Time of exposure for a reliable pupil dilation response to unexpected sounds

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INTRODUCTION

Pupil diameter response (PDR) can serve as a measure of auditory attention and potentially as an additional measure of hearing threshold (HT). While individual measure of HT requires an adaptive stepwise procedure, the overall trend in PDR to sounds at different intensities can be observed in a non-adaptive passive listening test. Both pediatric and adult groups were tested with the same procedure, and adult data are used here to explore:

- how much exposure is needed to reliably observe this difference at a comfortable levels of intensity,
- how reliable is the measure of PDR in individuals at various intensity levels, and
- whether we can observe systematic differences in the response to the different types of speech and non-speech sounds, and between the discrimination and detection paradigms.

METHODS

Participants:
We observed the PDR during passive listening at different intensities in three groups of young adults (N = 36, ME = 27 years, DS = 4.1, 22 females).

Procedure (Figure 1):
In Experiments 1a and 1b, participants listened to warble tones and speech stimuli (ling-6-sounds) in the discrimination test. In Experiment 1c participants listened to warble tones in a detection test.
The cluster-based statistic using the permuted likelihood ratio tests was used to assess the time windows of the PDR.

Analysis:
The difference between standard and deviant trials per participant were used to model the PDR as a function of intensity.
We performed a series of linear discriminant analyses (LDA), to determine the function that best separates the two types of trials. The quality of predictions of the LDA model was measured through the non-parametrical ROC analysis for the overall representation of true (sensitivity) and false positive (specificity) rates.

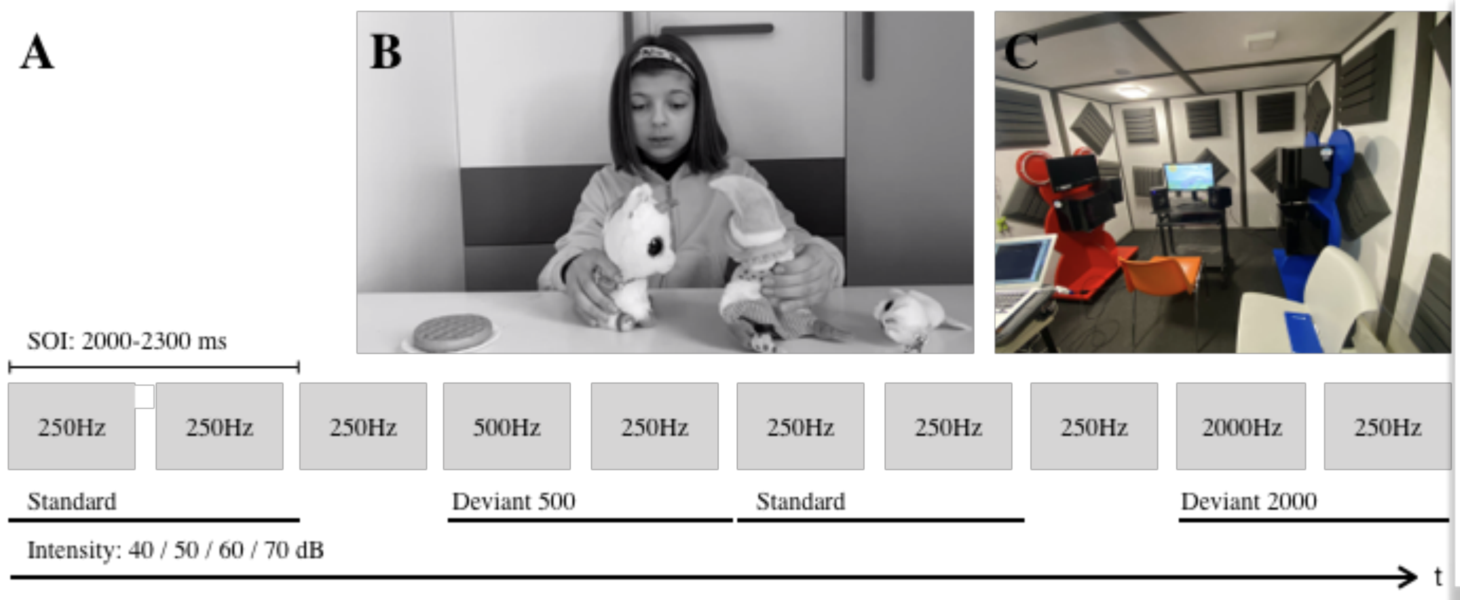

Figure 1. A The pictogram of the experimental procedure and stimuli in Experiment 1a. B The video shot presented on the screen. C The photo of one of the four experimental setups. In Experiment 1b, the setup and visual stimuli were the same, whereas auditory stimuli were the 6-ling sounds instead of the warble tones. In Experiment 1c, the setup and visual stimuli were the same, except that the 250 Hz tones were replaced by silence periods.

