- Tweets about noise complaints during the lockdown were more than twice of those before introduction of lockdown
- Number of tweets on neighbour noise sources was substantially increased during the lockdown
- Perceived outdoor noise level decreased but perceived neighbour noise level increased during the lockdown
- Talking/shouting and TV/music were most annoying during the lockdown

Attitudes toward outdoor and neighbour noise during the COVID-19 lockdown: A case study in London

Keywords: noise, lockdown, COVID-19, perception

Abstract

To stop the spread of COVID-19 transmission, the UK put a lockdown on the entire country during the months of March and May 2020, which strictly curtailed personal mobility and economic activities. The present study is aimed to understand attitude of people towards noise inside their homes in London during the lockdown. Tweets from the social media platform were collected during the lockdown and the same periods in 2019. Additionally, subjective responses to outdoor and neighbour noises were collected through a questionnaire survey. Tweets about noise complaints during the lockdown were more than twice of those before introduction of lockdown. A substantial increase in talking/shouting, and TV/music activities were observed among the neighbour noise sources. Similar findings were obtained from the survey. The respondents answered that the perceived outdoor noise level decreased but perceived neighbour noise level increased during the lockdown. The outdoor noise annoyance ratings were revealed to be significantly lower than those before the lockdown. In contrast, neighbour noises were more frequently heard and annoyance ratings increased compared to the pre-lockdown period. In particular, talking/shouting and TV/music were most annoying. Furthermore, neighbour noise was more annoying than outdoor noise during the lockdown. This suggests that neighbour noise is more problematic than outdoor noise during lockdown. The findings of this study would be useful in designing the future strategy to enhance the acoustic comfort and city sustainability.

1 Introduction

The outbreak of coronavirus disease (henceforth termed as COVID-19 in this study) has changed the world dramatically within several months, and the world is now facing a huge challenge like never before. The outbreak of COVID-19 has forced many countries to announce regional and national lockdowns to reduce the spread. For example, the UK government issued warnings to reduce infection rates amongst its population during the months of February and early March (Nicola et al., 2020). The prime minster of the UK announced a national lockdown on the 27th March (GOV.UK.) to enforce mandatory restrictions on the majority of non-essential domestic travel. The details of national lockdowns were slightly different across countries; however, many countries such as Italy and France restricted the movement of people by urging them to stay at home and work from home.

Restrictions on the movement of people and transportation consequently led to a substantial reduction in traffic flow in urban areas. For instance, transport use in the UK was dramatically reduced during the lockdown (DfT, 2020); motor vehicle usage was dropped by more than 50% and the use of national rail was decreased by up to 4% compared to before the introduction of lockdown. Another survey study (Shakibaei et al., 2020) in Turkey also demonstrated significant changes in travel behaviours during the pandemic. In particular, the use of all major public transportations, including rail and bus, significantly decreased. The absence of people and vehicles has brought several changes to the urban environment. Particularly, air quality in large cities, such as Wuhan (Lian et al., 2020), Madrid (Baldasano, 2020), Kang Vally (Latif et al., 2020), and São Paulo (Nakada & Urban, 2020) have vastly improved in nitrogen dioxide (NO_2) and ozone (O_3) concentrations.

The substantial decrease in traffic flow during the lockdown also significantly affected the acoustic environments in urban areas. Short-term noise levels (L_{Aeq}) were reduced by 1.2 dB-10.7 dB during the lockdown in London (Aletta et al., 2020). There was also a decrease in noise levels measured for 24 h in Madrid, ranging from 4 dB to 6 dB (Asensio et al., 2020). Basu et al. (2020) analysed hourly noise levels measured from 12 noise monitoring stations in Dublin before and after the lockdown. Decreases in noise levels during the lockdown were observed at 11 stations, which varied from 2.8 to 6.3 dB. A similar finding was obtained from urban noise monitoring data from Stockholm, Sweden. Rumpler et al. (2020) demonstrated that façade noise levels were reduced by 1–4 dB and 2–4 dB during the weekday and weekend, respectively, due to travel restrictions. Another recent study conducted short-term noise measurements in residential areas during the emergency state (partial lockdown) in Japan and observed slight changes in noise levels (< 3 dB) (Sakagami, 2020). However, recent studies (Aletta et al., 2020; Asensio et al., 2020; Basu et al., 2020; Rumpler et al., 2020; Sakagami, 2020) have mainly focused on the impact of lockdown on noise levels rather than on human behaviour in acoustic environments. Only Sakagami (2020) reported the perceived outdoor sound sources, along with the noise measurements in residential areas during the partial lockdown. Numerous studies (Kang, 2006; Nilsson & Berglund, 2006; Park et al., 2020) have demonstrated that sound has an important role in the perception of built environments. In particular, natural sounds were a significant factor in enhancing the acoustic comfort and sustainability of the environments (J. Y. Hong et al., 2020; X. Hong et al., 2019; Truax, 2019). Thus, it is necessary to examine people's reactions to noises during the lockdown. Before the pandemic, only a quarter of the respondents heard any noise from their neighbours (Langdon & Buller, 1977). Another study reported that noise from neighbouring flats was the second most source of noise annoyance in eight European cities (WHO, 2007). The lockdown forced people to stay at home; thus, they had to spend their time doing various activities (e.g., watching TV), which could have led to noises inside their dwellings (OfN, 2020). Therefore, it is logical to expect more noise sources from neighbours during the pandemic. However, it is still unknown how the lockdown affects the perception of neighbour noise.

The present study aims to investigate people's attitudes toward outdoor and neighbour noise during the lockdown. Social media data collection and analysis were conducted to explore the changes in people's reactions to noise complaints. A questionnaire survey was then conducted to investigate attitudes toward neighbour noise and outdoor transportation noise when people are inside their homes. People's attitudes toward noise during the lockdown were compared to those collected before the lockdown to examine the impact of the lockdown on human responses to noise.

2 Methods

2.1 Social media

2.1.1 Data collection

Among the various online social networks (OSNs), Twitter was chosen because people express their opinions more frankly on Twitter because of the limitation of characters. To download data from Twitter, the GetOldTweets3 library for Python (https://pypi.org/project/GetOldTweets3/) was used in Jupyter Notebooks. This library uses Tweepy, which is one of the streaming APIs developed for accessing the Twitter API. In this study, only tweets written in English were collected; tweets in other languages were not gathered. From the downloaded data, only tweets where the word 'noise' is included and tweeted in 'London' were collected using specific functions of the GetOldTweets 3. First, the data were limited to the lockdown period of the UK from the 27th March 2020 to 12th May 2020. For comparison, a second set of data was collected for no lockdown period in 2019 (i.e., the 27th March 2019 to 12th May 2019). From the collected data, retweets and tweet responses were removed to focus only on the context of the original person's tweet. During the lockdown, a total of 427 tweets were collected, whereas 367 tweets included noise in 2019.

2.1.2 Data preparation

Pre-processing of extracted data was conducted to convert the unstructured textual data into structured textual data by removing the punctuations and additional symbols. For pre-processing, first, tweets were tokenised using the natural language toolkit (NLTK) library. Using NLKT library tweets were split into individual parts called tokens (e.g., words, punctuation, letters, and special characters). The tokens were then transformed into lowercase and contractions were converted into a canonical (standard) form (e.g., 'would've → would have'). Tokens with repeated characters were changed to their original forms (e.g., 'loooove' to 'love'). To replace slang, a dictionary consisting of 228 words and their replacements was constructed. For instance, 'omg' was replaced with 'oh my god'.

2.1.3 Identifications of noise complaints and noise sources

From the collected tweets including' noise, only tweets about noise complaints were extracted. Previous studies used a machine learning technique to extract appropriate tweets; however, this study extracted tweets manually because of the small size of data. Thus, 68 and 149 tweets were finally extracted for 2019 and 2020, respectively. During the extraction process, the tweets that contained any other meaning of noise were removed. For instance, there were many tweets about noise cancellation headphones (e.g., 'first flight with noise-cancelling headphones') and football matches (e.g., 'we expect more noise from royal supporters').

The tweets on noise complaints were classified into outdoor and neighbour noise sources. The outdoor noise sources were then categorised into six groups based on a taxonomy of acoustic environment for soundscape (Brown et al., 2011). These were 1) nature and animal,

2) transport, 3) mechanical, 4) voice and instrument, 5) social and communal, and 6) others (for unspecified sources). The neighbour noise sources were grouped into structureborne and airborne sources. However, some noise sources could not be clearly classified into structureborne or airborne sources; thus, they were grouped into another group ('general'). There were three noise sources in the structureborne noise group: footsteps, banging, and door closing. In contrast, there were six noise sources in airborne noise groups: talking/shouting, TV/music, home appliances, alarm, dog barking, and electric socket.

2.2 Questionnaire survey

2.2.1 Sample

An online questionnaire survey was conducted during the lockdown in London in May 2020 before the lockdown eased. Those aged 18 years and above and living in London, and fluent in English were invited. The participants were recruited through the Smartsurvey, who had their own registered participant pool, and a total of 183 participants took part in the survey. Details of the participants are listed in Table 1. From the survey, it was found that most participants (169, 92.3%) were in lockdown (i.e., staying at home and working from home) for more than 4 weeks. Of these 183 completed participants, 96 (52.5%) were from male respondents and 87 (47.5%) were female respondents. The majority of the respondents (38.8%) were aged between 36 and 50 years, and more than half of the participants lived in flats. The majority of the respondents had a university degree and approximately 40% were full-time workers.

