Efficient parameter-based estimates of auditory filters

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Introduction

The estimation of the auditory filter shape is time-consuming, making routine estimates difficult. A rapid “parameter-based” Bayesian adaptive procedure is proposed tested. Rather than estimating thresholds and then fitting the data to a model, the model parameters are directly estimated. The proposed computational procedure has the potential for the rapid estimation of psychophysical and physiological functions that can be parametrically defined.

Computational Procedure

The approach draws from Kontsevich and Tyler (1999) and parallels the development by Lesmes et al (2006). The goal is to estimate the parameters of the roex(*r*,*p*) auditory filter via the power spectrum model of masking (Patterson et al, 1982). The result is the qAF (quick Auditory Filter) procedure.

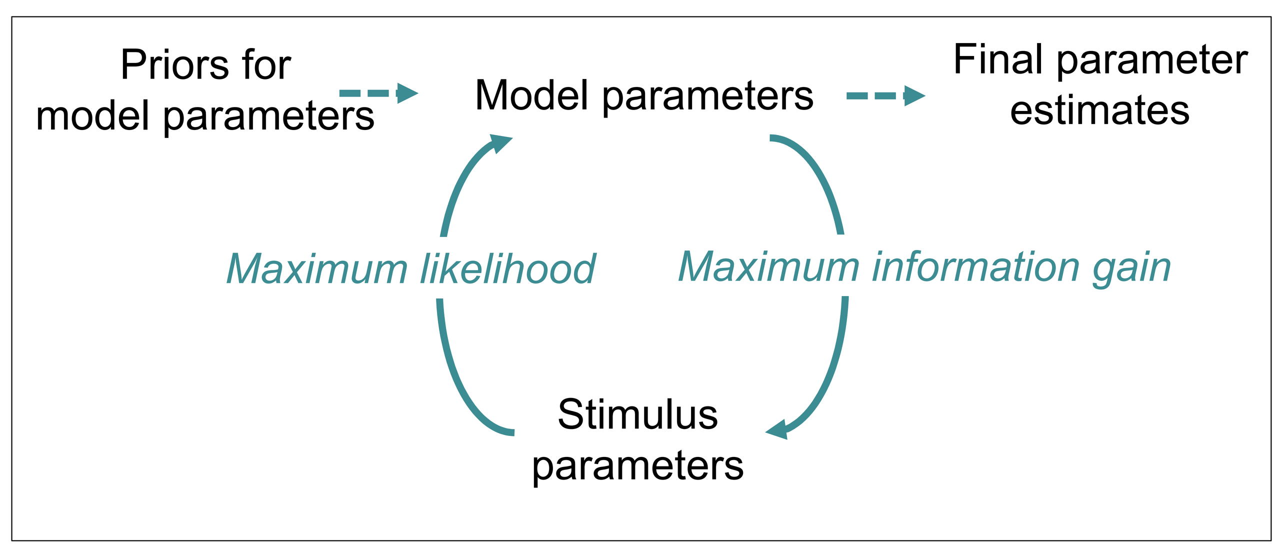

Figure 1: Schematic of qAF procedure.

•Stimulus space: The values of signal levels and notch bandwidths (2-D space) available for testing.

•Parameter space: The range and gradation of parameters *p*, *r*, and *K* associated with the auditory filter shape and the power spectrum model of masking. Prior distributions for these parameters may be defined.

•Psychometric function: *Links* the stimulus space and the parameter space.

•After trial *n*, based on past stimuli and past responses, choose the best estimate of parameters *p*, *r*, and *K*.

•For that current estimate of the model, the test stimulus (signal level and notch bandwidth) for trial *n+1* is the stimulus that provides the most information about parameter estimates (one-step-ahead search algorithm with entropy-based criterion).

