Abstract

This term paper presents an exploratory analysis of the Lombard effect, focusing on changes in vocal output under varying background noise conditions. The experimental data were collected as part of a group project during the 10th edition of the Bioacoustics Winter School held at Jean Monnet University, where the author participated in the design and execution of the data collection protocol alongside other group members.

The present work does not claim full credit for data acquisition. Instead, it isolates and documents the author's individual contributions, which include post processing of the recorded speech signals, extraction of acoustic metrics using Audacity, implementation of custom Python scripts for data analysis and visualization, and independent interpretation of the observed trends. All figures, analyses, and observations presented in this paper apart from the raw data collection were produced by the author.

The study demonstrates a clear increase in vocal intensity with increasing background noise when analysed relative to individual baselines, consistent with the Lombard effect, while pitch-related changes remain inconclusive under the present experimental conditions. Beyond the specific results, this work emphasizes methodological reasoning, transparency about limitations, and reflective learning from a collaborative experimental setting.

Hypothesis: A human seeking to be located acoustically will increase the intensity of their vocalizations proportionally to the level of ambient noise.

Methodology

To study the Lombard effect, controlled auditory masking was introduced using white noise at varying sound pressure levels (SPL). White noise signals were generated using Audacity and delivered binaurally through over-ear headphones.

Six human subjects participated in the experiment. During each trial, participants were instructed to imagine a listener positioned approximately 5 meters away and to repeatedly vocalize the utterance "ohho" in a continuous manner for 20 seconds.

The masking noise was presented at multiple SPL levels. The order of SPL conditions was randomized for each participant using a random sequence generated in Microsoft Excel to minimize order and adaptation effects.

Participants' vocalizations were recorded using the same microphone and recording setup across all trials to maintain consistency. The recorded speech signals were later analysed using Audacity to extract SPL values, enabling comparison of vocal output levels across different noise conditions.

Limitations

This study is intended as an exploratory investigation of the Lombard effect under controlled but constrained conditions. The following limitations are acknowledged:

1. **Limited Sample Size**

Only six participants were included in the experiment. As a result, the findings should be interpreted as within subject trends rather than population level conclusions. No statistical inference or generalization is attempted.

2. Absence of Absolute SPL Calibration

The sound pressure levels of the masking white noise delivered through headphones were not calibrated to absolute ear level SPL values. Consequently, noise levels are treated as relative conditions rather than precise physical measurements. The analysis focuses on comparative changes in vocal output across conditions.

3. Use of Imagined Communication Distance

Participants were instructed to imagine a listener positioned approximately 5 meters away. This instruction serves as a psychological standardization cue rather than a physical constraint and may introduce inter subject variability related to perception and imagination.

4. Single Vocal Task and Utterance

The experiment used a single repeated utterance ("ohho") for all trials. While this reduces linguistic and cognitive variability, it limits the generalizability of results to natural speech or varied phonetic content.

5. Broadband SPL Analysis Only

Vocal output was analysed using broadband SPL values. Frequency dependent changes in speech production, which are known to be relevant to the Lombard effect, were not examined in this study.

6. Single Trial per Condition

Each noise level condition was recorded once per participant. This limits the ability to estimate intra subject variability or measurement uncertainty.

7. Fixed Recording Geometry

Microphone position, orientation, and recording environment were held constant, but environmental reflections and room acoustics were not explicitly characterized or modelled.

Results:

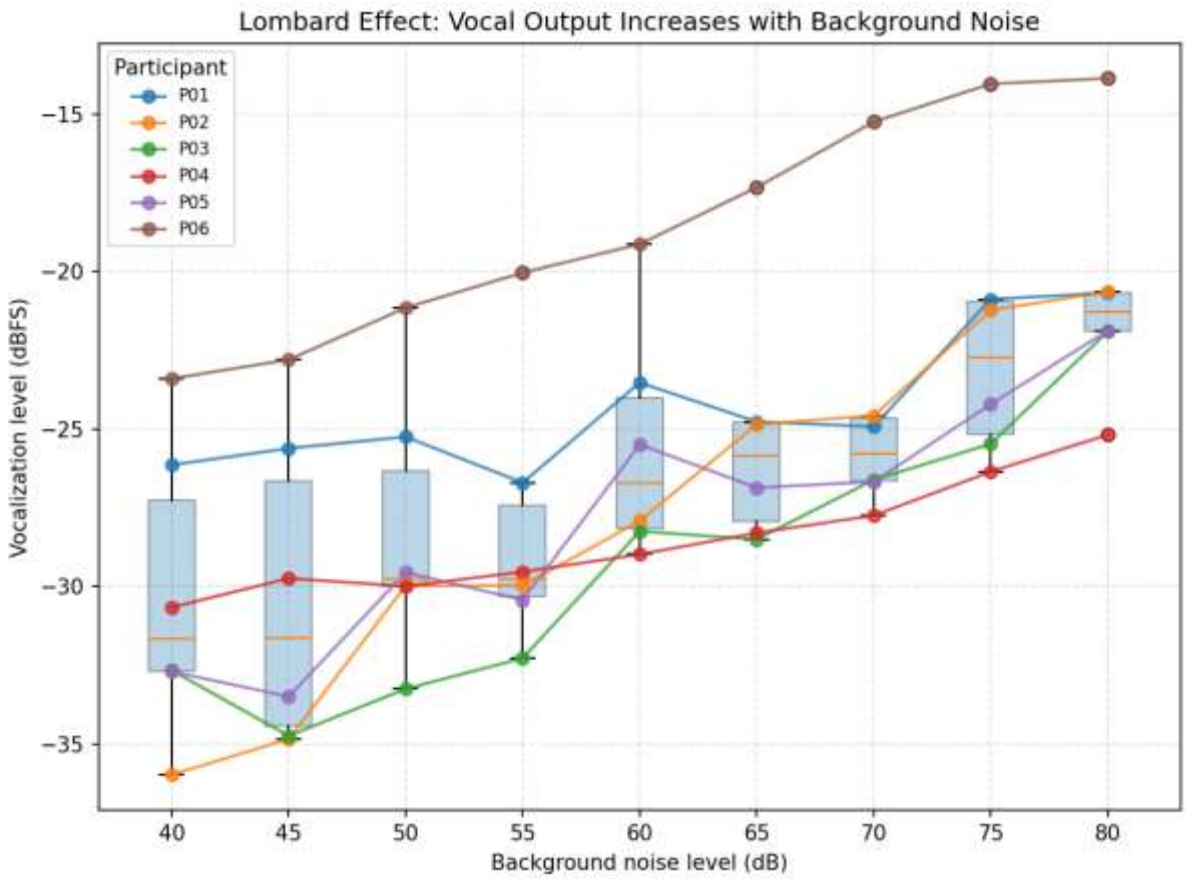

Figure 1: Absolute vocalization intensity

Figure 1 shows vocalization sound pressure levels (SPL) as a function of background noise level for six participants. Across all participants, an overall increase in vocal output is observed with increasing background noise, consistent with the Lombard effect.

At lower background noise levels (40–50 dB), vocalization SPL values are relatively low and clustered within a narrow range for most participants. As background noise increases beyond approximately 55–60 dB, a systematic upward shift in vocal output is observed across all individuals.

While the magnitude of the response varies between participants, the trend of increasing vocalization SPL with increasing noise level is consistent. Some participants (e.g., P06) exhibit a stronger and more monotonic increase across the full noise range, whereas others show a more gradual or variable response at intermediate noise levels. Despite this inter-subject variability, no participant shows a decrease in vocal output with increasing noise.

The box plots illustrate the distribution of vocalization levels across participants at each noise condition. Median vocal output increases steadily with background noise level, and the interquartile range remains relatively stable, indicating that while absolute SPL values differ between individuals, the overall response pattern is shared.

These results demonstrate a clear positive relationship between background noise level and vocal output intensity under the experimental conditions.