Table 1

2.2.2 Questionnaire design

For comparison, the design of our questionnaire the same as that used in a previous study (Lee et al., 2020) which was conducted in London immediately before the pandemic (December 2019–January 2020). First, the participants were asked to compare the outdoor and indoor noise level changes during the lockdown with that to before the introduction of lockdown (i.e. December 2019–January 2020) using a 5-point scale (1 = *'much reduced'* and 5 = *'much increased'*). Those who answered that they heard transportation noise were then asked to rate the annoyance of four noises (road traffic on major roads, road traffic on minor roads, airplanes and/or helicopters, and trains and/or trams) using an 11-point scale (0 = *'not at all'* and 10 = *'extremely'*). Participants were asked to rate the noise annoyance for the past four weeks during the lockdown. Similarly, participants who heard noise from the neighbour's house were also asked to rate the annoyance caused by 10 structureborne and airborne noise sources using the same 11-point scale. Structureborne sources were footsteps, dropped objects, movement of furniture, and door closing, while airborne noise sources included talking/shouting, TV/music, telephone ringing, home appliances, dog barking, and water installations.

2.3 Data analysis

Annoyance ratings were converted to the percentage of highly annoyed (%HA) with a cut-off of 72 on a scale from 0 to 100, according to the previous studies (Jeon et al., 2010; Miedema & Vos, 1998) and international standard (ISO1996-1, 2016). Statistical analysis was carried out using SPSS for Windows (Version 25.0, SPSS Inc. Chicago, IL). The Shapiro–Wilk normality test results indicated that all variables were normally distributed. Thus, *t*-tests were carried out for comparison of the variables. Independent samples *t*-tests were used to compare the responses between groups (e.g., before the lockdown and during the lockdown). A paired-samples *t*-test was also used to examine differences between annoyance ratings for outdoor and neighbour noise sources during the lockdown. In the present study, *p* values of less than 5% ($p < 0.05$) were considered as statistically significant.

3 Results

3.1 Social media

Table 2 lists the number of tweets including 'noise' and the number of tweets with noise complaints before and during the lockdown. The number of tweets including noise was 367 before the lockdown and it increased by 16.3% during the lockdown in 2020. A similar tendency was observed in the number of tweets with noise complaints showing that the numbers increased by two times during the lockdown. Specifically, tweets on outdoor noise complaints slightly increased from '47' to '68', whereas tweets on neighbour noise complaints increased significantly from '21' to '81'.

Table 2

The number of tweets on noise complaints for all outdoor noise sources are listed in Table 3. The changes in the number of tweets were depended on the categories and sources. Before the lockdown, there were only three tweets on nature and animal; however, during the lockdown, there were 12 tweets about noise due to birds. Some people simply expressed annoyance due to noise made by birds, such as pigeons and robins, whereas others said they did not realise that birds singing is loud and irritating before the lockdown. Another significant increase in noise during the lockdown was due to construction/building or works/machinery, and the number of tweets complaining about this issue increased from 4 to 13. In contrast, there were fewer number of tweets on transport and voice/instrument compared to 'before the lockdown'. For instance, the number of tweets on transport noise complaints decreased by around 40%.

Table 3

Table 4 lists the number of tweets on noise complaints across neighbour noise sources. In general, the noise complaints significantly increased for all the categories. More specifically, the complaints about structureborne noise sources were rare before the lockdown but slightly increased during the lockdown. More significant increases were found for the airborne noise sources. In particular, the complaints on talking/shouting, TV/music, home appliances significantly increased. Among the noise sources of general category, the tweets about DIY/home repair and neighbour during the lockdown were much more than those before the lockdown. There were several tweets on neighbour noise about noise events during night or early in the morning; some people also complained about sleep disruption due to noise from their neighbours. In particular, the number of tweets on sleep disturbance by noise was doubled, from four to eight, during the lockdown, likely because some people changed their life patterns during the lockdown, for example, were awake until late night.

Table 4

3.2 Questionnaire survey

Figure 1 shows the comparison of perceived changes in outdoor and neighbour noise levels during the lockdown and before the lockdown. Approximately 60% of the respondents answered that the outdoor noise levels were either significantly or somewhat reduced, whereas only 12% said that the level increased (Figure 1(a)). In contrast, as shown in Figure 1(b), more than half of the participants responded that indoor noise levels somewhat or significantly increased during the lockdown.

Figure 1

Figure 2 shows the percentage of respondents that heard outdoor noise, mean annoyance, and %HA ratings during the lockdown along with the responses collected before the lockdown (Lee et al., 2020). The percentages of respondents who heard outdoor noise were similar to those before the lockdown. But the percentage of respondents for trains/trams slightly increased from 22.0% to 30.6%. The mean annoyance ratings during the lockdown were significantly reduced for all the transportation noises. Independent *t*-test results confirmed that the differences in the mean annoyance ratings before the lockdown and during the lockdown were statistically significant ($p<0.01$ for all). Before the lockdown, road traffic noise on major roads showed the highest mean annoyance rating; however, during the lockdown, road traffic on minor roads showed the highest mean annoyance rating, followed by road traffic on major roads and airplanes/helicopters. The decreases in mean annoyance ratings for trains/trams and road traffic on major roads were greater than those for other noise sources. In contrast, annoyance ratings in terms of %HA were not changed considerably during the lockdown and the %HA ratings were less than 20% for all the sources.

Figure 2

Figure 3 shows the percentage of respondents hearing neighbour noise, mean annoyance, and %HA ratings during the lockdown along with the responses collected before the lockdown. During the lockdown, talking/shouting was the most frequently heard noise source with more than 60% of responses, followed by footsteps and TV/music. Compared to before the lockdown, seven out of ten neighbour noise sources showed the increased percentage of respondents hearing noise. In particular, the respondents heard the structureborne noise sources more frequently during lockdown than before the lockdown except for water installations. For the airborne noise sources, talking/shouting and TV/music showed increase in the percentages of respondents hearing noise, whereas fewer people heard telephone ringing and dog barking during the lockdown. Overall, the structureborne noise sources (mean=6.2) and airborne noise sources (mean=6.3) showed similar mean annoyance rating. However, talking/shouting and TV/music of the airborne noise sources were the most annoying in terms of the mean annoyance ratings. Compared to before the lockdown, the mean annoyance ratings during the lockdown increased for all the noise sources. Independent *t*-test results revealed that the differences in the mean annoyance ratings before the lockdown and during the lockdown were statistically significant for talking/shouting, TV/music, and home appliances ($p<0.01$ for home appliances and $p<0.05$ for talking/shouting and TV/music). Similar results were observed for %HA with talking/shouting and TV/music showing the highest %HA. The annoyance ratings during the lockdown was higher than those before the lockdown except for the dog barking.

Figure 3

To examine whether neighbour noise annoyance ratings are different across dwelling types, mean annoyance ratings of neighbour noise between flats and houses (defined as semi-detached and terraced houses) were compared. As shown in Figure 4, respondents living in flats showed higher percentage of responses hearing neighbour noise, mean annoyance ratings, and %HA. In particular, statistical differences between flats and houses were found in footsteps, dropped objects, and TV/music ($p<0.01$ for dropped objects and $p<0.05$ for footsteps and TV/music). Residents in flats answered that structureborne noise sources were more annoying than airborne noise sources although TV/music was still the most annoying noise source.

Figure 4

An additional comparison was performed to observe the difference between people who spent the most time in the living room and those who spent most time in their home office during the lockdown. It was assumed that some people, in particular, young adults and students spend most time in their bedrooms with desks and computers. However, only 14 respondents selected bedroom as the space used to spend most time of the day; thus, they were not considered in this analysis. As shown in Figure 5, those who spent their most time in the living room had a higher percentage of responses hearing neighbour noise than those who spent time in their home office except for talking/shouting. Moreover, those who spent the most time in home office showed greater mean annoyance ratingscompared to others for all the airborne sources and most of the structureborne sources; however, the differences between them were not statistically significant. Similarly, annoyance ratings in terms of %HA were higher for those who spent most time in home office compared to those who spent their most time in the living room for most noise sources.

Figure 5

Paired samples *t*-tests were conducted during the lockdown to examine the difference between annoyance ratings for outdoor and neighbour noise sources. The outdoor noise annoyance ratings were averaged for the four transportation sources, while the neighbour noise ratings were averaged separately for structureborne and airborne sources. The results revealed that both neighbour noise sources were more annoying than outdoor noise during the lockdown ($p<0.01$ for structureborne and airborne sources).

4 Discussion

4.1 Effect of lockdown measures on perception of outdoor noise

Several studies recently reported physical changes in acoustic environments in terms of noise level. Based on short-term noise measurements, Aletta et al. (2020) reported that the noise levels in London decreased by 1.2 dB-10.7 dB (L_{Aeq}) due to the lockdown. Similarly, long-term noise measurements for 24 h (L_{den}) in Madrid showed a 4–6 dB noise reduction during the lockdown (Asensio et al., 2020), while 1-4 dB noise decrease were reported in Stockholme due to travel restrictions (Rumpler et al., 2020). However, these studies did not report how people reacted to these changes in noise levels. Therefore, this study aimed to investigate the perception of noise during the lockdown using both qualitative and quantitative data. In particular, the people's attitudes towards noise during the lockdown were compared to those before the lockdown (Lee et al., 2020).

Social media analysis revealed that the tweets about outdoor noise complaints were slightly increased for most sources during the lockdown. In particular, there was a substantial increase in complaints on birds during the lockdown. This finding is not consistent with previous studies (Coensel et al., 2011; Hedblom et al., 2014; Jeon et al., 2010), highlighting the positive perception of bird song in urban soundscape settings. The disagreement between previous studies and this study could be attributed to differences in place and scenarios. Most of the previous studies dealt with bird songs as a component of sound environment in which traffic noise is considered to be dominant. In contrast, in the present study, most negative tweets on birds were made while people were staying at home, and the ambient noise level was reduced during the lockdown. In addition, bird songs with strong energy at high frequencies might be annoying rather than pleasing while working from home. Another dominant source found in social media was construction/building works/machinery. This is because essential building works were still allowed to continue by maintaining social distancing even during the lockdown, and noise from construction sites became louder with less traffic noise.

