Humming and Buzzing
Acoustical Features of Annoying Mosquito Noises

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Introduction

Mosquitoes can transmit diseases like malaria or dengue and are difficult to monitor due to their tiny sizes ranging from 3-15 millimeters, depending on the species [1]. A method of documenting the population and occurrence in special areas is the acoustical analysis of species-specific wing beats, which allows a rough interpretation of species and sex [2]. In Germany and Austria, mainly the species Culex Pipiens is native and widespread [3].

For humans and animals, only the bigger, female mosquitoes are dangerous as they are the only ones sucking blood. With their wings, females produce a buzzing sound of around 300-400 Hz, while the wing frequency of male mosquitoes is above 600 Hz [2; 4]. These differences in pitch range can help to estimate the bite ability of mosquitoes. For example, a free online tool [5] allows recording any mosquito noise and roughly recognizes from signal composition, if it‘s a biting, female mosquito or not:

Research Question

Until now, there’s no study that examines specifically the sound of mosquitoes and if how buzzing sounds are perceived in humans. This study therefore investigates:

Which timbre characteristics are responsible for mosquito buzzing being considered annoying and dangerous?

Method and stimuli

15 buzzing sounds with length between 4 and 6 s were taken from the Boom and the Blastwave FX library, and equalized in loudness (26.6 sone).

These stimuli were rated in an online questionnaire on the two scales annoyance [not annoying – really annoying] and estimated bite probability [0-100%]. 59 participants‘ (26♂, 31♀, 2⚥; aged 18-80; Ø: 40 years) assessments were evaluated. Besides rating buzzing sounds, sociodemographic data and attitudes towards general annoyance of mosquitoes, as well as frequency and fear of mosquito bites were collected.

Results

The estimated bite probability is related to the rated annoyance ($r = 0.939$, $p < 0.001$). Bite probability ratings are influenced by participants‘ general rated mosquito exposure in everyday life, with frequently or constantly stung individuals assigning higher probabilities ($t_{(57)} = 3.310$; $p < 0.001$).

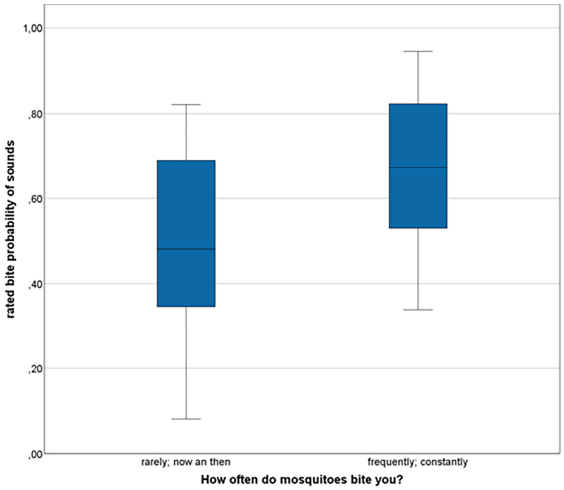

Figure 1: Differences in rated bite probability by experienced stung frequency of participants ($p < 0.001$).

Sound composition

Addressing timbre characteristics of buzzing, estimated annoyance and bite probability of buzzing sounds correlate with…

- the minimum pitch of the sound
  ($r_{annoy} = 0.828$, $p < 0.001$; $r_{bite} = 0.940$, $p < 0.001$).
- the strength of the first partial
  ($r_{annoy} = 0.539$, $p = 0.038$, $r_{bite} = 0.770$, $p < 0.001$).
- the roughness (according to Vassilakis)
  ($r_{annoy} = -0.531$, $p = 0.042$, $r_{bite} = -0.607$, $p = 0.016$).
- the frequency modulation hub
  ($r_{annoy} = -0.661$, p 0 0.007).

