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Motorcyle Noise Study Baden-Württemberg, Part II: Short-term noise annoyance in residents of busy motorcycle routes in the south of Germany

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ABSTRACT

Few socio-acoustic surveys exist with results on annoyance and disturbances due to motorcycle noise compared to noise from other road traffic sources such as passenger cars, lorries, or coaches. In Germany, a considerable number of complaints, particularly from rural, touristically attractive areas, specifically refer to noise from motorcycles. In this contribution, we present the design and main results of the Motorcycle Noise Study Baden-Württemberg on short-term motorcycle noise annoyance. In this second study part, the aim was to assess time-depending differences in the impact of motorcycle noise on annoyance in more detail and closer to the event. Therefore, the experience sampling approach was applied to repeatedly assess residents' hourly perceptions of and reactions to motorcycles within a 2-weeks period. Based on sound measurements at multiple positions along selected routes the sound propagation to the participants' home addresses was modelled and, for passenger cars, motorcycles, lorries, and coaches, the address-related hourly continuous sound level $L_{Aeq,1h}$ estimated. In total, 213 of the 493 subjects that took part in study part I further participated in study part II using their smartphone to answer a questionnaire multiple times a day for 10 days allowing to assess reactions to source-specific road traffic noise. Results show that in exposure-response relationships for the percentage highly annoyed (% HA_v) annoyance due to motorcycle noise exceeded annoyance due to other road traffic vehicles. Motorcycle noise annoyance was higher during the weekend compared to weekdays. Further, variations in noise annoyance depending on the time of the day were found.

Keywords: Noise, Road traffic, Motorcycle, Annoyance, Experience sampling

INTRODUCTION

Noise from motorcycles is critical especially in warmer months of the year when more time is spent outside. Residents living nearby busy and attractive motorcycle streets are often exposed to high numbers of passing motorcycles.

Few studies are available on the impact of motorcycle noise on residents. A recently conducted study discovered noise from motorcycles causing significantly higher annoyance than noise from cars at the same sound pressure levels[1,2]. A laboratory study reported more sleep disturbance related to motorcycle noise in comparison to other road noise sources[3]. Sound characteristics seem to play a crucial role for the effect of noise, that is, perceived loudness and roughness of the sound[4]. Further, another laboratory study investigating acoustic properties of different motorcycle and car types showed that driving behaviour was one factor that determined the extent of the psycho-acoustically measured annoyance rates[5].

In the Motorcycle Noise Study Baden-Württemberg we conducted a two-fold study assessing long-term and short-term effects of motorcycle noise using a mixed method design [6,7]. In this contribution, the short-term motorcycle study is presented. Experience sampling method was applied as it allows to collect acute evaluations of situations in the respective setting[8]. The hourly annoyance due to motorcycle noise was investigated with a subsample of the survey participants described in [6]. Over the course of 10 days, the road traffic noise was measured at 5 study areas during the daytime (8 am to 8 pm) while assessing the hourly annoyance due to different vehicle types. Address and source-specific hourly sound levels were modelled for each participant. The aim was to assess time-depending differences in the impact of motorcycle noise on annoyance in more detail and closer to the event.

METHOD

Study Design

Five study areas with busy motorcycle routes in Baden-Württemberg, in the rural areas of the south of Germany, were selected. Study areas were selected according to the following criteria: no significant other noise sources (industry, aircraft noise, rail traffic, wind turbines), no relevant construction sites on selected roads, a sufficient number of households, preferably no relevant occurrence of other emissions.

Based on official register data, a random sample of adult residents was drawn in each study area. 2.500 people were invited by mail to participate in the study. In the first part of the study, participants were asked to fill in a questionnaire via mail or online (for details, see [6,7]). After participating in the first part of the Motorcycle noise study, participants could register to participate in the second part of the study, the MotoApp study. A mobile phone application, the MotoApp, was programmed for Android and iOS operating systems. Therefore, a mobile phone with an Android or iOs operating system was required for participation.

The MotoApp study was conducted in July 2022. Over the course of 14 days, 2 x 5 study days were scheduled. One 5-day period was scheduled from Wednesday to Sunday, and the other one was scheduled for the subsequent Friday to Tuesday. An interval-contingent protocol was applied. Participants received 6 notifications per day with the invitation to fill in brief questionnaires on their mobile phones. Participants were randomly assigned to one of two groups starting the first 5-day period at 9 am or 10 am with the MotoApp study. Accordingly, the other measurement time points were scheduled at 2-hour intervals (11 am, 1 pm, 3 pm, 5 pm, 7 pm or 10 am, 12 pm, 2 pm, 4 pm, 6 pm and 8 pm). In the following 5-day period, the starting times were switched. At each measurement point, participants received a notification on their mobile phone requesting to fill in the current questionnaire. The questions had to be

answered within 15 minutes after notification. A later completion was not possible. 6.732 single measures were filled in by 213 participants. From these, 4.040 questionnaires were filled in while participants were at home (inside/outside). The participants of the MotoApp study received incentives for their participation.