References

Kontsevich, L.L. and Tyler, C.W. (**1999**). “Bayesian adaptive estimation of psychometric slope and threshold,” Vis. Res. **39.**

Lesmes, L. A., Jeon, S.-T., Lu, Z.-L., Dosher, B. A. (**2006**). “Bayesian adaptive estimation of threshold versus contrast external noise functions: The quick TvC method,” Vis. Res. **46.**

Patterson, R.D., Nimmo-Smith, I., Weber, D. L., and Milroy, R. (**1982**). “The deterioration of hearing with age: Frequency selectivity, the critical ratio, the audiogram, and speech threshold,” J. Acoust. Soc. Am. **72.**

Function to be estimated	roex(*p*,*r*) Auditory Filter
Stimulus parameters	Level of the signal tone Masker notch bandwidth
Model parameters	Filter slope: *p* Dynamic Range *: r* efficiency: *K* ➔ AF bandwidth: ERB

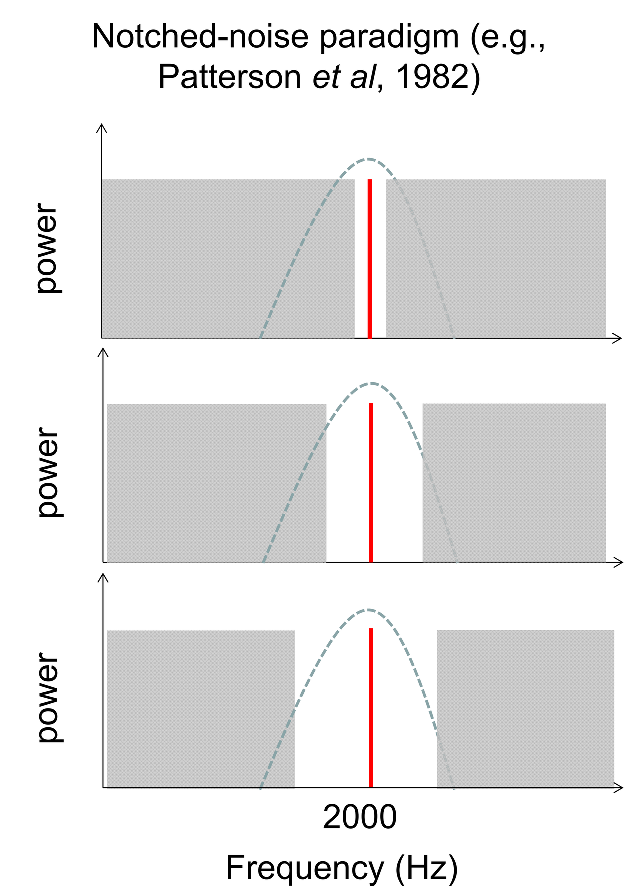

Figure 2: The stimulus and model parameters are listed in the left panel. The task is to detect a target tone (red) added to maskers with different notch bandwidths (gray; right panels). The dashed line is the assumed auditory filter.

Experiment 1: Evaluation of qAF procedure

Psychophysical Procedures

•Stimulus Space: The signal frequency was 2000 Hz. A wide range of signal levels and notch bandwidths of 100, 200, 400, 800, and 1200 Hz could be tested.

•Parameter Space: Values of *p* (related to the bandwidth) ranged from 10-40; *K* ranged from 0.2-2; and values of *r* were 0 and $1X10^{-5}$ to $1X10^{-1}$. The slope of the underlying logistic psychometric function was 1.

Results

•The procedure converges quickly, within 150 or so trials (Figure 3).

•The agreement with traditional methods is good, although on occasions (red circle) the agreement was less than one would hope for.

