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Assessment of short-term annoyance due to shooting noise using the experience sampling method

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ABSTRACT

Experience Sampling or Ecological Momentary Assessment allows researchers to assess behavioral and psychological phenomena directly in a given situation. In a longitudinal study, we aim to model short-term annoyance due to shooting noise as a function of intra- and inter-individual differences in perceived annoyance by using a hierarchical data modelling approach. The MovisensXS app is used to collect data from 80 participants at three different study sites in Germany. They are asked to participate for a period of five consecutive days per week. During this time, the participants fill out a survey consisting of 19 items, five times a day at set intervals. This will add up to approximately 4,000 single measurements depending on the response rate and the compliance. We describe the methodology of this study, the planning and executional steps taken to ensure a proper data quality. Furthermore, we will explain what has been done to prepare the data analysis. Finally, we will give a forecast into data analysis and will exemplarily talk about longitudinal data analysis and linear mixed effect modelling.

Keywords: Short-term annoyance, shooting noise, experience sampling

1. INTRODUCTION

For years, environmental noise has been recognized and treated as an important public health issue, being among the top environmental risks to health (1). For gaining insight into the implications environmental noise exposure has on the life and health of individuals, noise assessments are conducted regularly in the context of city noise mapping and health impact assessments [HIAs]. Usually, for purposes of assessing health impact of noise exposure and resident's responses to noise, Surveys on long-term community response to noise are carried out in defined areas. While this practice has been proven to be a valid strategy, there are some implications deriving from real-life circumstances that cannot be thoroughly reflected by the established study methodologies.

For once, there are several short-term noise events, which can cause high annoyance, but which will most likely not be displayed in a long-term annoyance rating approach. Examples for this can frequently be found throughout all countries and communities: Construction sites, vehicle noises (e.g. motorbike noise in summer), increased noise exposure for people spending time in their gardens on a summer's night compared to indoor stay, etc. Additionally, there are various personal (2) and areal differences (3–5), which not only cause differences in perceived annoyance but also in sound propagation, altering the perception of a noise emitted at point A distinctively from the sound immissions at point B and C. As the regular regression-derived exposure-response functions do not offer a solution to consider these individual differences in perceived annoyance, the differences in explained variance are potentially lost to insufficient study design set ups. Here, we propose and describe a solution to the question of how to model short-term annoyance by illustrating a study as an example. The study examines short-term noise annoyance caused by small and large firearms at three different military training sites in Germany. Several studies on blast noise annoyance have been carried out in the last decades. However, for Germany, no updated information on shooting noise annoyance exists since the 1980's and 1990's.

We meet the implications of a repeated measure, short-term blast noise annoyance analysis by exercising an Ecological Momentary Assessment, which is also known as Experience Sampling Method [ESM] or Diary Study. Our aim is to describe the process of obtaining data and setting up a study design, granting to fulfil all requirements for proper scientific data obtainment once the study is

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running. Although, we cannot report any results, yet, we aim at giving insight into the process of in-situ noise assessment strategies. We describe the process of preparing a multilevel analysis and explain possible pitfalls during the phase of data collection.

2. THEORY

The current issue of the technical instructions on noise [TA Lärm] stipulates noise thresholds for stationary noise sources in Germany. This is also true for small calibre firearms (<20mm projectiles and <50mg of a TNT equivalent). However, military training grounds are not considered by this instruction, including all weapons with bigger projectiles and explosive charges. Lenart et al. (4) assume that there are two reasons for this:

1. The defence contract has a somewhat special status in regards to noise regulation;
2. Due to many different physical implications and lack of physical knowledge specifics, a standard regulation cannot be imposed.

The German armed forces do practice "*kooperatives Lärmmanagement*" [cooperative noise management]. This includes the following self-imposed noise related restrictions:

- A daily average noise level of 70 dB(C) L_{den} in mixed zones and 65 dB(C) L_{den} in residential areas including all shots from heavy guns is not to be exceeded more than 5% of the days in a year
- The maximum level of 100dB(C) L_{den} in mixed zones and 95 dB(C) L_{den} in residential areas for a single noise event is not to be exceeded more than 5% of the days in a year
- Both of these goals must be fulfilled for every inhabited grid cell with the dimensions 250 meters *250 meters.

Shooting noise emissions from military bases are, therefore, monitored by the responsible authorities. To take the impacts of different weapons and their characteristics (e.g. small and large guns, cannons, missiles, rapid and slow fire) into account, different sound exposure levels [SELs] have been chosen to assess correlated annoyance ratings. As Schreckenberg (6) has summed up, annoyance caused by small firearms correlates more with an A-weighted sound level, while the correlations between big gun fire are more appropriately reflected with a C-weighted SEL.