Questionnaire

Each brief questionnaire concerning the past hour contained the following topics and questions:

- Current location of the participant in past hour (at home inside, at home outside, not at home). In case of selecting '*not at home'* no further questions were asked for this measurement point.
- Window position (question only asked if located '*inside*'): closed, tilted, open
- Annoyance due to different sources of road traffic noise: cars, lorries, coaches, agricultural traffic, and motorcycles in the past hour (assessed with the ICBEN verbal 5-point scale from (1) *'not at all'* to (5) *'extremely'* as recommended by the International Commission on Biological Effects of Noise (ICBEN)[9] and ISO/TS15666[10]). The two upper response categories of the verbal scale *'very'* and *'extremely'* are classified as high annoyance (HA_V according to ISO/TS 15666[10])
- Disturbing aspects/characteristics of motorcycle traffic or sound (high revolutions while accelerating, fast and aggressive riding, groups of motorcycles, and low frequencies ('humming'), rattle), based on assessments from Lechner & Schnaiter[1], assessed with the 5-point ICBEN scale[9,10] from (1) *'not at all'* to (5) *'extremely'*. These questions were only asked if participants indicated to be at least (2) *slightly* annoyed by motorcycle noise.
- Disturbance of activities in the past hour by motorcycle noise (communication inside/outside, relaxation inside/outside, concentration, housework).
- After the last assessment of the day (7 pm / 8 pm, respectively), noise annoyance due to different sources of traffic noise (cars, lorries, coaches, agricultural traffic, motorcycles) was assessed referring to the whole day (assessed with the ICBEN verbal 5-point scale from (1) *'not at all'* to (5) *'extremely'* [9,10]).

Road traffic noise exposure

In each study area depending on the topography, street alignment and traffic regulation of each route, up to four measurement points were selected where sound measurement devices were installed for the study period of 14 days.

Noise levels and vehicle type of each vehicle passing the measurement devices were extracted/identified. Address-based hourly sound levels of each vehicle class were modelled for each participant based on these measurements (for more details, see [7]).

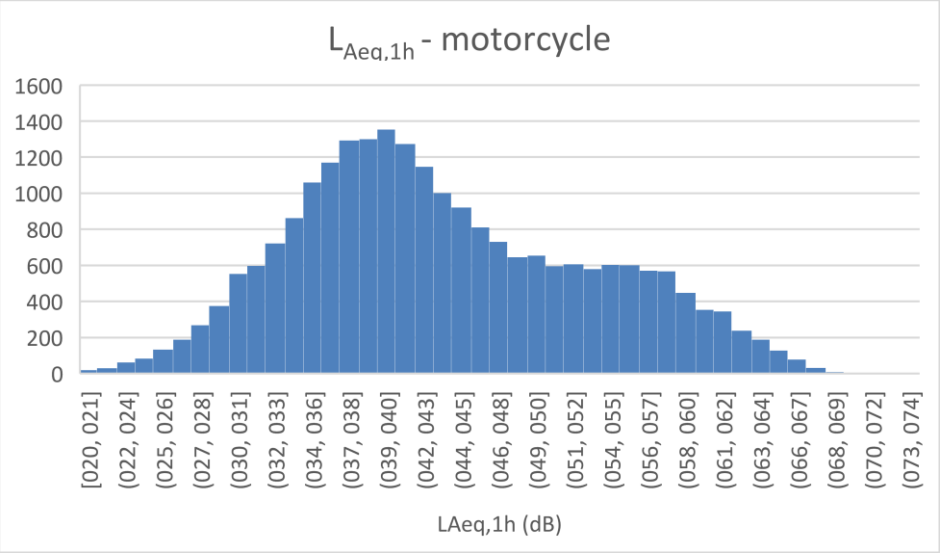
Statistical analysis

Statistical analysis was performed using the software package R, Version 4.2.1. Correlations between variables of exposure variables (motorcycle, cars, lorries, coaches) and corresponding annoyance variables were analysed by calculating the repeated measurement correlation coefficients r_{rm}[11]. Exposure-response relationships for noise annoyance and assessed exposure were calculated using Generalized Estimating Equations (GEE)[12] for repeated measurement design. In the regression models, the criterion variable is the probability of being highly annoyed in per cent (%HA_V) due to different road traffic vehicles (motorcycles, cars, lorries, coaches), and the predictor is $L_{Aeq,1h}$ of the corresponding noise exposure. Covariance analyses were performed using the GEE approach to conduct group comparisons (e.g., for noise annoyance at different hours of the day). Group comparisons were controlled for the effect of noise levels.