Minimum pitch of the sound means the lowest mosquito humming pitch that could be measured in the respective sound sample. The strength of the first partial, is collected by cutting all partials included in one signal and calculating how much of the overall signal's energy falls on the first partial. Roughness according to Vassilakis means summing the dissonance contributions of all pairs of sinusoidal components in a sound, weighted by their amplitude product and a function of their frequency separation (peaking around 1/4 of the critical bandwidth). The frequency modulation hub finally describes the extent or strength of a frequency modulation.

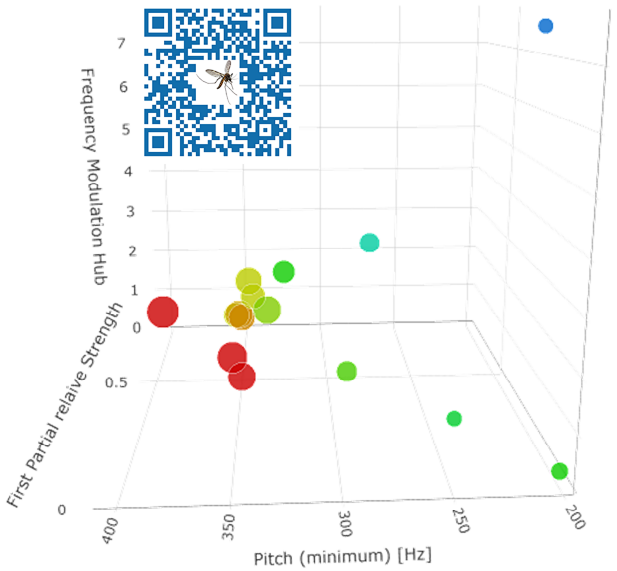

Figure 2: Audio features that are connected to the annoyance of mosquito buzzing: the redder the dots, the more annoying the mosquito buzzing was perceived to be; the estimated likelihood of being bitten rises with the size of the dots. (Interactive plot at: https://muwiserver.univie.ac.at/gnats)

Based on these main findings regarding the sound components, a linear regression model for perceived "annoyance" of tested subject was trained and tested using the holdout method, which shows a fit of $R^2 = 0.968$ (test set: $R^2 = 0.836$). All of the three variables significantly contribute to the model ($p < 0.001$).

Annoyance =
1.643 · pitch (min) - 1.096 · first partial strength
- 0.461 · frequency modulation hub

Differences in age and gender

Interestingly, the estimation of how often someone is generally bitten by mosquitoes depends on age, a connection which has already been studied with different outcomes [6]. In this study, comparing younger subjects (≤ 40 years) estimation of mosquito bites in general and those of older participants shows that younger people experience being stung more frequently ($t_{(57)} = 2.992$; $p = 0.004$).

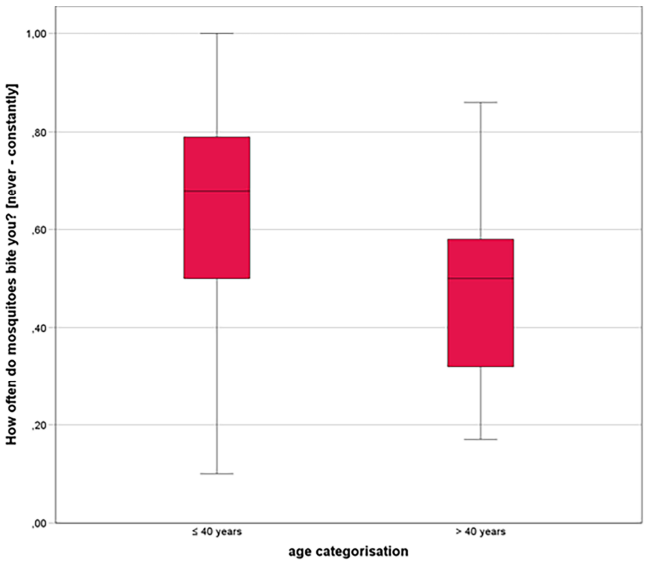

Figure 3: Estimated general frequency of being stung by mosquitoes [never – constantly] in terms of younger (≤ 40 years) and older participants (> 40 years).