The results of the questionnaire survey demonstrated significant changes in attitutes to outdoor noise during the lockdown. More than half of the respondents reported that perceived outdoor noise levels were reduced during the lockdown probably due to the decrease in noise levels. In addition, as shown in Figure 2, the mean annoyance ratings of transportation noise were significantly reduced due to the lockdown. This finding confirmed the social media analysis, showing that the tweets on transportation noise were reduced during the lockdown. More specifically, mean annoyance due to trains/trams showed the most dramatic change compared to before the introduction of lockdown, followed by road traffic on major roads. This result is also consistent with the statistical data from the UK Government, indicating that traffic flows of national rails and tubes were more significantly dropped than motor vehicles due to the lockdown measures (DfT, 2020). However, the %HA ratings of outdoor noise were less than 20% for all the sources and were not significantly changed during the lockdown. This indicates that there was still a similar percentage of people who were highly annoyed, although the noise levels were reduced during the lockdown. It is not known which factors led to their consistent high annoyance ratings before and during the lockdown; thus, more data including situational and personal factors could be examined in further studies.

4.2 Effect of lockdown measures on perception of neighbour noise

The number of tweets on neighbour noise was significantly increased and neighbour noise was more tweeted than outdoor noise during the lockdown. In particular, airborne noise sources such as talking/shouting, TV/music, and home appliances were frequently tweeted. These results were in line with the UK government data (OfN, 2020), explaining that there was a substantial increase in the amount of time spent in a day on entertainment and the most popular activity was watching TV or streaming videos. The data also indicated that 71.3% of people enjoyed watching films or streaming videos to cope with the lockdown. The noise complaints about neighbour and DIY (do-it-yourself)/home repairs were much more tweeted than other neighbour sources. This is because the time spent on gardening and doing DIY was substantially increased by 147% during the lockdown (DfT, 2020). There are no official statistics, but several news articles reported that the increase in noise complaints during the lockdown in the UK. For instance, a BBC news article (BBC, 2020) reported that a rise in neighbour noise complaints was found in 44 out of 51 councils in the UK and Leeds City Council recorded the highest increase with 1171 noise complaints in April 2020 compared to 780 in the same month in 2019.

Similar findings were obtained by the questionnaire survey results. As the tweets on neighbour noise increased, more than half of the respondents in the questionnaire agreed that neighbour noise levels increased during the lockdown. This is because more people were staying at home or working from home during the lockdown, and their daily activities caused noise inside their dwellings. From the UK government data (OfN, 2020), it was confirmed that daily time spent working from home increased from 14.5 min in 2014–2015 to 54.8 min during the lockdown in March and April 2020. It was observed that talking/shouting and TV/music were the most frequently heard neighbour noise sources during the lockdown, which confirms the dominant number of tweets on these issues. Moreover, approximately 52% of the participants responded that they had heard TV/music noise during the lockdown and it is higher than 34% before the lockdown. Talking/shouting and TV/music were also the most annoying neighbour noise sources during the lockdown in terms of mean annoyance rate.

A comparison between people living in flats and houses indicated that flat dwellers showed a greater percentage of responses hearing neighbour noise and annoyance ratings than people living in houses during the lockdown. (Lee et al., 2020) reported the same results before the lockdown; thus, this result indicates that the lockdown had little impact on the flat dwellers' attitudes to neighbour noise. This might be because flats still have more adjacent neighbours and noise sources compared to houses. However, minor differences were found between with and without lockdown measures. Before the lockdown, TV/music was not a dominant source, but it became the third most frequent noise source in both flats and houses. In addition, no significant difference in mean annoyance ratings was found before the lockdown (Lee et al., 2020); however, the annoyance ratings of three sources (footsteps, dropped objects, and TV/music) in flats were found to be significantly greater than those in houses during the lockdown.

It was assumed that attitudes of people toward neighbour noise would be different across the places where people spend most of their time at home (i.e., home office and living room) during the lockdown. However, the differences in annoyance ratings between places were not significant for all the neighbour noise sources. This result is not consistent with previous studies (Kjellberg and Sköldström, 1991; Zimmer et al., 2008), in which noise annoyance is affected by the amount of task disruption by noise. This disagreement in results may be attributed to the different research methodologies and different situations. Previous studies (Kjellberg & Sköldström, 1991; Zimmer et al., 2008) examined the effect of tasks on noise annoyance in the laboratory setting, and they included only work-related tasks such as proofreading and memory tasks. In contrast, the present study is based on an online questionnaire. In addition, major task types in the home office and activities in the living room were not specified. Thus, further research is required to examine the effects of different task types and activities on noise annoyance at home.

The present study revealed that the structureborne and airborne neighbour noises were more annoying than outdoor noise during the lockdown. However, previous studies demonstrated opposite results in pre-lockdown period. (Lee et al., 2020) reported that the difference between annoyance rates for indoor and outdoor sources was not significant, and a UK survey in 2012 (Notley et al., 2014) demonstrated that noise annoyance ratings from road traffic and neighbour noise were similar. This inconsistency between this study and previous studies suggests that the lockdown measures led to the increase and decrease in neighbour and outdoor noises, respectively.

4.3 Implications to sustainable cities

Recent studies (Aletta et al., 2020; Asensio et al., 2020; Basu et al., 2020; Rumpler et al., 2020; Sakagami, 2020) have reported the decrease in outdoor noise levels due to the travel restrictions during the lockdown. The present study also highlighted that outdoor noise annoyance ratings were significantly reduced during the lockdowon. These findings imply that physical and subjective quietness in urban areas can be achieved through traffic restriction approaches such as limiting transportation and encouraging cycling. Therefore, more discussions are required to enhance acoustic comfort and sustainabilities in urban environment by supproting green transporations (Guo et al., 2017; Wang et al., 2020). This study also revealed that the bird song was one of negative noise sources during the lockdown. This indicates that positive and natural sound sources (Coensel et al., 2011; Jeon et al., 2010) also can be disturbing and distracting while outdoor noise levels are significantly reduced. Thus, new design approaches should be developed to optimise the soundcape for city sustainability. For instance, more reliable sound maskers with proper levels could be investigated. In addition, in contrast to outdoor noise, the tweets and annoyance ratings of neighbour noise were substantially increased. This represents that the current sound insulation performances of building elements such as wall, floor, and ceiling (Rasmussen & Rindel, 2010) would not be good enough to have acoustic comfort at home. A recent survey (Bartik et al., 2020) reported that around 20% of employees will continue remote working after the pandemic. Therefore, it is necessary to discuss how to reinforce the sound insulation guidelines after COVID-19.

4.4 Limitations

Significant differences in the noise complaints before and during the lockdown were observed in social media data analysis. However, the tweets were limited to a specific place (London), periods, keyword (noise), and language (English); thus, the number of collected data for this case study was relatively small. Therefore, it would be beneficial to expand social media analysis to wider ranges at the national or international level with various languages. In addition, the identification of noise sources from the social media data was performed manually because of the limited size of the data. In the future, machine learning approaches could be used to automatically detect the sound source for large-scale data. Another limitation of this study is related to the lack of objective data of noise measurement and sound insulation of buildings. As already reported by a previous study (Lee et al., 2020), it is not possible to constantly monitor the sound pressure levels of indoor noise sources in occupied conditions. Therefore, for a large-scale investigation in the future, low-cost and portable measurement systems using a smartphone's microphone (Nast et al., 2014) and Raspberry Pi (Rumpler et al., 2020) can be used for indoor noise measurements. Furthermore, several data such as year of construction and windows type (e.g., single or double glazing) could be collected to predict the sound insulation performance of building elements. In addition, other non-acoustic factors may affect subjective responses to noise such as the attitude brought by the inconvenience during the lockdown. Thus, further research is needed to investigate their effects on the attitude towards noise during the lockdown and pandemic.

5 Conclusions

This study investigated the attitudes of people towards outdoor and neighbour noise in London during the lockdown using Twitter analysis and a questionnaire survey. The number of tweets with noise complaints during the lockdown increased by more than two times compared to before the introduction of lockdown. Tweets regarding neighbour noise increased more than those about outdoor noise sources due to the lockdown. Among outdoor noise sources, the number of tweets on bird and construction/building/machinery significantly increased with less traffic flow during the lockdown. For neighbour noise sources, an increase in number of tweets about airborne noise sources such as talking/shouting and TV/music was significant during the lockdown. A questionnaire survey demonstrated a decrease in the perceived outdoor noise level and an increase in perceived neighbour noise level during the lockdown. The percentage of respondents who heard outdoor noise during the lockdown were similar to those reported before the lockdown. However, the introduction of lockdown led to less outdoor noise annoyance ratings for all the sources, mainly because of a substantial reduction in traffic flow. Contrary to outdoor noise, the percentage of respondents who heard neighbour noise increased during the lockdown. In particular, talking/shouting was the most frequently heard noise during the lockdown. Compared to before the lockdown, the mean annoyance ratings of neighbour noise increased and talking/shouting and TV/music were most annoying. The lockdown had little impact on the flat dwellers' attitudes to neighbour noise, and the annoyance ratings of neighbour noise were not affected by the places where people spent the most time. Respondents were more annoyed by neighbour noise than outdoor noise during the lockdown. This research can be further extended to national or interregional levels to understand how dwellers react to noise during the lockdown. The findings of this study would be useful in designing the future strategy to enhance the acoustic comfort and city sustainability.