RESULTS

Of the 493 participants in the first part of the Motocycle Noise Study (in Baden-Württemberg), 213 participated in the MotoApp study. 101 are female, 110 are male, and none identified as diverse. No gender information was available for 2 participants. Mean age was 46.3 years (*SD*=16.3). The average period of residence was 16.3 years (*SD*=15.1). Average self-reported social status on a leather with 7 levels was *M*=4.2 (*SD*=0.9). Mean satisfaction with the living environment was *M*=4.3 (*SD*=0.8), which corresponds to *fairly/rather satisfied* on the verbal scale.

a)



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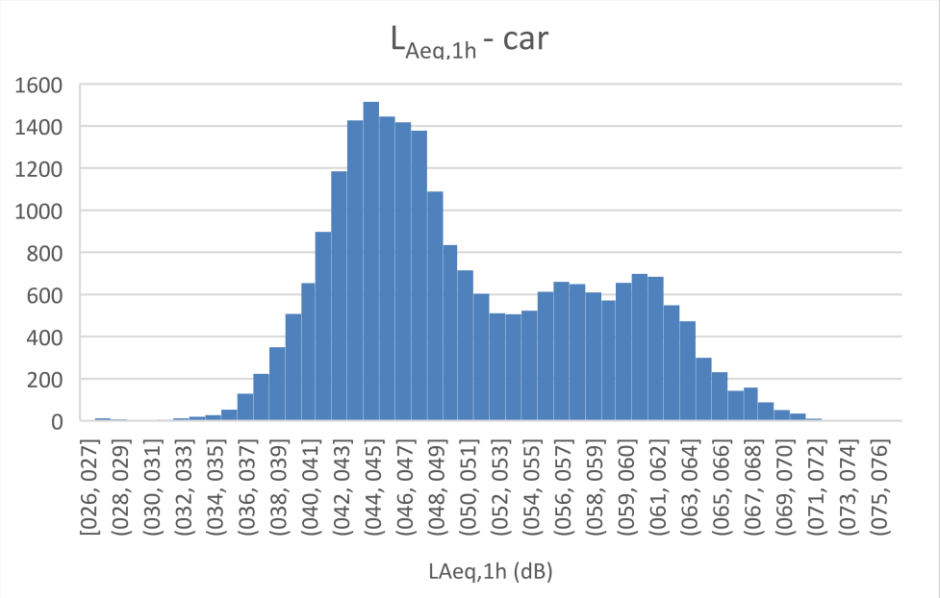

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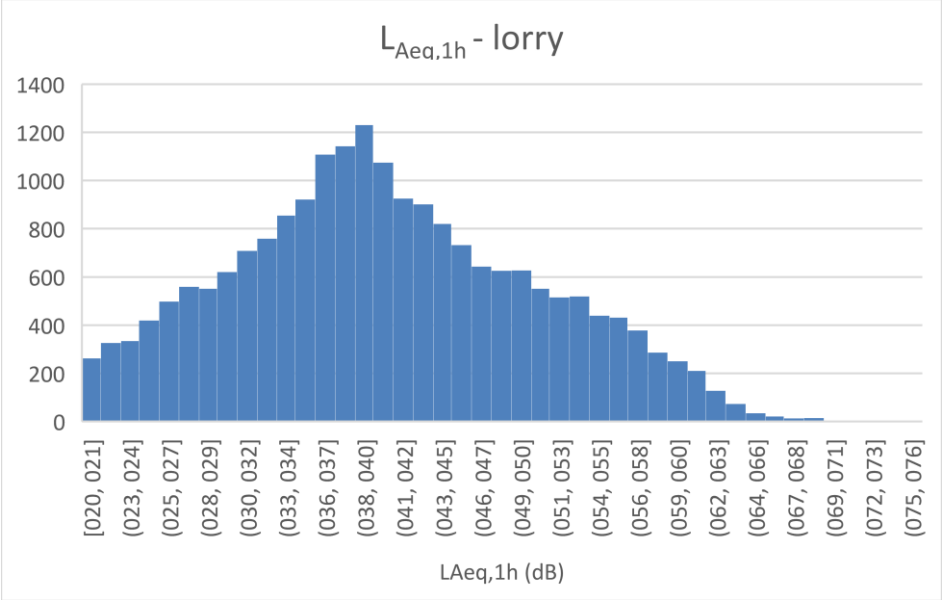

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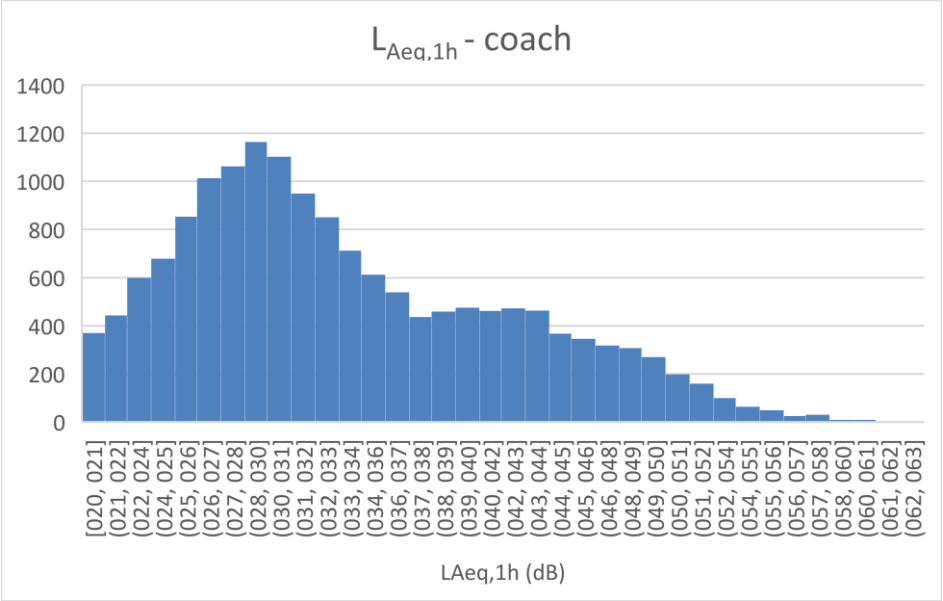

