shouting, construction) are typically localized and vary significantly in annoyance depending on exposure patterns. While these sources can be highly disruptive, their effects are less studied compared to transportation noise [13].

To study noise annoyance around an airport, a survey is a helpful tool to measure and understand aircraft annoyance in relation to other noise annoyance sources and to people's location and social and economic situation. The goal of this study was to find a better understanding of indoor aircraft noise annoyance and the effectiveness of home isolation methods applied at residents' homes. To better understand aircraft noise annoyance, a comparison was made with other common noise sources, such as road traffic noise, industrial and neighbourhood noise. Even though not often included in this type of research, home appliance noise, such as a vacuum, or a loud refrigerator might also affect the annoyance of residents and is therefore included in this study.

2. METHODOLOGY

2.1 Sample

A survey was conducted for residents living nearby Amsterdam Airport Schiphol who are exposed to overflying aircrafts. Residents were recruited through a recruiting agency in October 2024 via an online survey website. Participants needed to live in a postal code area within a 30km radius from Amsterdam Airport Schiphol.

Out of the 400 respondents, a dataset with 372 participants remained due to missing data and residents living too far from Amsterdam Airport Schiphol. Participant ages ranged from 17 to 70, with an average age of 39. Out of 372 participants, 165 (44.1%) identified as male, 205 (55.4%) as female and 2 (0.5%) did not specify gender identity. Type of house was evenly distributed with 50.3% living in a rental residence, 49.2% in a bought residence and 0.5% did not specify.

2.2 Material

An online survey study provided the participants with questions on their indoor and outdoor noise experiences. The questionnaire, asked in the local Dutch language, contained a total of 46 questions. Eight questions were related to participant's age, occupation, their house ownership situation, family situation and education. This survey included one question on which home isolation methods were applied, e.g. floor or roof isolation. Four general questions were included on aviation annoyance (from the last 12 months), worries and perception of aviation. Six questions were included on indoor noise experience towards aircraft noise, noise from neighbours, road traffic noise, industry noise, nuisance from neighbours and home appliances or other noise sources. The same questions were asked on aircraft noise, noise from neighbours, road traffic noise, industry noise, nuisance from neighbours or other noise sources outside of the home. Questions were answered on a 5-point Likert scale ranging from not at all to very much. See Table 1 for an overview of the indoor and outdoor annoyance questions.

Other questions in this survey were related to quality of life, as in an earlier study by the authors [14], questions were asked about people's quality of life, but only with limited questions on noise annoyance. This previous study was also conducted in a time (November 2020) where the COVID-19 pandemic happened which lead to a significant reduction of air travel [15]. For this reason, this survey also contained the original questions from the previous quality of life survey with air travel almost back to its original numbers. Although some questions on weighting (on importance for quality of life factors) were left out to ensure the time needed to fill in the survey was not too long. Although these additional quality of life questions were available to the researchers, this study emphasizes only on the analysis of the indoor noise annoyance questions.

Postal code information from residents was related to aircraft noise exposure at that residence expressed in Lden over the year 2024. With this data, an additional analysis was performed for people living in a certain sound exposure range measured in Lden, the amount of home isolation methods were applied, their annoyance and their perception

of aviation. For this analysis, residents were divided in either low aircraft noise exposure, lower than 45dB Lden or higher aircraft noise exposure, higher than 45dB Lden.

Table 1. Survey questions asked and evaluated in this study.

Identifier: Question (Translated from Dutch)	**Response category**
Home isolation: What insulation measures have been put in place in your home? (multiple choices are possible)	☐ Floor insulation ☐ Roof insulation ☐ Insulating glazing ☐ Facade insulation None ☐ Other ☐ Not known
Aviation: Are you concerned about the impact of aviation on the climate?	Not at all / Very much
Aviation: Are you concerned about the impact of aviation on your quality of life?	Not at all / Very much
Aviation: Have you been disturbed by aircraft noise in your living environment in the last 12 months?	Not at all / Very much
Aviation: What was your perception on aviation over the past 12 months?	Very negative / Very positive
Indoor noise: Looking back over the last 12 months, to what extent does road traffic noise annoy, disturb or hinder you when you are indoors?	Not at all / Very much
Indoor noise: Looking back over the past 12 months, to what extent does aircraft noise annoy, disturb or disturb you when you are indoors?	Not at all / Very much
Indoor noise: Looking back over the past 12 months, to what extent does industry noise annoy, disturb or disturb you when you are indoors?	Not at all / Very much
Indoor noise: Looking back over the past 12 months, to what extent does noise from neighbours or other people, children playing and/or pets annoy, disturb or disturb you when you are indoors?	Not at all / Very much
Indoor noise: Looking back over the past 12 months, to what extent does noise from home appliances annoy, disturb or disturb you when you are indoors?	Not at all / Very much
Indoor noise: Looking back over the past 12 months, are there other sounds that annoy, disturb or disturb you when you are indoors?	Open question
Outdoor noise: Looking back over the last 12 months, to what extent does road traffic noise annoy, disturb or hinder you when you are outside?	Not at all / Very much
Outdoor noise: Looking back over the past 12 months, to what extent does aircraft noise annoy, disturb or disturb you when you are outside?	Not at all / Very much
Outdoor noise: Looking back over the past 12 months, to what extent does industry noise annoy, disturb or disturb you when you are outside?	Not at all / Very much
Outdoor noise: Looking back over the past 12 months, to what extent does noise from neighbours or other people, children playing and/or pets annoy, disturb or disturb you when you are outside?	Not at all / Very much
Outdoor noise: Looking back over the past 12 months, are there other sounds that annoy, disturb or disturb you when you are outside?	Open question