RESULTS

In all groups, the augmented PDR was significantly associated with deviant sound stimuli.

The average timeline of the PDR response is presented in **Figure 4**.

When the lowest intensity level is excluded, the effect of intensity is significant in Experiments 1a and 1c (**Figure 2**).

At 70 dB, reported as comfortable by all participants, reliable model predictions with high test accuracy were obtained regardless of the amount of trials analysed in **Experiment 1a** (0.60 < sensitivity < 0.76; 0.61 < specificity < 0.75, 0.61 < PPV < 0.76) and **Experiment 1c** (0.73 < sensitivity < 0.86; 0.59 < specificity < 0.82, 0.68 < PPV < 0.83). In **Experiment 1b,** the most reliable model predictions were achieved when all trials in the intensity block were analysed (sensitivity = 0.82, specificity = 0.60, PPV = 0.71). For all intensities see **Figure 3**.

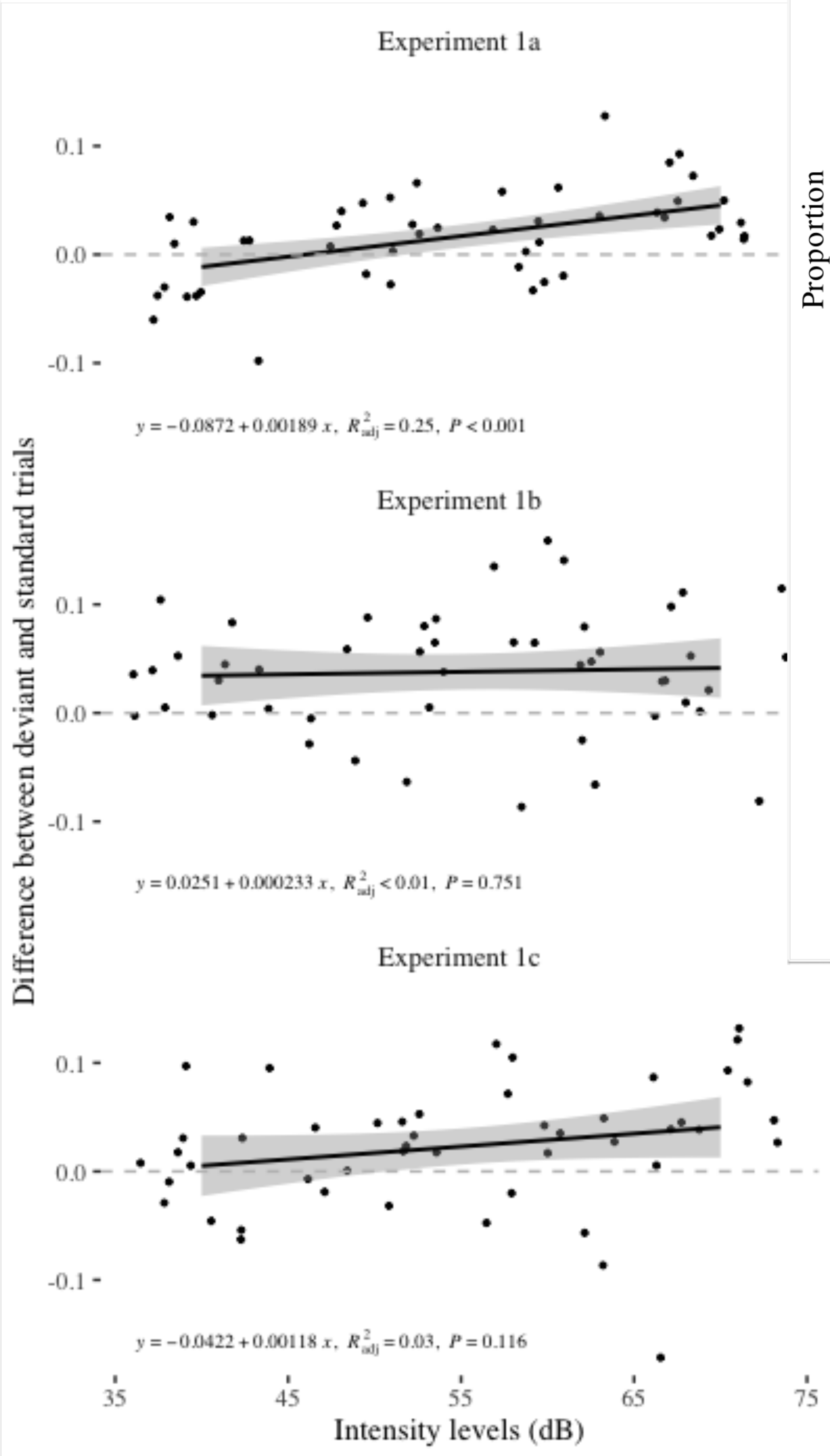

Figure 2. Each point represents the PDR difference between deviant and standard trials per participant per intensity in Experiments 1a-1c. The equation, adjusted R², and p-values are displayed below the regression lines