Figure 1: Distribution of traffic noise levels $L_{Aeq,1h}$ for motorcycle (a), cars (b), lorries (c), and coaches (d) in the sample.

During the 10 days study period (2 x 5 days) each passing vehicle and its sound pressure levels was documented and identified in the exposure measurement. Figure 1 shows the distribution of road traffic noise levels $L_{Aeq,1h}$ for different vehicle types in the sample. Hourly noise levels $L_{Aeq,1h}$ for motorcycle ranged from 20 dB to 74 dB. Similar exposures were measured for cars with a range in $L_{Aeq,1h}$ of 26 dB to 76 dB. Compared to noise levels for motorcycle and cars, lower hourly noise levels $L_{Aeq,1h}$ were measured more often for lorries and coaches.

Annoyance judgments regarding noise from different vehicle types were assessed. Figure 2 shows the proportion of motorcycle noise annoyance ratings for the five survey areas in the course of the day and for each survey date (10 days). Colours indicate annoyance ratings ranging from dark blue (1=not at all) to higher noise annoyance as marked in green and yellow (5=extremely). Stronger proportion of high noise annoyance is reported during weekends. Further, there seems to be variation in the course of the day, with higher annoyance ratings in

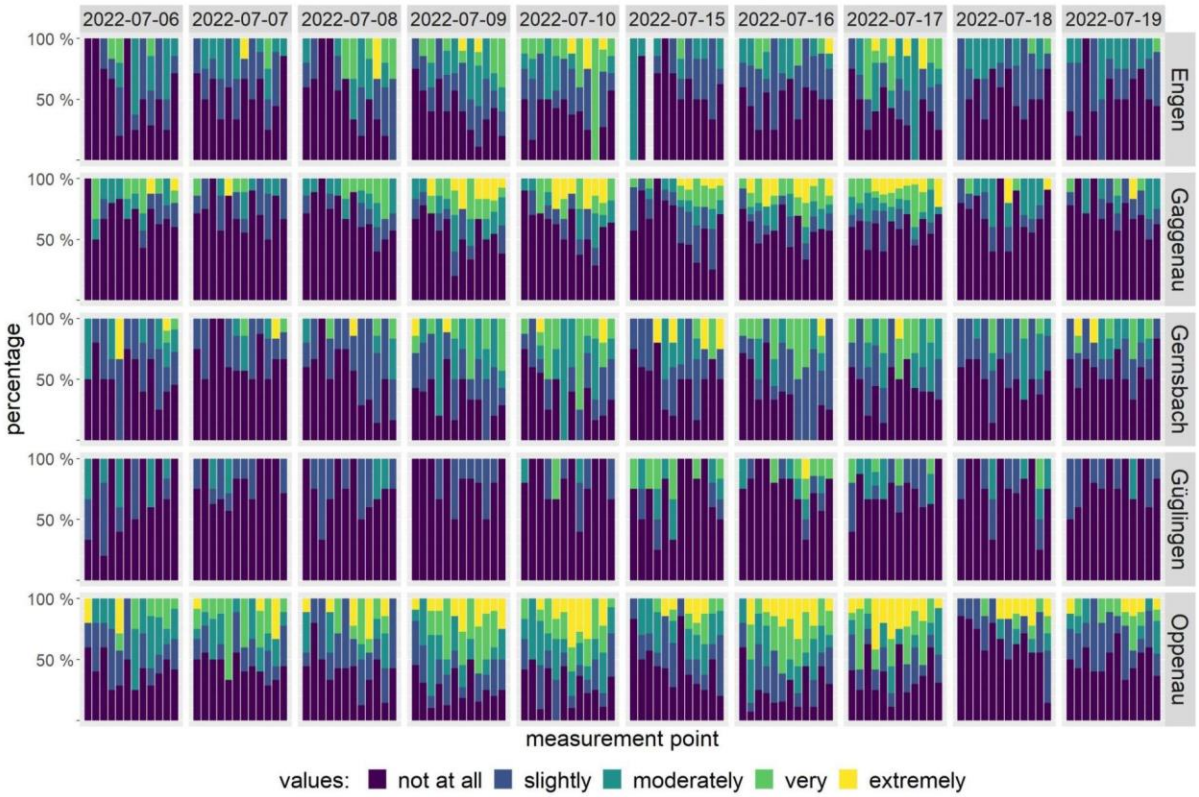

Figure 2: Proportion of the five values of the scale for annoyance due to motorcycle noise for each survey hour during the course of the day and over the ten days of the survey, sorted by survey area.