3. RESULTS

3.1 Effect of home isolation methods on annoyance and aviation acceptance

A spearman correlation showed no significant relation between the amount of home isolation methods, measured with the sum of isolation methods applied, and general aircraft annoyance, $r_s(370) = .009$, $p = .867$, as well as indoor aircraft annoyance, $r_s(369) = .066$, $p = .203$.

A significant positive correlation was however found between the amount of home isolation methods applied and the perception towards aviation $r_s(370) = .165$, $p = .001$.

This means that the more isolation methods participants applied, the more positive the perception to aviation was.

3.1.1 Comparison with different groups exposed to higher or lower aircraft sound exposure (Lden)

Residents exposed to Lden values below 45dB showed similar results as above, where a significantly positive correlation between perception on aviation and the amount of home isolation methods that were applied at their home was found, $r_s(232) = .173$, $p = .008$. This difference was not found for annoyance, where residence that had more home isolation methods applied in their home did not experience less general annoyance, $r_s(232) = .-.004$, $p = .956$ and indoor annoyance, $r_s(232) = .-.041$, $p = .529$.

Residents exposed to Lden values above 45dB showed different results, where no significant correlation was found between the amount of home isolation methods applied and both annoyance $r_s(136) = .-.012$, $p = .885$ and aviation perception $r_s(136) = .195$, $p = .072$.

3.2 Comparison of aircraft annoyance with other noise sources inside of the home

A Friedman test revealed a significant difference in annoyance towards different indoor sound exposures χ^2 (4, n = 371) = 89.21, p < .001. The medians indicate the highest annoyance towards neighbour sounds (Md = 2.00), and road traffic noise (Md = 2.00), followed by aircraft noise (Md = 2.00), home appliance noise (Md = 1.00) and industry noise (Md = 1.00). The means indicate a similar result and showcase, even though not significant, the differences between these noise sources in Table 2. Further Wilcoxon tests reveal that aircraft noise only significantly differed from industry noise (z = -6.35, p < .001) and home appliance noises (z = -3.22, p = .001).

Table 2. Means and standard deviations of annoyance towards different noise sources inside the home

Variable	Mean	Std. Deviation
Road traffic annoyance inside the house	1.91	1.08
Aircraft annoyance inside the house	1.87	1.03
Industry noise annoyance inside the house	1.51	0.92
Annoyance from neighbours inside the house	1.90	0.96
Annoyance from home appliances inside the house	1.67	0.90

3.3 Comparison of aircraft annoyance with other noise sources outside of the home

A Friedman test revealed a significant difference in annoyance towards different outdoor sound exposures χ^2 (3, n = 372) = 49.49, p < .001. The medians indicate the highest annoyance towards road traffic noise (Md = 2.00), and aircraft noise (Md = 2.00), followed by neighbour sounds (Md = 2.00) and lastly industry noise (Md = 2.00). The means indicate a similar result and showcase, even though not significant, the differences between these noise sources in Table 3. Further Wilcoxon rank tests reveal that aircraft noise only significantly differed from industry noise (z = -5.85, p < .001).

Table 3. Means and standard deviations of annoyance towards different noise sources outside the home

Variable	Mean	Std. Deviation
Road traffic annoyance outside the house	1.90	0.97
Aircraft annoyance outside the house	1.92	1.03
Industry noise annoyance outside the house	1.58	0.92
Annoyance from neighbours outside the house	1.80	0.93

3.4 Aircraft annoyance, aviation perception for different Lden aircraft sound exposure

A Mann-Whitney U test showed that participants that were exposed to Lden noise exposure below 45dB experienced less annoyance (mean rank = 172.76) than participants exposed to higher Lden values above 45dB (mean rank = 209.80) (z (N_{lowdB}=234, N_{highdB}= 138) = -

3.45, p = .001). The same results were found for aircraft annoyance inside the house (z (N_{lowdB}=233, N_{highdB}= 138) = -2.42, p = .016) and aircraft annoyance outside the house (z (N_{lowdB}=234, N_{highdB}= 138) = -3.14, p = .002).