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Table 1. Information about the participants of questionnaire survey

Personal characteristics	Number of respondents
Gender	
Male	96
Female	87
Total	183
Age (years)	
18 to 35	57
36 to 50	71
51 to 64	50
65 or over	5
Type of dwelling	
Flats	118
Semi-detached house	34
Terraced house	24
Detached house	7
Room spending most time during the day	
Living room	95
Home office	74
Bedroom	14
Education	
School level	82
University level	101
Employment	
Full time	77
Part time	24
Self-employed	25
Unemployed	18
Student	16
Homemaker	19
Retired	4

Table 2. Number of tweets collected for 2019 and 2020

	2019	2020
Number of tweets including 'noise'	367	427
Number of tweets with noise complaints	68	149
Outdoor noise sources	47	68
Neighbour noise sources	21	81

Table 3. Number of tweets about outdoor noise sources

Category	Sources	2019	2020
Nature & animal	Rain	1	0
	Bird	0	12
	Wind and rustling objects	1	1
	Animals (i.e. dog and cat)	0	2
Transport	Road traffic	8	7
	Airplanes/helicopters	10	5
	Trains	3	0
Mechanical	Gardening	0	2
	Construction/building works/machinery	4	13
Voice & instrument	Talking/shouting/singing/children	6	4
	Amplified music/speech	3	0
Social & communal	Alarms/bells	1	2
	Fireworks	1	2
	Bin collection	1	5
Others	Not specified	8	13
Total		47	68

Table 4. Number of tweets about neighbour noise sources

Category	Sources	2019	2020
Structureborne	Footsteps	1	3
	Banging	1	4
	Door closing	0	1
Airborne	Talking/shouting	1	9
	TV/music	2	8
	Home appliances	2	11
	Alarm	0	2
	Dog barking	0	1
	Electric socket	0	1
General	DIY/home repair	1	13
	Neighbour	12	22
	Not specified	1	6
Total		21	81

Figure captions

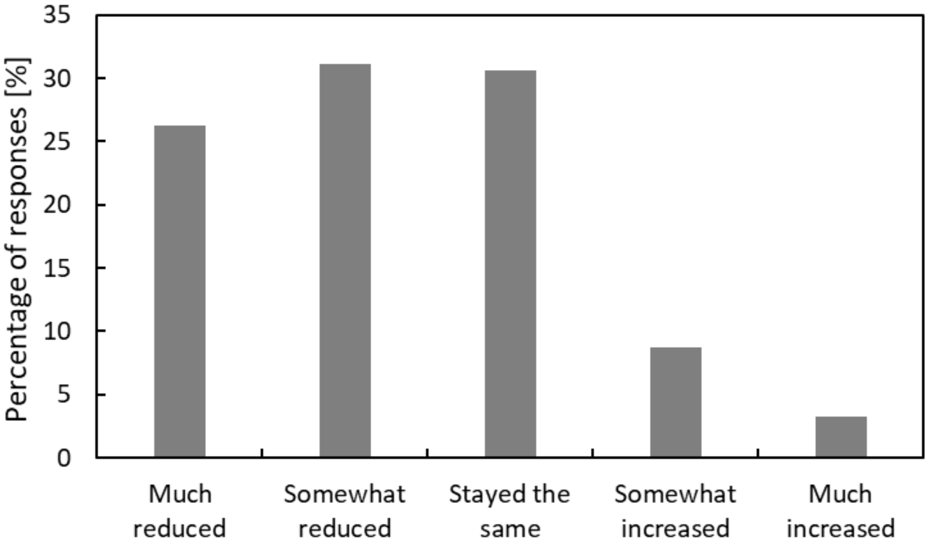
Figure 1 Perceived changes in noise levels. (a) outdoor noise and (b) neighbour noise.

Figure 2. Outdoor noise. (a) percentage of respondents hearing noise for all the respondents, (b) mean annoyance, (c) %HA ratings. Error bars indicate standard errors (** $p < 0.01$).

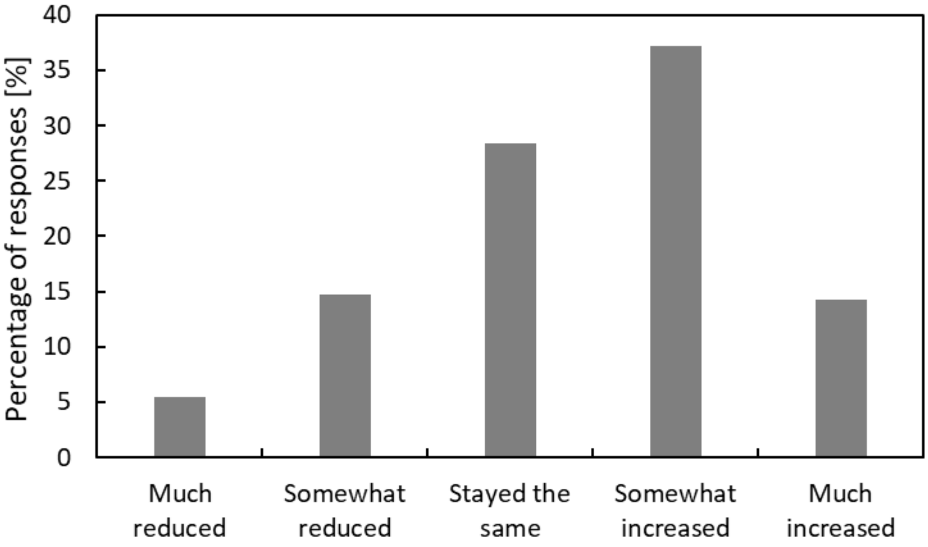
Figure 3. Neighbour noise. (a) percentage of respondents hearing noise for all the respondents, (b) mean annoyance, (c) %HA ratings. Error bars indicate standard errors (* $p < 0.05$, ** $p < 0.01$).

Figure 4. Neighbour noise for flats and houses. (a) percentage of respondents hearing noise, (b) mean annoyance, (c) %HA ratings. Error bars indicate standard errors (* $p < 0.05$, ** $p < 0.01$).

Figure 5. Neighbour noise for those who spend the most time in home office and living room. (a) percentage of respondents hearing noise, (b) mean annoyance, (c) %HA ratings. Error bars indicate standard errors.

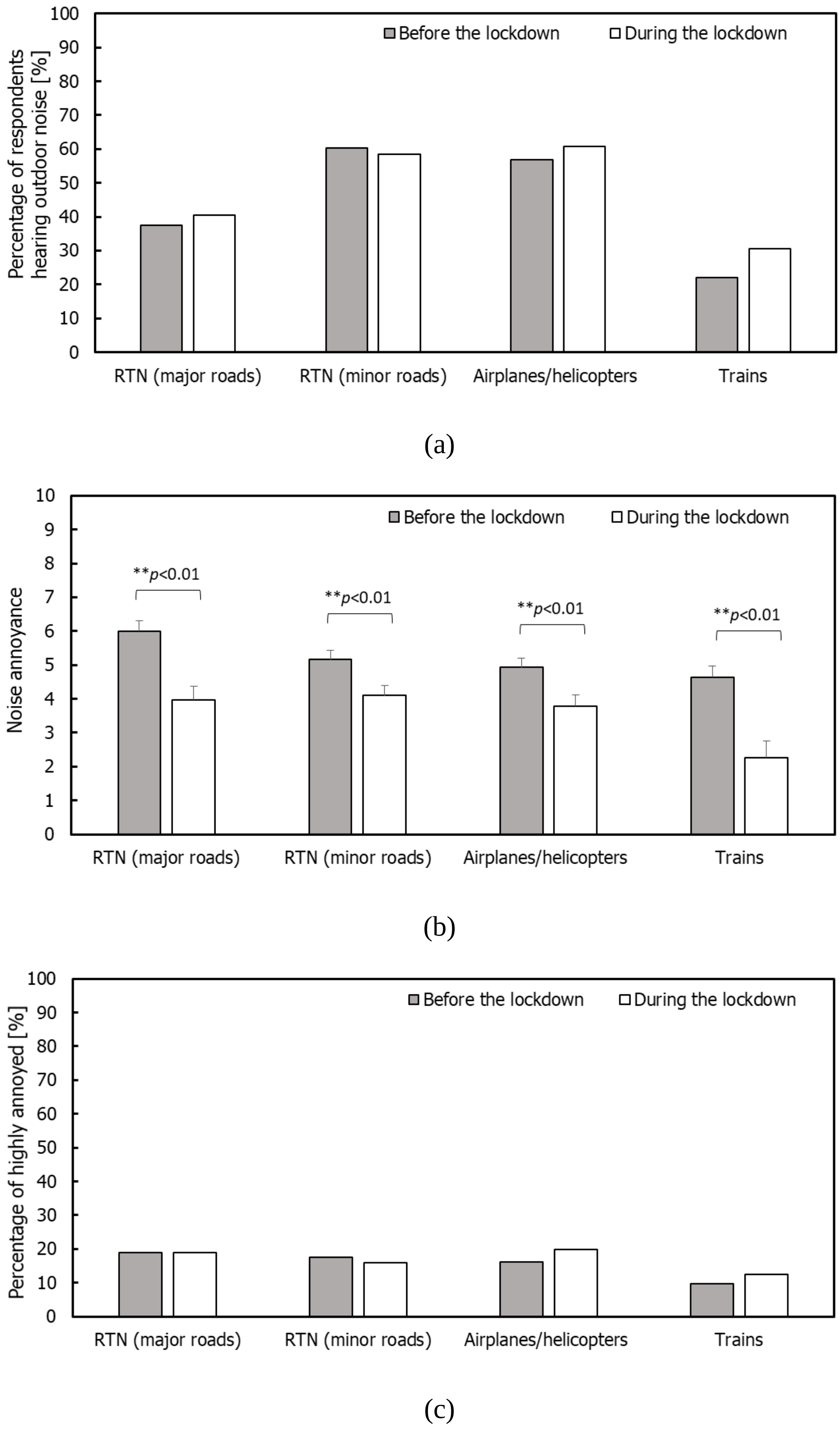

Percentage of responses [%]
35
30
25
20
15
10
5
0
Much reduced
Somewhat reduced
Stayed the same
Somewhat increased
Much increased