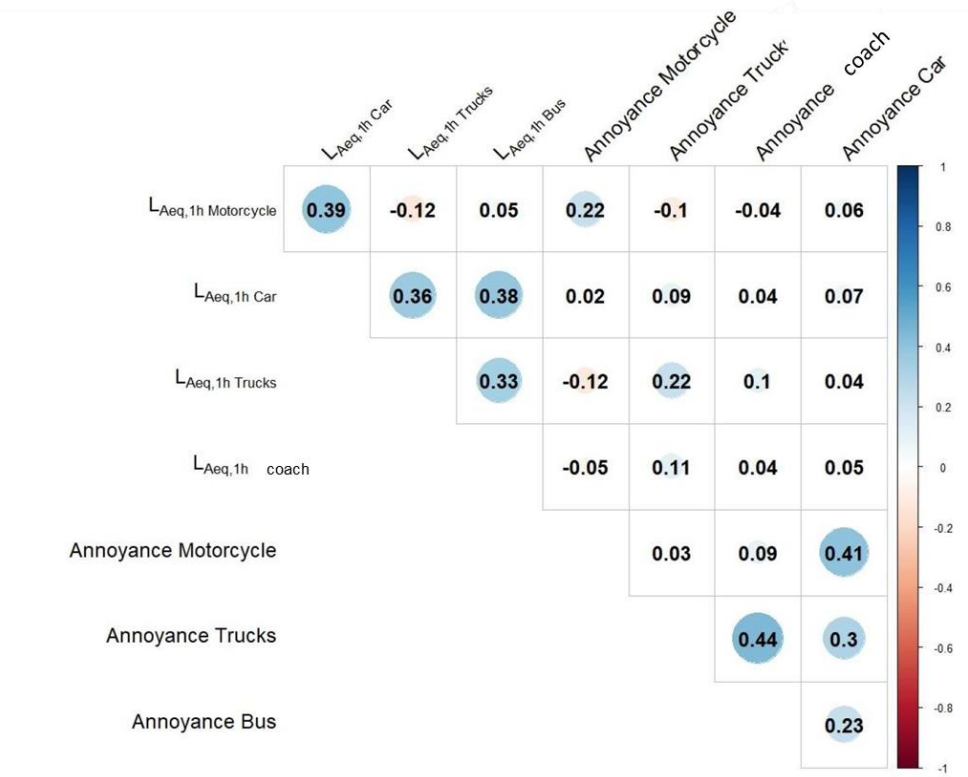

Figure 3: Repeated measurement correlations r_{rm} between 1-h noise levels $L_{Aeq,1h,motorcycle}$, $L_{Aeq,1h,car}$, $L_{Aeq,1h,lorry}$, $L_{Aeq,1h,coach}$ and the corresponding 1-h annoyance ratings.

the afternoons.
Correlations between 1-h noise levels for different vehicles and 1-h annoyance ratings were calculated (Figure 3). All in all, correlations between 1-h noise annoyance and 1-h exposure variables were rather low. Highest correlation coefficients were observed for motorcycle noise exposure and corresponding annoyance ratings with r_{rm}=.22. The same was found for lorries.1-h noise levels for cars and 1-h annoyance rating was found to be lower with r_{rm}=.07.

A central aim of the project was to gather insight into acute evaluations of the noise situation and its determining aspects around busy motorcycle routes. Therefore, exposure-effect curves for the 1-hour exposure to motorcycle noise and other road traffic vehicles and the probability of high annoyance (%HA_v) were calculated. Exposure-response curves for noise from different road traffic types (motorcycles, cars, lorries, coaches) and divided into weekdays (Monday to Friday) and weekends (Saturday, Sunday) are displayed in Figure 4. For the same exposure levels, higher annoyance due to motorcycles in comparison to other road traffic vehicles is reported. At weekends the slope of the curve for the probability of high annoyance due to motorcycle noise is steeper, starting at a higher intercept for low noise levels (12% HA_v at 40 dB).