Although this could lead to the assumption that at least differences in weapons and projectiles used in training have been considered by research before, the majorities of studies examine small firearms (6, 9) and large firearms (10) independently, without considering the effects of another weapon type. Practice sessions run on a schedule determined by the Bundeswehr (German Armed Forces), which is being communicated to the residents in the area. Although projectable, noise emissions caused by guns, cannons and rifles on military training grounds occur throughout all hours of a day, because the armed forces have to practice day and night.

As stated above, no updated information exists for the the exposure-response relationship for %HA due to shooting noise in Germany. However, Lenart et al. (4) estimate an increase in %HA at 70 dB (C) L_{den}. This is fairly close to the estimates of Nykaza et al. (2), who see the threshold for a considerable increase in %HA at 60-65 dB (C) L_{den}.

Like road, aircraft, railway, industrial and leisure noise, noise deriving from military practice routines potentially interferes with people's leisure time and interrupts or disturbs daily activities. However, during our research, we found three particularly relevant sound characteristics, which are not unique to shooting noise, but potentially have a significant impact on human perception and response:

1. Low frequencies: especially big gun blasts and explosions (assumed the explosive charge is above a 1kg TNT equivalent) elicit deep frequencies at 10-100 Hz (11, 7). Until today, findings suggest that groups of respondents may react particularly sensitive to low-frequency noise (e.g. 12).
2. Impulse noise: unlike a train or a plane that moves towards a receptor or a constant traffic flow, shots, blasts, and explosions occur suddenly and unpredictably. The impulse character of gunfire may cause people to jump and startle (13, 14). It shall be noted that an impulse sound cannot only be produced by the shot itself, but also by sonic boom, which is propagated along the flight path of a projectile, assumed the projectile reaches speed of at least Mach 1.
3. Vibration and rattle: (15–19) The so-called "rattle-factor" (17) is of importance whenever

people experience sound derived vibration and rattle inside their homes (20). That is, people are likely induced with fear of structural damage to their dwellings and belongings, which-although very unlikely (21)- has potential to increase annoyance.

At military training grounds, shooting practice sessions vary day by day. The cooperative noise management aims at monitoring the practise sessions which, again, results in a fine-tuning of following practise sessions from the perspective of (modelled) noise exposure. The objective of this study is to evaluate the cooperative noise management from the perspective of noise responses of residents living in the vicinity of military training grounds. In order to conduct the survey that considers relevant variables of shooting noise with regard to human perception and response, we have to operationalize each of the above mentioned aspects in our questionnaire. A translation of altogether 18 questions used in the diary study is given below (see table 2).

3. STUDY SITES AND SAMPLING

We used QGIS (22) to define a 5 km radius along the outskirts of the military training grounds for the definition of the study areas. Once the geographical coordinates of these 5 km contours had been extracted, we obtained addresses and geographical coordinates of all residential properties within these study areas from the responsible surveying and mapping authority agency (Zentrale Stelle für Hauskoordinaten und Hausumringe, Köln [ZSHH]).

Having obtained the addresses, we contacted the registration offices in each administrative region to complete our building data sets with personal data. Altogether, the process took several months until all personal data was received. Unfortunately, one sub-region had to be left out from the final examination due to unsuitable (not processable) format.

In each study area a survey on long-term shooting noise annoyance precedes the experience sampling study. For this, random samples are drawn from the obtained register data sets. A mixed mode (postal and online survey) will be applied for the long-term survey. The recruitment will be done 'offline' by means of personalised invitation letters. Altogether, the aim is to get 800 participants of the long-term annoyance survey and 80 persons participating in the ESM study. At the end of the initial long-term questionnaire we ask participants if they would, in general, be willing to participate in an in-depth study on shooting noise.

As the long-term study will last for a couple of months we will regularly check for volunteers and will be able to reach out to them while the long-term assessment is still ongoing. This enables us, to react flexibly on participants preferences in regard to their daily life.

Three independent study sites throughout Germany are selected for the study (see figure 1).

Figure 1: Locations of the selected military training ground in Germany (markers are showing the estimated center of the military training grounds), map data provided by © OpenStreetMap

Munster and Bergen are both located fairly close to each other in Lower Saxony and Baumholder is located in Rhineland-Palatinate, south of Frankfurt on the Main.

4. STUDY PROCEDURE AND QUESTIONNAIRE

The short-term questionnaire of the ESM study, which will be implemented on the participant's own mobile device (smartphone, tablet), features 18 questions, each of which addresses the recently passed time period. Table 1 shows the time frames to be observed and the alarm settings for each measurement. Participants will have to fill-in the questionnaire five times per day at fixed points of time. The overall ESM study time will be 14 days, with a four days break after five days, followed by another five days of the trial. The four days break helps avoiding oversampling weekends.