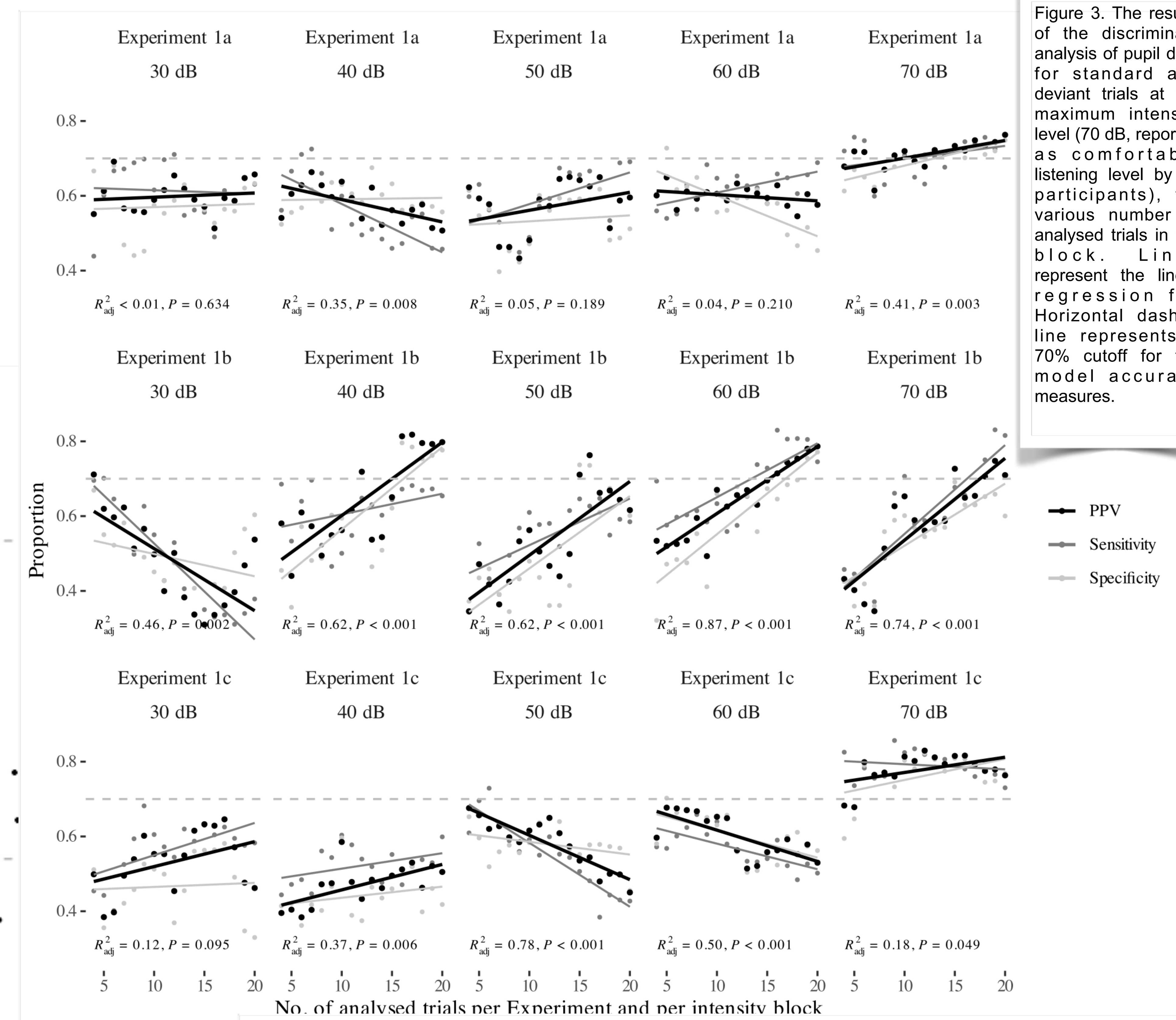

Figure 3. The results of the discriminant analysis of pupil data for standard and deviant trials at the maximum intensity level (70 dB, reported as comfortable listening level by all participants), for various number of analysed trials in the block. Lines represent the linear regression fit. Horizontal dashed line represents a 70% cutoff for the model accuracy measures.