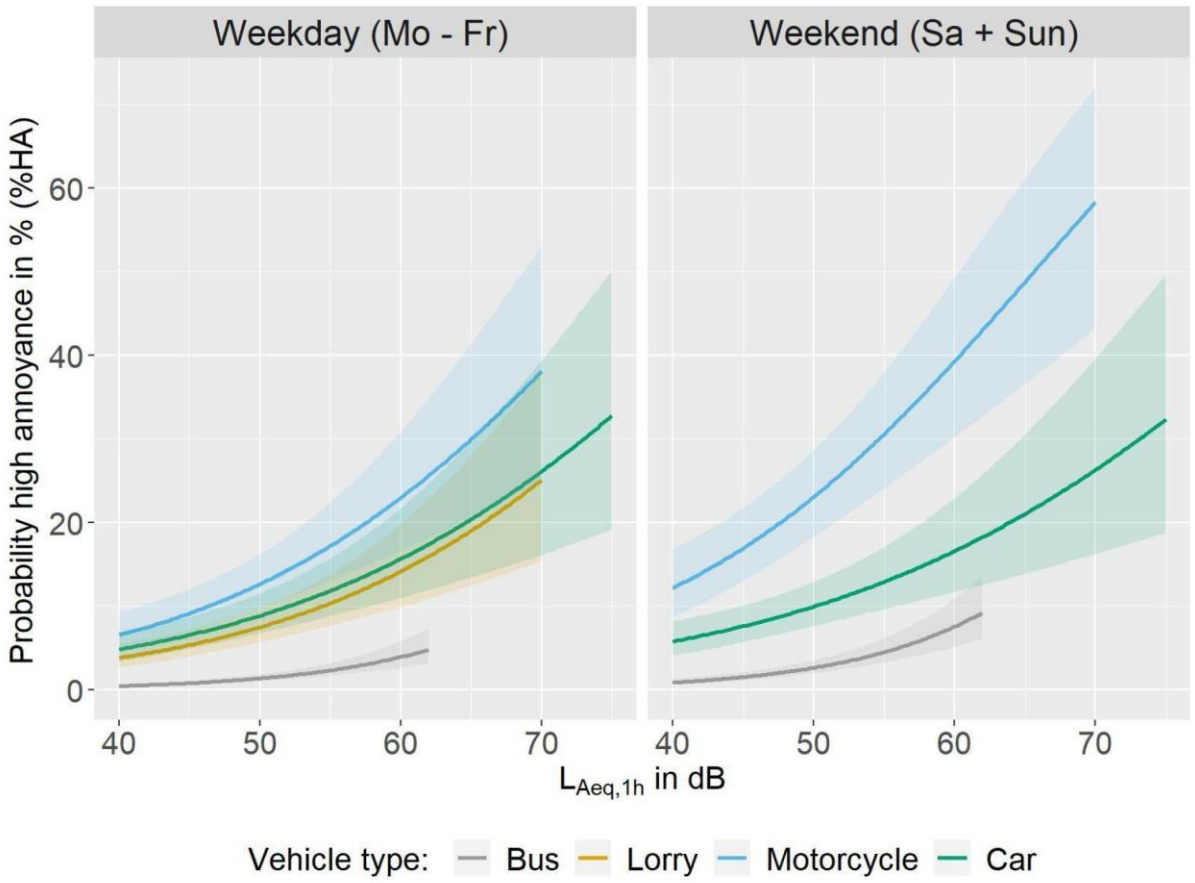

Figure 4: Exposure-response relationship for $L_{Aeq,1h}$ of the vehicle types motorcycle, car, lorry, coach, and %HA_V of the corresponding vehicle types.

In addition, potential differences in motorcycle noise annoyance ratings were investigated throughout the course of the day. Therefore, average hourly motorcycle noise annoyance during the course of the day was controlled for the hourly motorcycle noise levels (see Figure 5), in that the effect of the noise level was controlled in the results. Accordingly, the curves show the effect of motorcycle noise for certain times of the day when the noise level is kept the same. Annoyance ratings during the day were found to be higher for specific times of the

day, e.g. peaks were found around lunchtime (12-13 pm) and during the afternoon (14-15 pm and 16-17 pm). Similarly, annoyance levels were higher in the afternoon time at the weekends with generally higher average annoyance levels. Motorcycle noise annoyance judgments further differed depending on the whereabouts of a person: On both weekdays and weekends, the annoyance caused by motorcycle noise when staying outside during the day is significantly higher than the curve of motorcycle noise annoyance when staying inside, with one exception (weekdays before 10 a.m.).