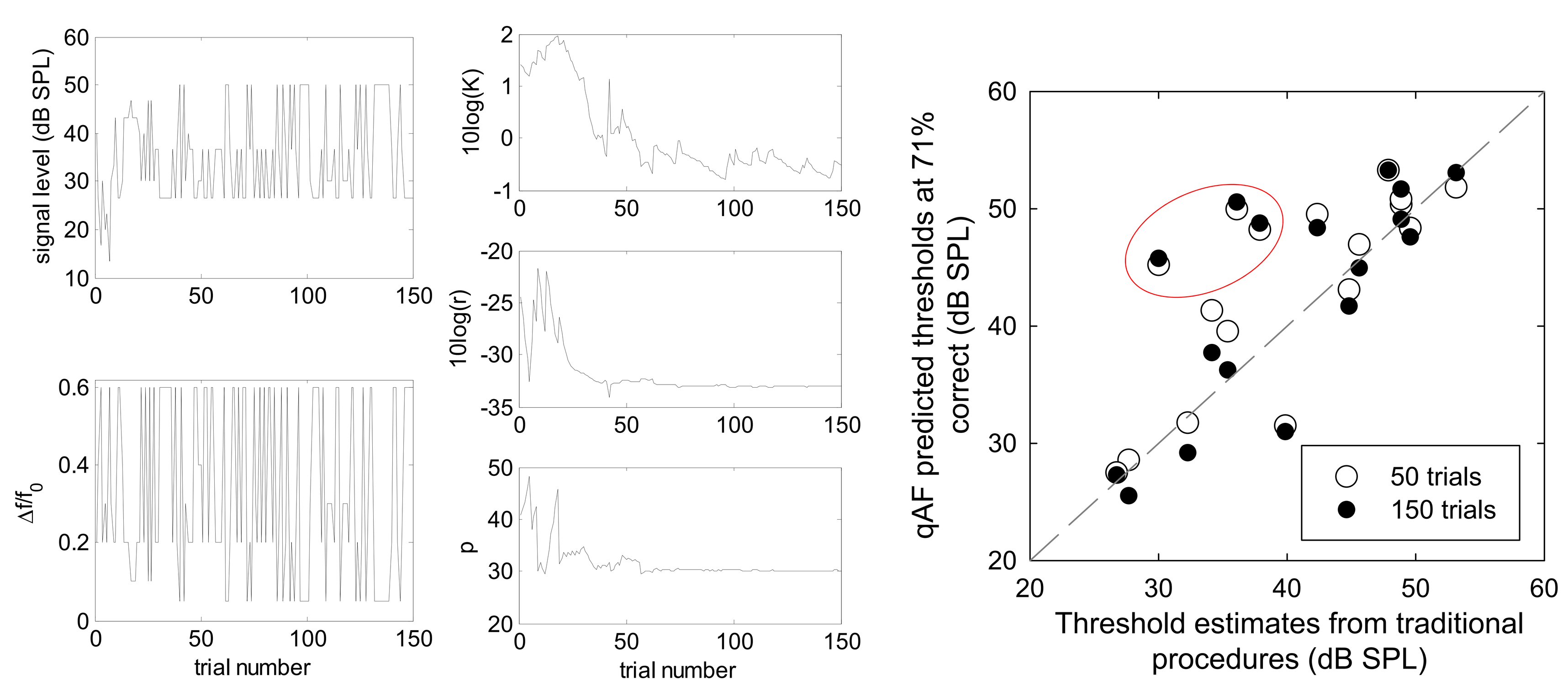

Figure 3: The stimuli tested (left panels) and the parameter estimates after each trial (center panels) are plotted for one listener. The right panel plots threshold estimates from the qAF procedure vs. thresholds estimated using traditional procedures.

Experiment 2: Early Errors

Computer simulations indicated that errors on the first few trials led to biased parameter estimates. A logistic psychometric function with an upper asymptote less than 1 (lapses of attention) reduced the impact of these early errors. Parallel measurements were made in a psychophysical experiment.

Methods

The methods are as in Exp. 1 except (a) regardless of the listeners’ responses to the first three trails, the trials were treated as incorrect, (b) in two conditions a lapse rate parameter (λ) either was or was not estimated for the linking psychometric function. Both well-trained and naïve listeners participated.

Results

•Early errors cause biases in parameter estimation.

•Including a lapse term in the psychometric function reduced these biases, allowing the rapid estimation of the auditory filter bandwidth (as ERB) for young normal-hearing listeners.