Although the perception towards aviation was more positive for the lower aircraft sound exposed group (mean rank = 190.56) than the higher aircraft sound exposed group (mean rank = 179.62), this difference was not statistically significant, (z (N_{lowdB}=234, N_{highdB}= 138) = -1.02, p = .308).

4. DISCUSSION

Indoor aircraft noise annoyance was assessed in comparison to other noise sources and outdoor noise annoyance. Also the relation between home isolation, such as window or façade isolation and aircraft annoyance was studied. Results show that even though no relation was found between annoyance and home isolation, the perception towards aviation was more positive when more home isolation methods were applied. This effect was especially found for the group exposed to Lden values below 45dB. This result could indicate that aircraft noise is low or even inaudible for residence that live further away from the airport and have more home isolation in place. It may also prove that home isolation for those exposed to levels lower than 45dB Lden may not directly help to reduce noise annoyance, but it does help to improve people's perception towards aviation. With low levels of noise exposure, residents might not experience aircraft noise annoyance, but still experience the positive aspects from a large neighbouring airport, such as economic ties or connectivity to the rest of the world [13].

As expected, residents exposed to higher aircraft noise exposure, above 45dB Lden were more annoyed towards aircraft noise than residents exposed to aircraft noise exposure below 45 dB Lden. From the group exposed to more than 45 dB Lden, nearly 80% were exposed to 45 to 50 dB Lden, indicating that even lower levels of aircraft sound exposure still result in annoyance. The World Health Organization guidelines for community noise [16] state that even though the percentage of highly annoyed people is low, at 45dB Lnight residents can experience sleep disturbance from aircrafts. In this sample, from the group exposed to Lden values exceeding 45 dB, nearly 40% of participants slept with the window open, which could account for the higher levels of annoyance. Note that the Lnight values were not examined in this study, but it can be expected that for an airport as Schiphol (without night curfew), similar results can be found as for Lden.

The average low exposure to aircraft noise could be considered the main limitation of this study, as the aircraft noise exposure for most of the participants was relatively low. For example 90% of this sample was exposed to 48dB Lden or less. Therefore no statistical differences could be determined on the difference in annoyance between residents with low and high aircraft noise exposure, as the group size of (e.g.) above 58dB Lden would be too small. The 58 dB Lden noise contour is used around Amsterdam Airport Schiphol to count houses where most highly annoyed residents are expected [17]. The overall low aircraft noise exposure also means that all participants in this study applied the home isolation themselves without the help from the airport [6]. It is therefore questionable how these measures intended for a reduction of noise in general compare to home isolation measures specific against aircraft noise.

When compared to other noise sources, aircraft noise was rated as more annoying than industry noise both indoors, as well as outdoors. This difference was not found between indoor aircraft annoyance and noise from neighbours, while this was repeatedly mentioned in the open question on other indoor noise sources. This could partially explained by the large variation in neighbour sounds, such children crying, dogs barking, loud footsteps, etc. In future studies further insight could be provided in the exact relation between aircraft noise and other background sounds.

5. CONCLUSION

In this study a survey was conducted for residents living nearby Amsterdam Airport Schiphol to study the relation between aircraft annoyance and perception to aviation and home insulation, as well as understanding how indoor aircraft noise annoyance relates to other noise experiences. Postal code information was related to aircraft sound exposure expressed in Lden to find the relation between noise exposure and experienced annoyance.

Results showed no relation between the amount of home isolation methods applied and aircraft annoyance. A

positive relation was found between home isolation and aviation perception, where the more home isolation methods were applied, the more positive the perception of aviation was. This effect was especially found for residents with an aircraft noise exposure below 45dB Lden. This group of residents with a lower aircraft noise exposure indicated less aircraft annoyance than residents exposed to more than 45 dB Lden.

Compared to other noise sources, aircraft noise indoors was more annoying than industry noise and home appliance noise. No difference was found between aircraft noise and road traffic noise, noise from home appliances, or noise from neighbours, while the latter was repeatedly mentioned in the open question on other indoor noise sources. Outside the house aircraft noise was more annoying than industry noise, but not more annoying than road traffic noise or noises from neighbours.

This study showed that even in areas with a relatively low noise exposure, aviation considerably affects residents' annoyance. While residents exposed to less than 45dB Lden experienced less annoyance, the perception of aviation was more positive when more home isolation methods were applied, such as window or façade isolation.