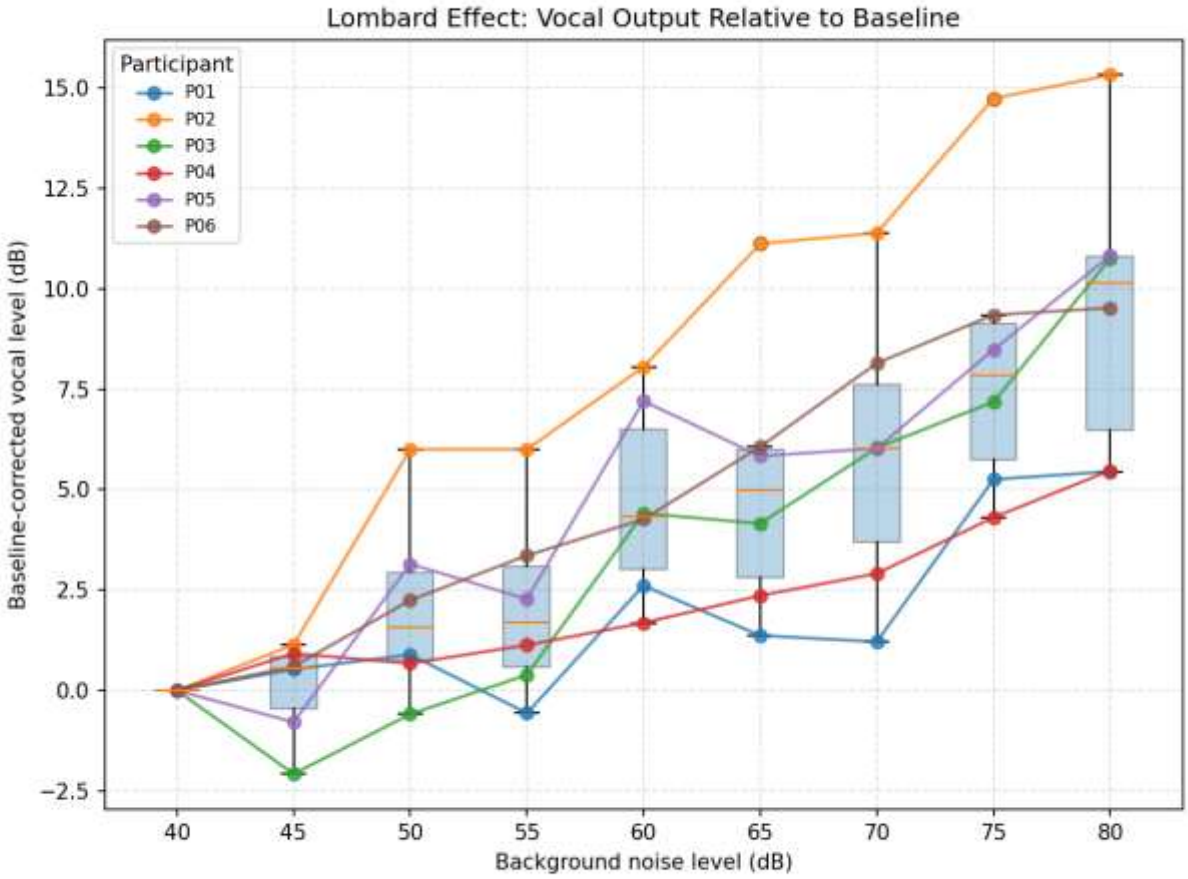

Figure 2: Vocal intensity normalized

Vocal intensity was normalized to a standard baseline (40 dB), highlighting the progressive increase in vocal output with louder background noise levels. While the vocal response varies across participants, all show a positive increase from baseline at higher noise levels.

Figure 2 presents baseline corrected vocal output levels as a function of background noise level for six participants. Vocalization levels are expressed relative to each participant's baseline condition (40 dB), allowing direct comparison of noise-induced changes across individuals.

Across all participants, an increase in vocal output relative to baseline is observed with increasing background noise. At low noise levels (45–50 dB), changes relative to baseline are small and, in some cases, negative, indicating minimal or inconsistent Lombard response near threshold conditions.

A clear divergence from baseline emerges at approximately 55–60 dB of background noise. Beyond this range, all participants exhibit positive increases in vocal output, with the magnitude of the increase growing systematically as noise level rises.

Inter subject variability is evident in the magnitude of the response. Some participants show a steep increase in baseline corrected vocal output at moderate noise levels, while others display a more gradual response. Despite these differences, the direction of change is consistent across participants, with no participant exhibiting a sustained decrease in vocal output at higher noise levels.

The box plots summarize the distribution of baseline corrected vocal output across participants at each noise level. Median values increase monotonically with background noise, and the interquartile range widens slightly at higher noise levels, indicating increased variability in vocal adjustment under stronger masking conditions.

These results demonstrate a robust Lombard effect when vocal output is analysed relative to individual baseline levels, highlighting both a shared adaptive response and individual differences in response magnitude.