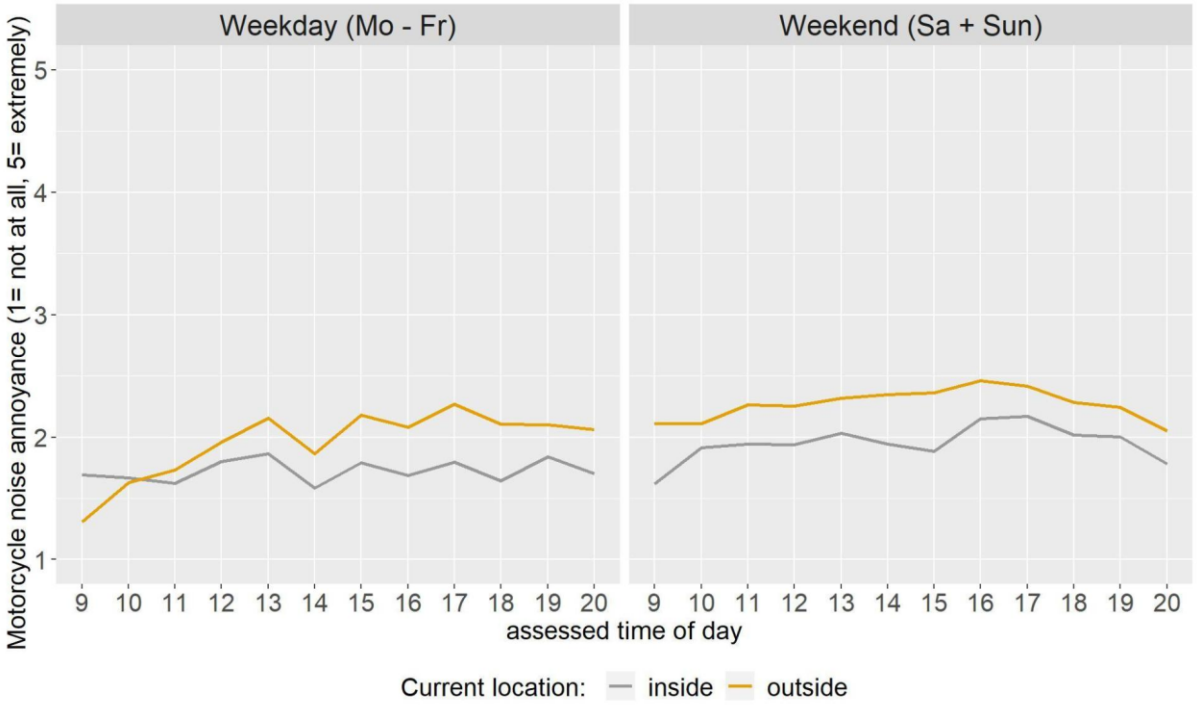

Figure 5: Average hourly noise annoyance due to motorcycle noise at the same hourly noise level over the course of the day

After the final assessment of the day, noise annoyance was assessed referring to the whole day. An analysis was calculated to investigate if the whole day motorcycle noise annoyance judgment was determined by recent events. Therefore, correlations were calculated between final motorcycle noise annoyance judgments referring to the whole day and all single hourly motorcycle noise annoyance judgments as well as exposure variables $L_{Aeq,1h}$ (for each 1-h judgement and maximum, arithmetic and energetic means of the day). Figure 6 shows the correlations. 'Recency1' is the most recent judgment (7 or 8 pm), 'recency2' is the second recent judgment (5 or 6 pm) and counting back until 'recency6' corresponding to the first measurement points (9/10 am).

Daytime annoyance due to motorcycle noise is highest correlated with the two most recent hourly annoyance ratings (Recency1_Annoy r_{rm}=.57, Recency2_Annoy r_{rm} =.57). Strength of the correlations between whole day judgement and single-hour annoyance ratings decreases with increasing time span between the whole day assessment and the hourly assessment. Regarding correlations with noise exposure, the motorcycle noise annoyance judgement for the whole day was observed to be highest correlated with the energetic means of the 1-h Leq measures (r_{rm}=.31).