Analyzing subgroups of ratings, there's also a significant effect of age, where in mentioned younger listeners, in addition to pitch ($r_{annoy} = 0.805$, $p < 0.001$) and the strength of the first partial ($r_{annoy} = 0.566$, $p = 0.028$), the absence of roughness ($r_{annoy} = -0.544$, $p = 0.036$) in sounds seems to be related to stronger annoyance perception.

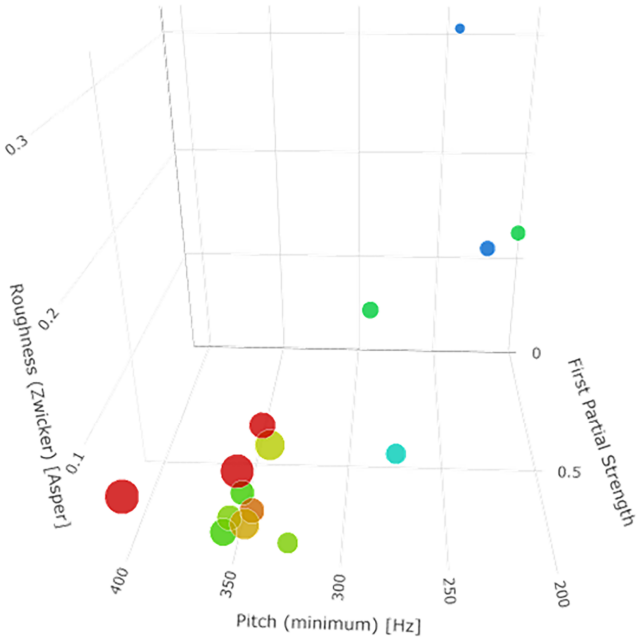

Figure 4: Audio features that are related to the annoyance of mosquito buzzing for **younger listeners**: the redder the dots, the more annoying the mosquito buzzing was perceived to be; the estimated likelihood of being bitten rises with the size of the dots. (Interactive plot at https://muwiserver.univie.ac.at/gnats/young)

Looking at gender of participants, less dynamic complexity of heard buzzes plays a further and significant role in stronger annoyance ratings of 31 female listeners (r_{annoy} = -0.584, p = 0.022).

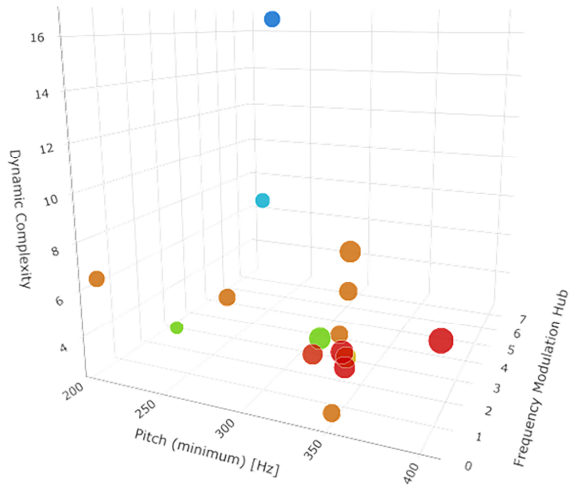

Figure 5: Audio features that are related to the annoyance of mosquito buzzing for **female listeners**: the redder the dots, the more annoying the mosquito buzzing was perceived to be; the estimated likelihood of being bitten rises with the size of the dots. (Interactive plot: https://muwiserver.univie.ac.at/gnats/female)

Limitations and Conclusion

Both the annoyance of mosquito buzzes and the estimated bite probability can be determined by the pitch, the frequency modulation hub and the strength of the first partial. Due to the small stimuli set of 15 sounds, this finding needs further research to validate the results from this online study.

References

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