(a)


Percentage of responses [%]
40
35
30
25
20
15
10
5
0
Much reduced
Somewhat reduced
Stayed the same
Somewhat increased
Much increased

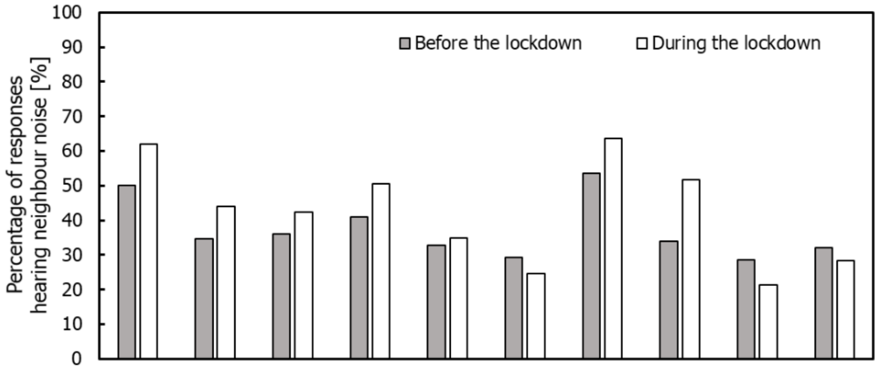
(b)

Figure 1

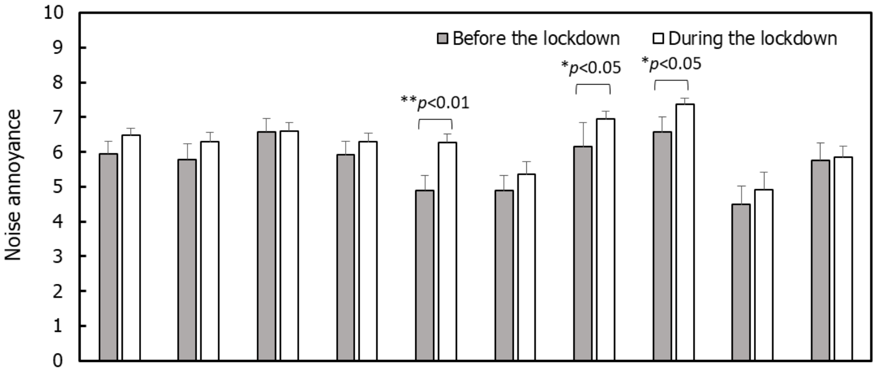


Before the lockdown
During the lockdown
Percentage of respondents hearing outdoor noise [%]
RTN (major roads)
RTN (minor roads)
Airplanes/helicopters
Trains
(a)
Noise annoyance
**p<0.01
(b)
Percentage of highly annoyed [%]
(c)

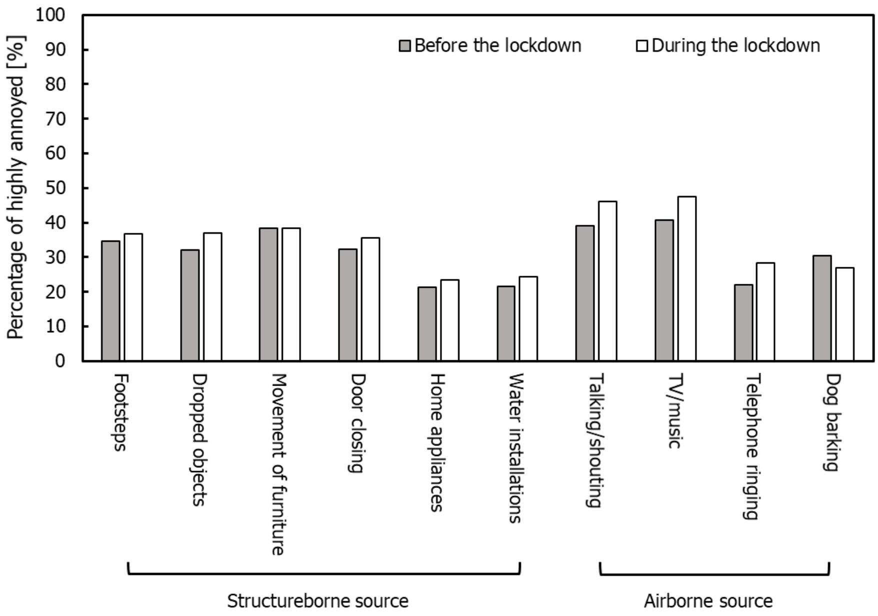
Figure 2


Before the lockdown
During the lockdown
Percentage of responses hearing neighbour noise [%]
100
90
80
70
60
50
40
30
20
10
0

(a)

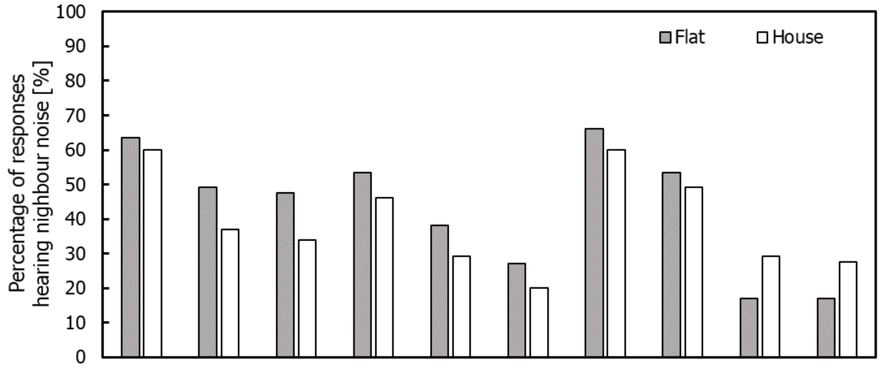

Before the lockdown
During the lockdown
Noise annoyance
**p<0.01
*p<0.05
*p<0.05
10
9
8
7
6
5
4
3
2
1
0

(b)

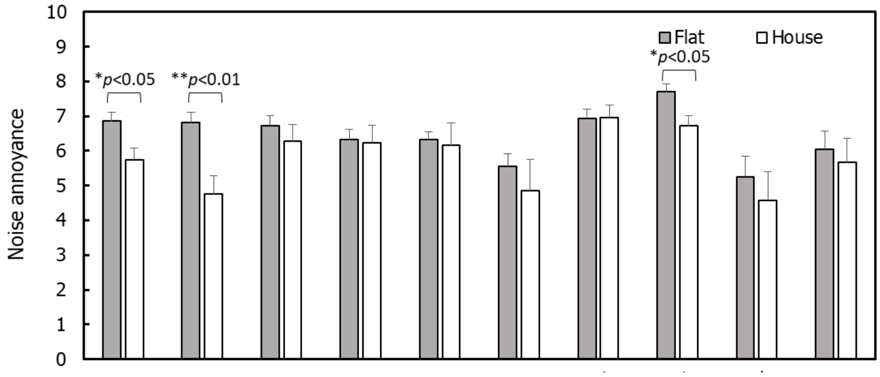

Before the lockdown
During the lockdown
Percentage of highly annoyed [%]
100
90
80
70
60
50
40
30
20
10
0
Footsteps
Dropped objects
Movement of furniture
Door closing
Home appliances
Water installations
Talking/shouting
TV/music
Telephone ringing
Dog barking
Structureborne source
Airborne source

(c)

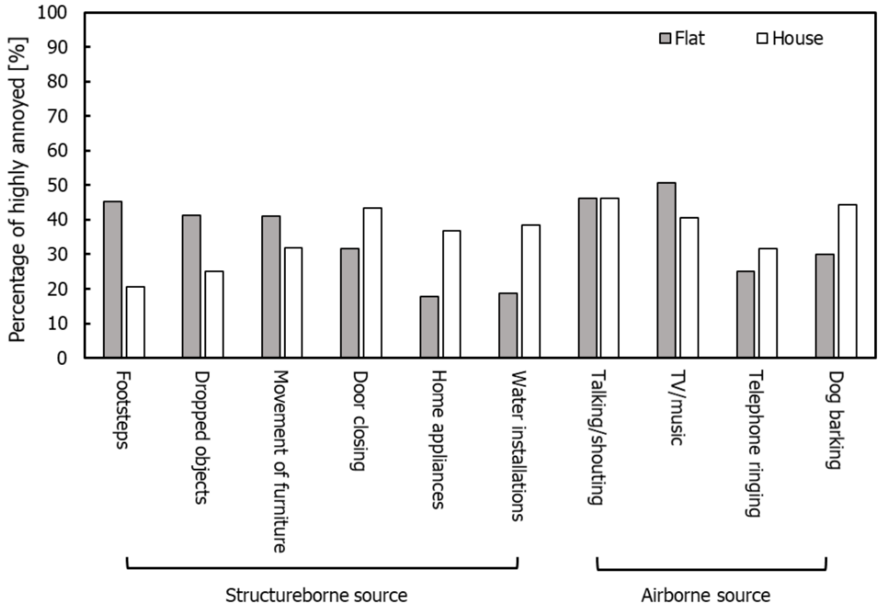
Figure 3


Percentage of responses hearing nighbour noise [%]
Flat
House

(a)