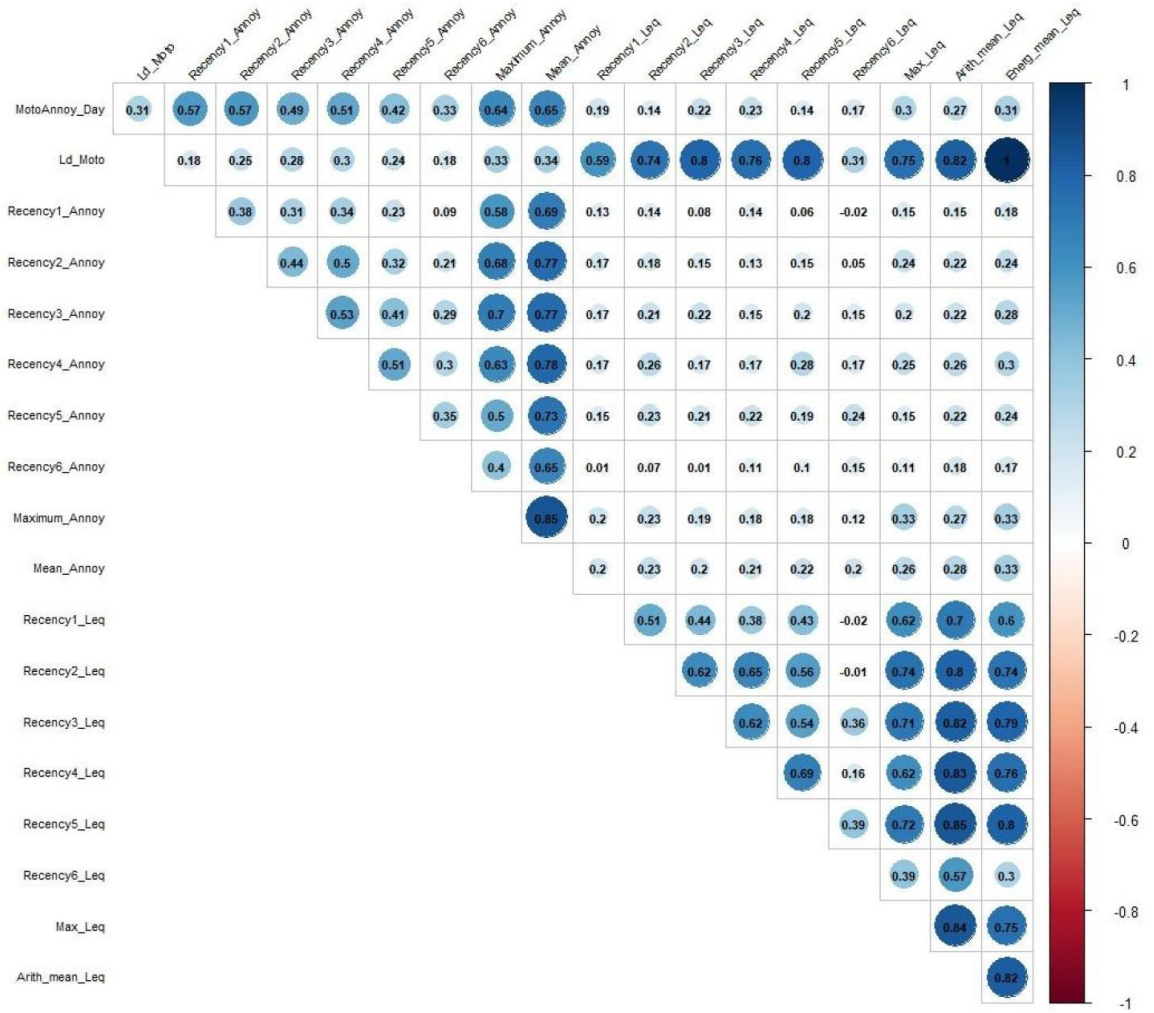

Figure 6: Correlations between average motorcycle exposure, single hourly exposure measurements and annoyance variables investigating for recency effects

DISCUSSION

The present study investigating short-term noise annoyance from motorcycle noise at busy routes in southwest Germany discovered noise from motorcycles are significantly more annoying compared to noise from other road vehicles. Results of the short-term study with source-specific exposure measures confirm results observed in the long-term study where only overall road traffic noise exposure was available[6,7]. Further, results are in line with results from few other existing studies focusing on motorcycle noise, as Lechner and Schnaiter also reported higher annoyance rates due to motorcycle noise in comparison to other road traffic sources[1,2]. One explanation could be the acoustical properties related to motorcycle noise, that differ from other road traffic vehicles, e.g. single events are often audible. As reported by Schreckenberg and colleagues[6], participants in the first study part of the Motorcycle Noise Study Baden-Württemberg pointed out certain aspects and characteristics of motorcycle traffic to be specifically annoying, such as high revolutions while accelerating.

Short-term judgments throughout the day allow for acute tracking of the perception regarding (motorcycle) noise. The observations of motorcycle noise annoyance at different times of the day showed increased annoyance rates at weekends and during the afternoon. Weekends and specific times of the day tend to be more critical for higher annoyance and disturbance rates. It can be assumed that during afternoons and weekends, there is a higher need for rest

and relaxation in the population, and people might anticipate quiet times. This may certainly also be related to the activities performed during critical times, such as meals, recreational activities or the mere mindset of an "after-work time". These demands can collide with higher numbers of motorcycle events at specific times of the day (afternoons and weekends).

Low correlations were found between short-term noise annoyance ratings and hourly motorcycle noise exposure variables. Literature indicates that noise annoyance is not only determined by noise levels but also varies with non-acoustic factors[13,14,15,16]. Regarding motorcycle noise, higher annoyance rates can further reflect the associated evaluation of noise as a socially caused disturbance. Man-made noise is often considered inconsiderate, avoidable/preventable and unnecessary. Noise from motorcycles is highly dependent on the driving mode of a motorcycle driver. It can be assumed that people not just perceive the audible sound of the noise source or the motorcycle but perceive the behaviour that causes the sound. Therefore, reckless driving is audible behaviour which influences noise perception. Then, noise is not a mere physical problem; it is a social problem. In that context, Stallen referred to it as "you expose me" [17].

CONCLUSION

The MotoApp study investigated the impact of motorcycle noise on the local population living along popular motorcycle routes in Baden-Württemberg. It was found that motorcycle noise is perceived as annoying, especially on weekends and in the afternoon hours, presumably also related to the current location of the participant and performed activities in the respective hour. In particular, the increased annoyance at certain times during the week and on weekends indicates an increased demand for peace and quiet on the part of the resident population of motorcycle routes. Results indicate that temporal and spatial limitations for motorcycle traffic could decrease/lower noise annoyance due to motorcycles.

Acknowledgements

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