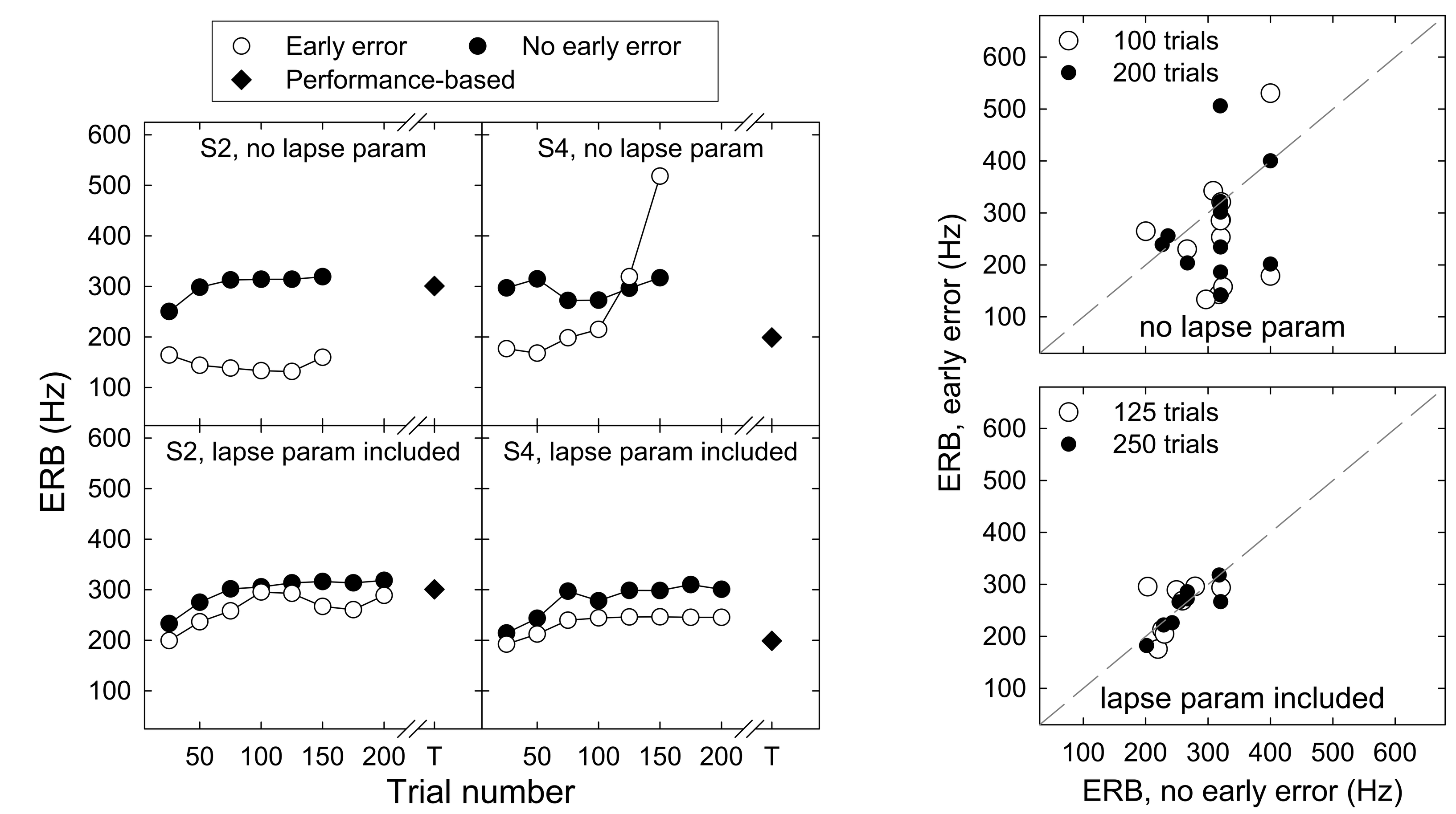

Figure 4. Left: For two trained listeners, estimates of the auditory filter bandwidth (as ERB) when the first three trials either were not (filed circles) or were (unfilled circles) forced to be incorrect. ERB were also estimated using traditional methods (T). For the top two panels no lapse parameter was included in the model and for the bottom two panels a lapse parameter was fitted. Right: The ERB estimates for naïve listeners when the first three trials were forced to be incorrect (ordinate) or not (abscissa). A lapse parameter either was not (top) or was (bottom) included in the model.

Conclusions

•A “parameter-based” Bayesian adaptive procedure was proposed and tested using normal-hearing young listeners. The procedure is an optimal sampling procedure; the experimenter may fit the resulting data using a *post hoc* analyses of choice.

•The procedure was biased when early errors occurred. The inclusion of a psychometric function with a lapse parameter corrected these biases.

•While promising, additional work may be required to adopt the qAF procedure to populations other than young, normal-hearing subjects.