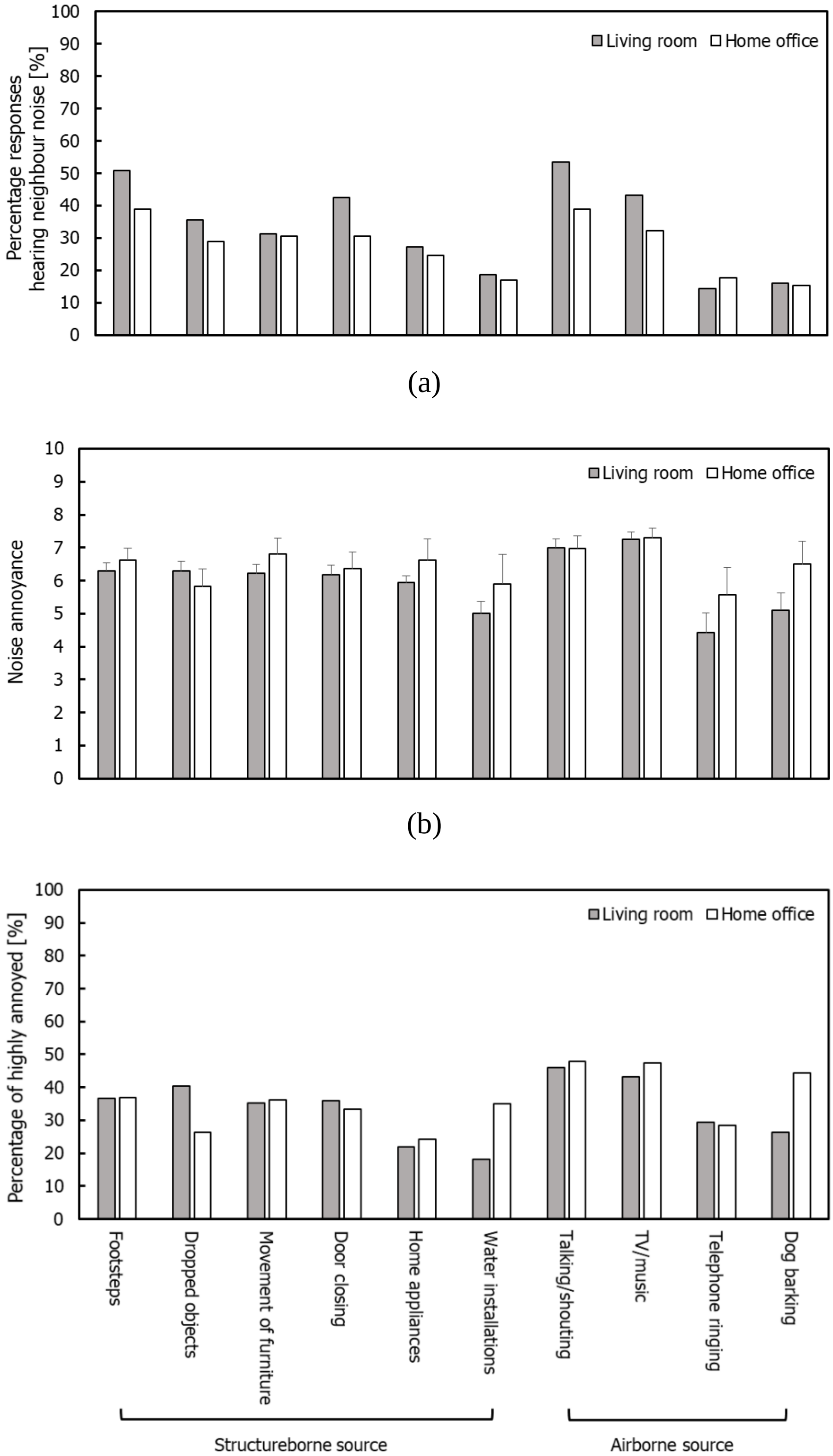

Noise annoyance
Flat
House
*p<0.05
**p<0.01
*p<0.05

(b)


Percentage of highly annoyed [%]
Flat
House
Footsteps
Dropped objects
Movement of furniture
Door closing
Home appliances
Water installations
Talking/shouting
TV/music
Telephone ringing
Dog barking
Structureborne source
Airborne source

(b)

Figure 4

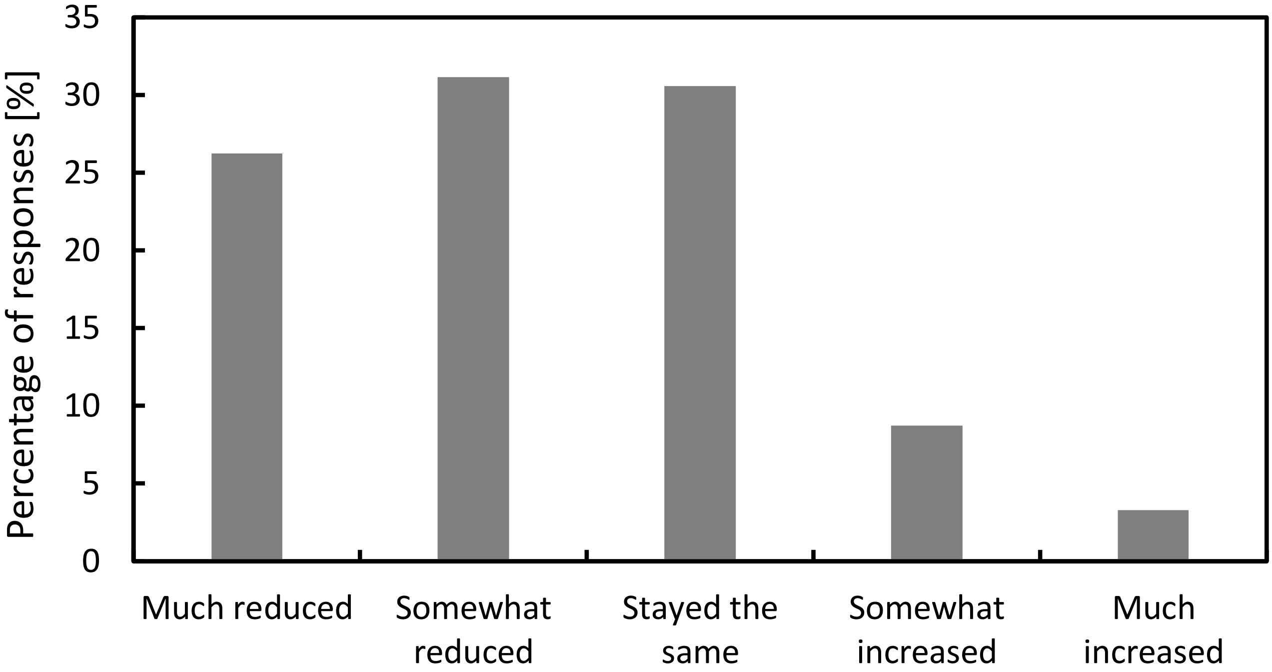

Percentage responses hearing neighbour noise [%]
Noise annoyance
Percentage of highly annoyed [%]
Living room
Home office
Footsteps
Dropped objects
Movement of furniture
Door closing
Home appliances
Water installations
Talking/shouting
TV/music
Telephone ringing
Dog barking
Structureborne source
Airborne source

(a)

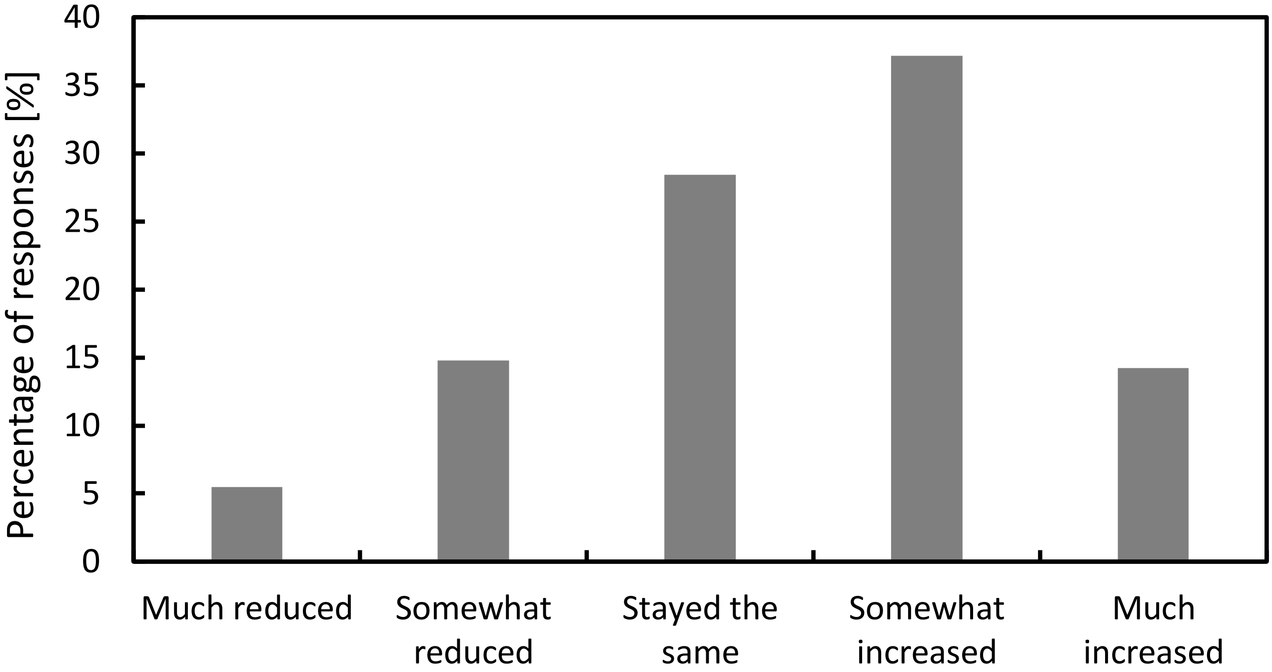
(b)

(c)