Table 1 – Alarm settings and time periods observed in the short-term ESM study

Measurement number	Time period observed per day		Alarm
1	10 pm -6 am	Night	8 am
	6 am – 8 am	Early morning	8 am
2	8 am - 12 pm	Morning	12 pm
3	12 pm - 3 pm	Noon	3 pm
4	3 pm - 6pm	Afternoon	6 pm
5	6 pm – 10 pm	Evening	10 pm

Although the experience sampling approach demands an in-situ measurement (23–25), we decided to combine the assessments for the night period (10 pm – 6 am) and for the early morning both in a measurement at 8 am. Corruption of compliance may occur when setting an alarm too early and data might be lost, because participants may still be asleep at 6 am or may abort the study altogether due to the strain of an alarm at 6 am.

Overall, an ESM study is quite demanding towards participants and, therefore, may need special considerations regarding the stability of participants' compliance. Accordingly, the alarm time is adjusted and the count of measurement points is set to a reasonable limit as the repeated measurements can be stressful and interfere with participants' daily routines (26, 27). Additionally, participants might as well be worried to divulge too much personal data by using their smartphone (e.g. 28). Participants will receive an expense allowance of € 1 per sent questionnaire to further increase compliance, which has been proven to be useful in ESM settings (29, 30). Reacting to each alarm and completing the questionnaire in every measurement will equal in a total expense allowance of € 50 for each participant.

Table 2 –Short-term survey questions and response scales (translated from German language)

Number	Question	Scale
	Block A) Preponderant whereabouts	
1.	During the last period, did you stay at home?	Yes, inside my house/flat Yes, outside (balcony, terrace, around the house) No, not at home
2.	*If No. 1 = 'Yes, inside my house/flat':* How was the window position while you were at home? [b]	Closed Partly open (tilted) Open
	Block B) Annoyance	
3.	Thinking about the [recent time period], when you are here at home, how much did noise from firearms bother, disturb, or annoy you?	ICBEN 5-point verbal scale (5) Extremely, (4) Very, (3) Moderately, (2) Slightly or (1) Not at all
4.	And how about vibration caused by gunfire, how much did that bother, annoy or disturb you?	
	Block C) Noise characteristics	
	Thinking about the [recent time period], how much did you feel bothered, disturbed or annoyed by	
5.	Frequency	ICBEN 5-point verbal scale (5) Extremely, (4) Very, (3) Moderately, (2) Slightly or (1) Not at all
6.	Nature of noise („boom“)	
7.	Unpredictability/ surprise	
8.	Startling	
9.	Vicinity or intensity	
10.	The low frequencies	
11.	other	Open question
	Block D) Preponderant activities	
	Thinking about the [recent time period], how much did you feel bothered, disturbed or annoyed by shooting noise during the following activities	
12.	Talking or calling inside the house/flat	ICBEN 5-point verbal Scale

<table>
<tr><td>13.</td><td>Listening to the radio or watching TV</td><td rowspan="6">(5) Extremely,
(4) Very,
(3) Moderately,
(2) Slightly or
(1) Not at all’</td></tr>
<tr><td>14.</td><td>Reading or focussing inside the house</td></tr>
<tr><td>15.</td><td>Relaxing after work inside the house/ flat</td></tr>
<tr><td>16.</td><td>Socializing/ having visitors inside the house/ flat</td></tr>
<tr><td>17.</td><td>Staying or relaxing outside</td></tr>
<tr><td>18.</td><td>Talking outside</td></tr>
</table>

We tested the time needed to the questionnaire in every measurement and estimated that participants will need approximately two minutes for each measurement. Those who regularly react to their alarms will likely speed up over time due to familiarity.

We use the movisensXS® (31) Android mobile device application to program the questionnaire for mobile devices. This enables participants to use their own devices.

A team of assistant researchers will be schooled in the handling of the app and visit all participants at home to assist them in setting up their devices and operating systems. This ensures an orderly execution of the study.

5. CONCLUSIONS

Conducting a short-term noise assessment with ESM methodology is a demanding exercise. Many steps in the process are methodical-specific and bear pitfalls, if not considered carefully. Although it takes a lot of preparation and effort to conduct a study like this, we think short-term, ESM based noise assessments are worth the trouble.

ESM and the accompanying data analysis with multilevel linear models offer possibilities beyond the scope of the usual long-term noise annoyance surveys. Here, we have described the details and implications necessary to set up a study using ESM methodology. There is reason to assume that a diary study can explain more variety in data than the usual retrospective surveys combined with regression derived approaches, by considering in-situ raised data and the discrimination of fixed and random effects when calculating the models.

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