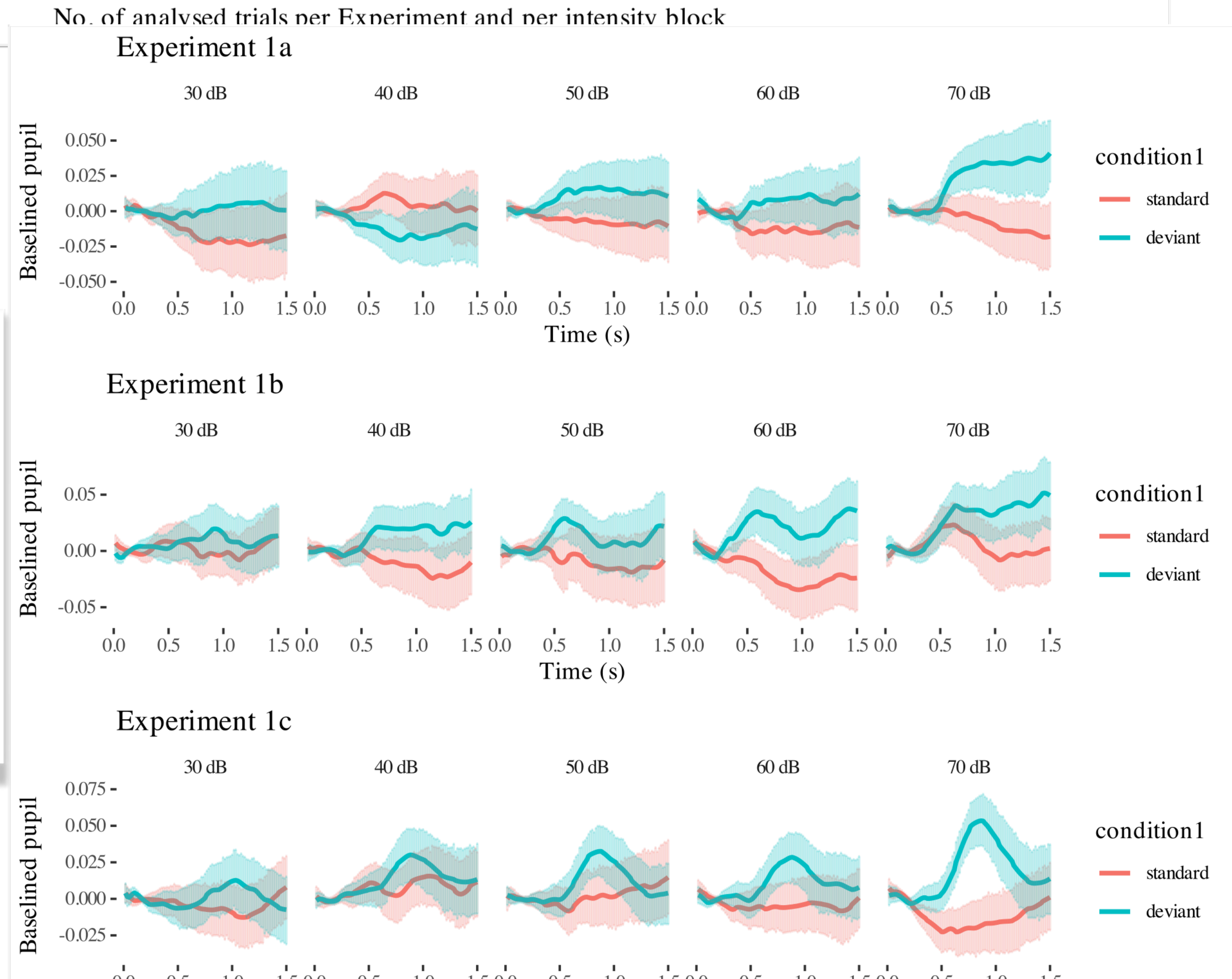

Figure 4. The average timeline of the PDR during the 1500ms post stimulus onset at the 70 dB intensity level for both experiments, when all 20 trials in the block are analysed. Vertical lines represent confidence intervals.

CONCLUSIONS

The minimal amount of exposure to tone and speech stimuli at the comfortable hearing level needed to fit a classification model and to reliably predict the performance in individual participants was measured.
This represents the necessary step in creating the PDR based adaptive procedure with which auditory attention at different audibility levels can be measured. We also show that the PDR does not only depend on the general type of the deviant sound (speech, noise, tones): not all deviant speech sounds or tones elicit the same type of PDR.

LITERATURE

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