Figure 5

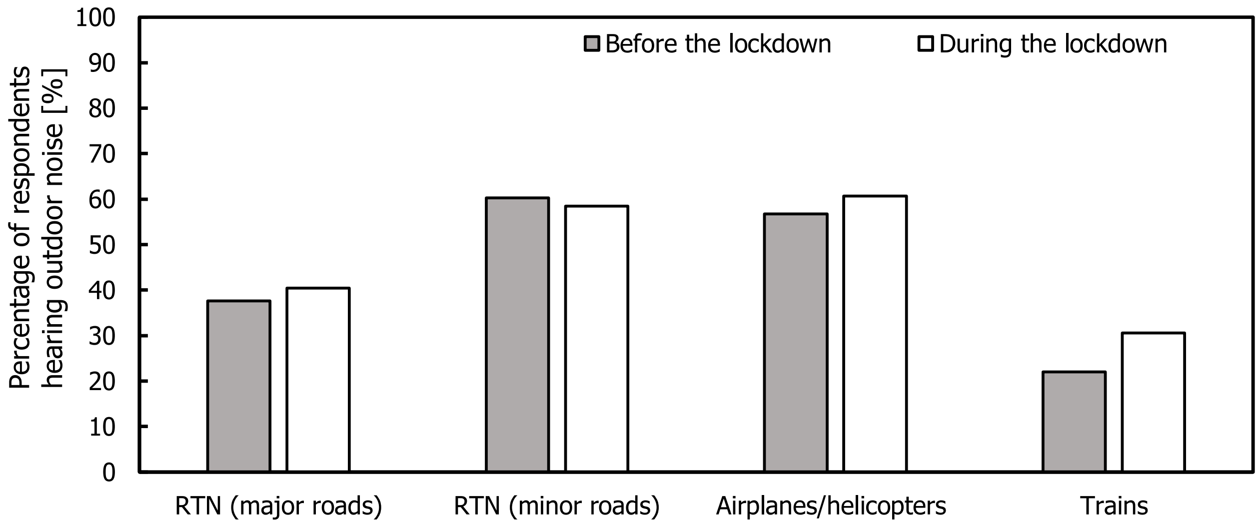

35
30
25
20
15
10
5
0
Percentage of responses [%]
Much reduced
Somewhat reduced
Stayed the same
Somewhat increased
Much increased

(a)

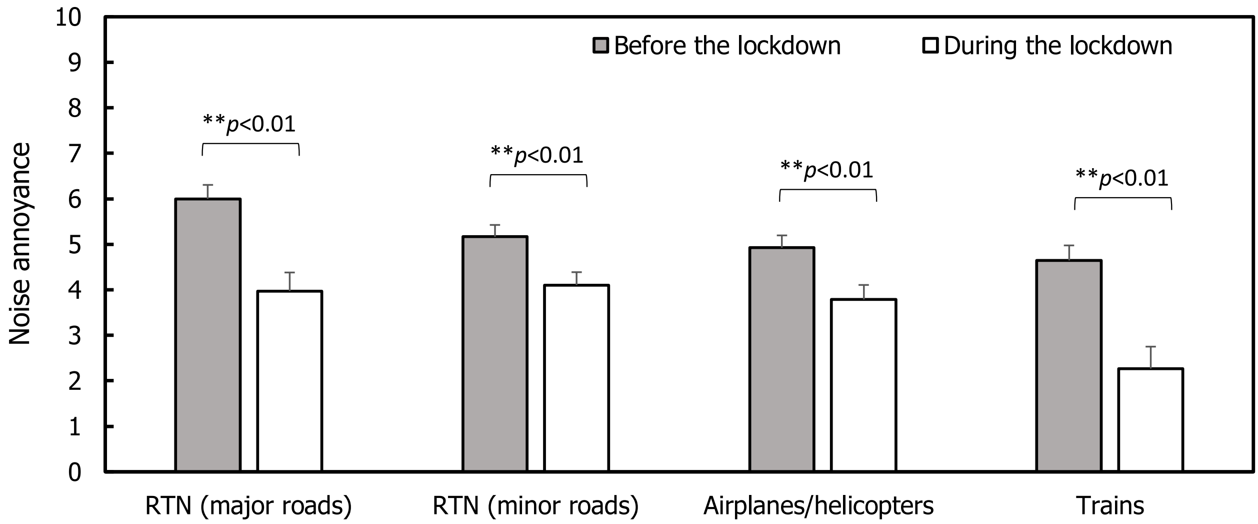

40
35
30
25
20
15
10
5
0
Percentage of responses [%]
Much reduced
Somewhat reduced
Stayed the same
Somewhat increased
Much increased

(b)

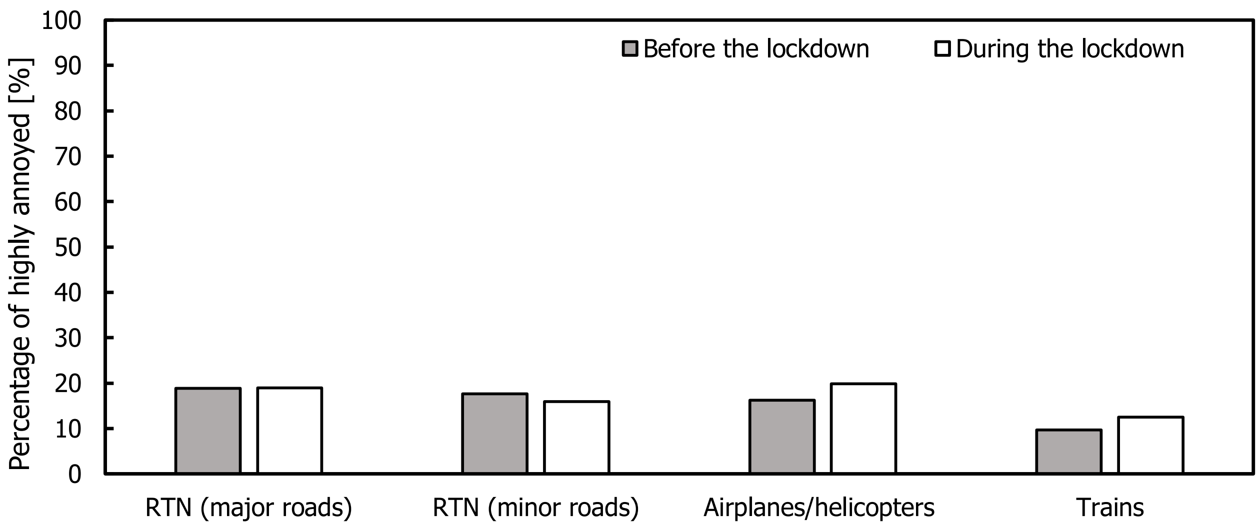
Figure 2


Before the lockdown
During the lockdown
Percentage of respondents hearing outdoor noise [%]
100
90
80
70
60
50
40
30
20
10
0
RTN (major roads)
RTN (minor roads)
Airplanes/helicopters
Trains

(a)


Before the lockdown
During the lockdown
Noise annoyance
10
9
8
7
6
5
4
3
2
1
0
**p<0.01
**p<0.01
**p<0.01
**p<0.01
RTN (major roads)
RTN (minor roads)
Airplanes/helicopters
Trains

(b)


Before the lockdown
During the lockdown
Percentage of highly annoyed [%]
100
90
80
70
60
50
40
30
20
10
0
RTN (major roads)
RTN (minor roads)
Airplanes/helicopters
Trains

(c)