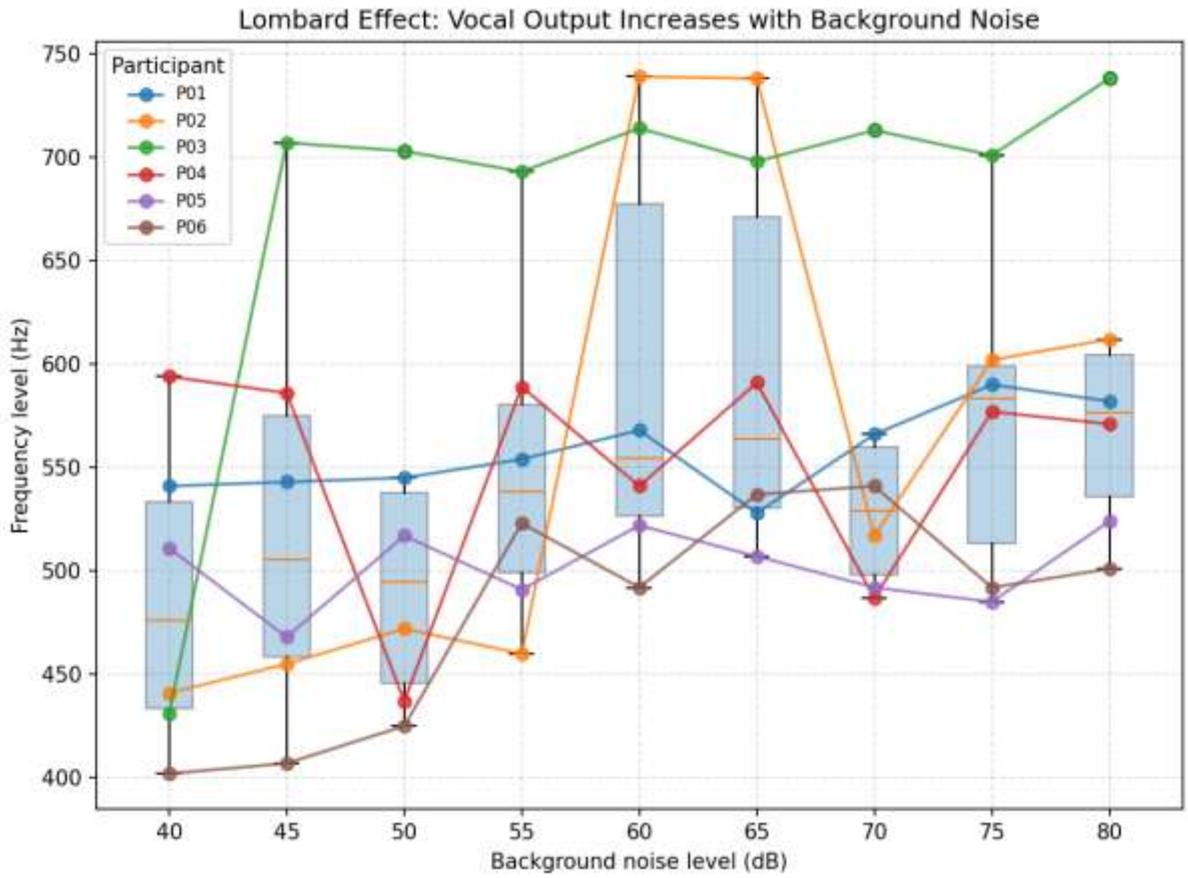

Figure 3: Frequency variation

In addition to vocal intensity, changes in fundamental frequency (pitch) were examined as a function of background noise level. Across participants, no clear or consistent trend in pitch variation with increasing noise level was observed.

Individual participants exhibited small fluctuations in pitch across noise conditions; however, these changes were not systematic and did not show a monotonic relationship with background noise level. In some cases, slight increases or decreases in pitch were observed at intermediate noise levels, but these effects were not consistently reproduced across participants.

When summarized across participants, measures of central tendency showed minimal change in pitch relative to baseline, and inter subject variability remained comparable across noise conditions. This contrasts with the robust and systematic increase observed in vocal intensity.

These results suggest that, under the present experimental conditions, vocal intensity was the primary adaptive response to increasing background noise, while pitch adjustments if present were weak or highly variable.

Future Work

Future extensions of this study could expand both the experimental scope and analytical depth. Increasing the number of participants would allow for statistical characterization of inter subject variability and enable investigation of population level trends. Stratifying participants by age and gender could further clarify whether demographic factors influence the magnitude or onset of the Lombard response.

In addition, the spectral characteristics of the masking noise could be systematically varied. Rather than broadband white noise alone, future experiments could examine the effects of band-limited noise or pitch shifted masking signals to assess frequency-specific vocal adaptations. Such an approach may be particularly relevant for investigating pitch related responses, which were not clearly resolved in the present study.

Methodological improvements could include calibrated sound delivery, frequency resolved analysis of vocal output, and repeated trials per condition to estimate uncertainty. Together, these extensions would enable a more complete characterization of the Lombard effect while building upon the exploratory framework established here.