6. CONFLICTS OF INTERESTS

This research was conducted with NLR internal funding. The authors declare no conflict of interest.

7. REFERENCES

[1] D. Schreckenberg, M. Meis, C. Kahl, C. Peschel, and T. Eikmann, “Aircraft noise and quality of life around Frankfurt Airport.,” *Int J Environ Res Public Health*, vol. 7, no. 9, pp. 3382–3405, Sep. 2010, doi: 10.3390/ijerph7093382.

[2] D. Welch, K. N. Dirks, D. Shepherd, and D. McBride, “Health-related quality of life is impacted by proximity to an airport in noise-sensitive people.,” *Noise Health*, vol. 20, no. 96, pp. 171–177, Oct. 2018, doi: 10.4103/nah.NAH_62_17.

[3] M. D. Seidman and R. T. Standring, “Noise and Quality of Life,” *Int. J. Environ. Res. Public Health*, no. 7, pp. 3730–3738, 2010, doi: 10.3390/ijerph7103730.

[4] World Health Organization. Regional Office for Europe, *Environmental noise guidelines for the European Region*. Copenhagen: World Health Organization. Regional Office for Europe, 2018. [Online]. Available: https://apps.who.int/iris/handle/10665/279952.

[5] ICAO. Balanced Approach to Aircraft Noise Management [Internet]. 2001 [cited 2022 Apr 29]. Available from: https://www.icao.int/environmental-protection/Pages/noise.aspx.

[6] Ministerie Infrastructuur en Waterstaat, “Regeling van de Minister van Infrastructuur en Waterstaat, van 21 september 2023, nr. IENW/BSK-276554, houdende vaststelling van regels inzake geluidwerende voorzieningen aan woningen binnen de geluidcontour voor de luchthaven Schiphol (Regeling gevelisolatie Schiphol 2023).” Staatscourant, Sep. 21, 2023. [Online]. Available: https://zoek.officielebekendmakingen.nl/stcrt-2023-26407.html.

[7] Basner, M., Müller, U., & Elmenhorst, E. M. (2014). Single and combined effects of air, road, and rail traffic noise on sleep and annoyance. Sleep, 37(11), 1533-1542.

[8] Locher, B., Piquerez, A., Habermacher, M., Ragettli, M., Röösli, M., Brink, M., Cajochen, C., Vienneau, D., Foraster, M., Müller, U., & Wunderli, J. (2018). Differences between Outdoor and Indoor Sound Levels for Open, Tilted, and Closed Windows. International Journal Of Environmental Research And Public Health, 15(1), 149. https://doi.org/10.3390/ijerph15010149.

[9] Babisch, W. (2014). Updated exposure-response relationship between road traffic noise and coronary heart diseases: A meta-analysis. Noise and Health, 16(68), 1-9.

[10] Clark, C., & Paunovic, K. (2018). WHO environmental noise guidelines for the European region: A systematic review on environmental noise and cognition. International Journal of Environmental Research and Public Health, 15(2), 285.

[11] Miedema, H. M., & Oudshoorn, C. G. (2001). Annoyance from transportation noise: Relationships with exposure metrics DNL and DENL and their confidence intervals. Environmental Health Perspectives, 109(4), 409-416.

[12] Janssen, S. A., Vos, H., Eisses, A. R., & Pedersen, E. (2011). A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources. Journal of the Acoustical Society of America, 130(6), 3746-3753.

[13] Babisch, W., Houthuijs, D., Pershagen, G., Cadum, E., Katsouyanni, K., Velonakis, M., & Dudley, M. L. (2013). Annoyance due to aircraft noise has increased over the years—Results of the HYENA study. Environmental International, 55, 29-36.

[14] R. Aalmoes, N. Sieben, B. Ohlenforst, S. Bartels, and D. Schreckenberg, "Impact of Large Airport on Residents' Quality of Life," presented at the INTER-NOISE, Aug. 2024.

[15] T. Adhanom Ghebreyesus, "WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020." Accessed: Sep. 07, 2021. [Online]. Available: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020.

[16] Schwela, D. H. (2001). The new World Health Organization guidelines for community noise. Noise Control Engineering Journal, 49(4), 193. https://doi.org/10.3397/1.2839659.

[17] Welkers, D., RIVM, Sahai, A., Van Kempen, E., & Helder, R. (2021). Analyse gelijkwaardigheidscriteria Schiphol. In RIVM-briefrapport 2020-0219 (pp. 2–60) [Report]. Rijksinstituut voor Volksgezondheid en Milieu. https://doi.org/10.21945/RIVM-2020-0219.