Figure 3

Click here to access/download;Figure;Figure 3.pdf

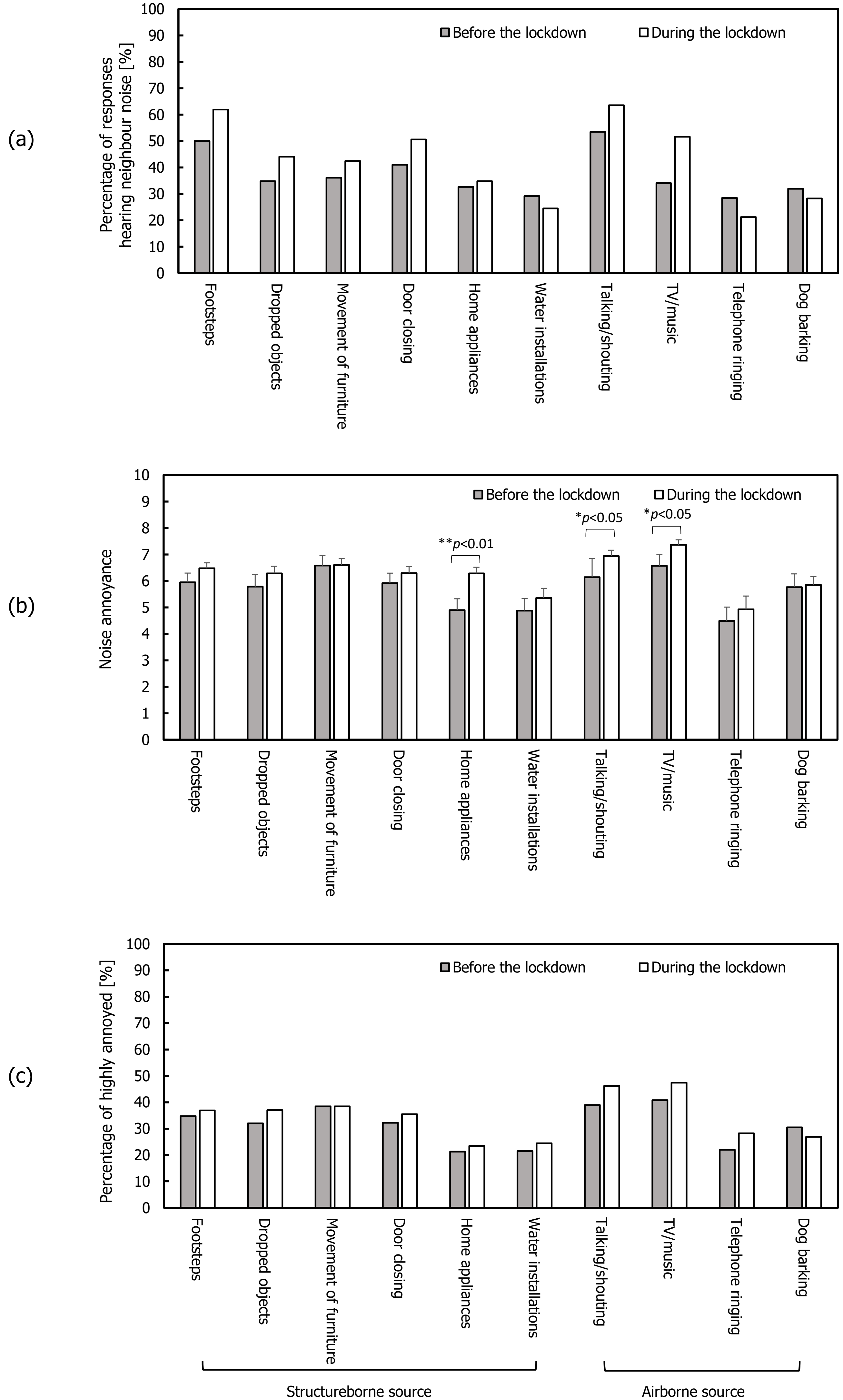


Figure 4

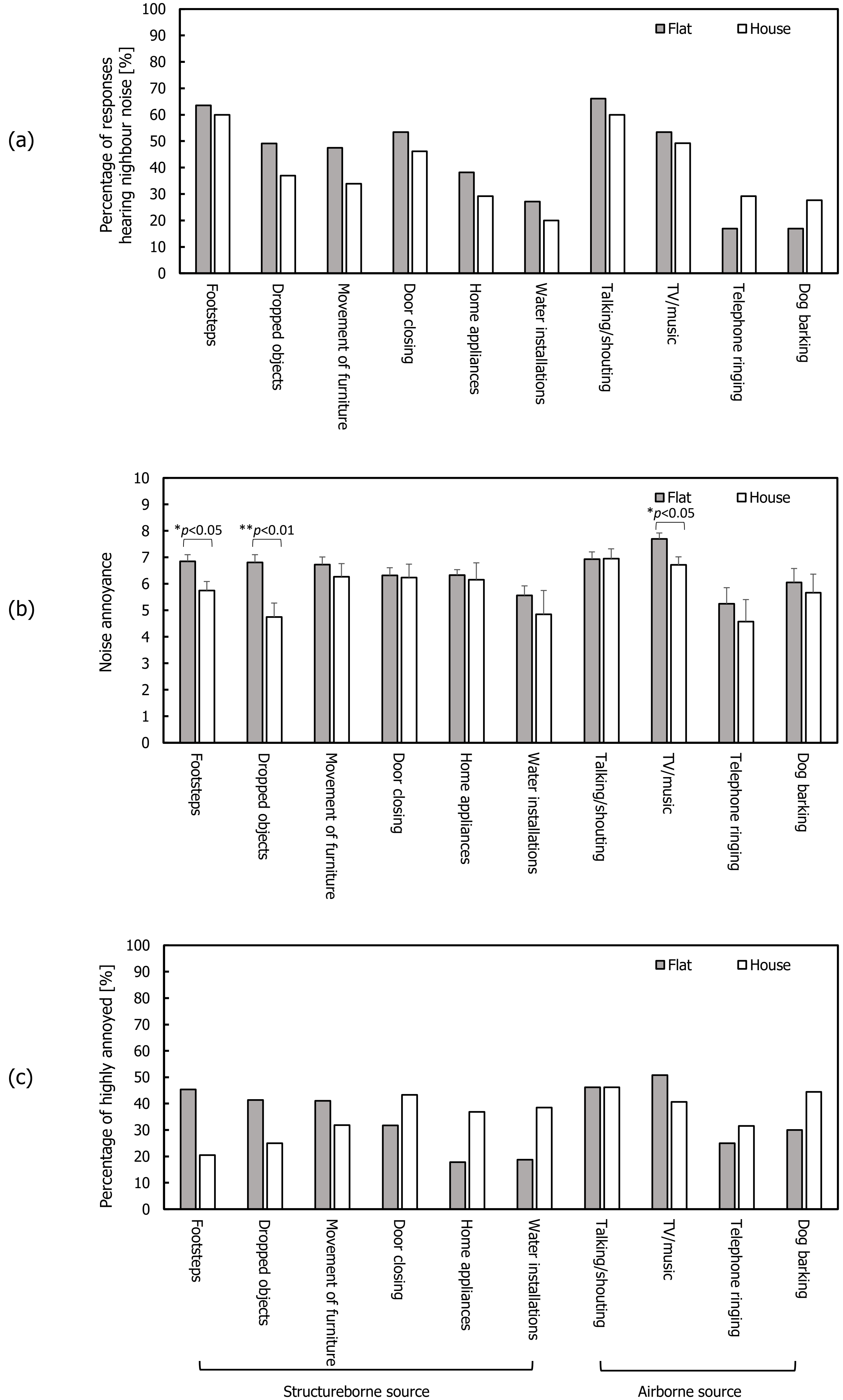
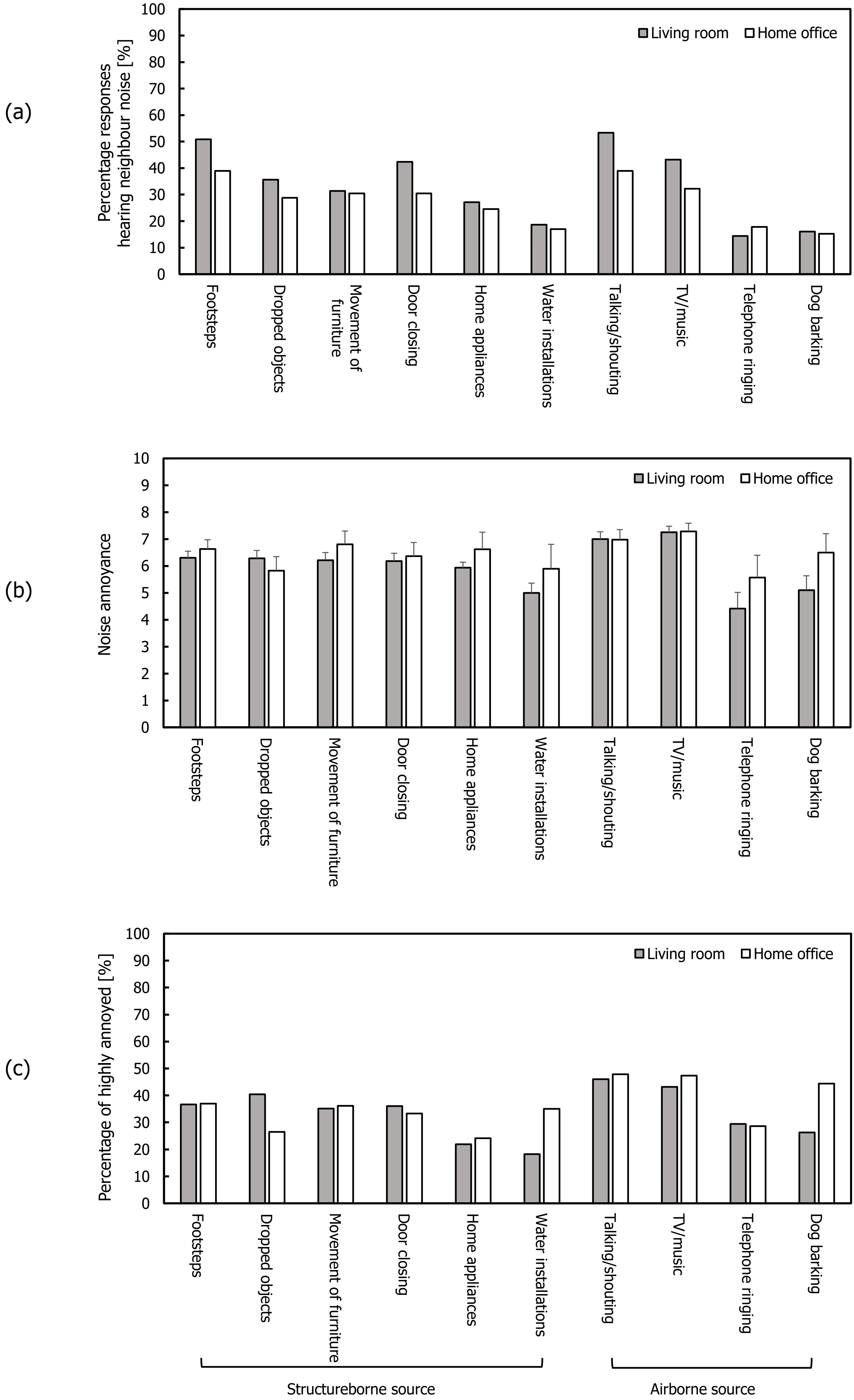

(a)
Percentage of responses hearing nighbour noise [%]
Flat
House
(b)
Noise annoyance
*p<0.05
**p<0.01
*p<0.05
(c)
Percentage of highly annoyed [%]
Footsteps
Dropped objects
Movement of furniture
Door closing
Home appliances
Water installations
Talking/shouting
TV/music
Telephone ringing
Dog barking
Structureborne source
Airborne source

Figure 5


(a)
Percentage responses hearing neighbour noise [%]
Living room
Home office
Footsteps
Dropped objects
Movement of furniture
Door closing
Home appliances
Water installations
Talking/shouting
TV/music
Telephone ringing
Dog barking
(b)
Noise annoyance
(c)
Percentage of highly annoyed [%]
Structureborne source
Airborne source