Frequency selectivity measured behaviourally in the ferret using forward masking

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1. Introduction

The ability to resolve the different frequency components of a complex sound, known as frequency selectivity, is quantified by measuring the bandwidths of auditory filters (AF). These can be estimated psychophysically and physiologically. However, how different measurements compare is still debated.

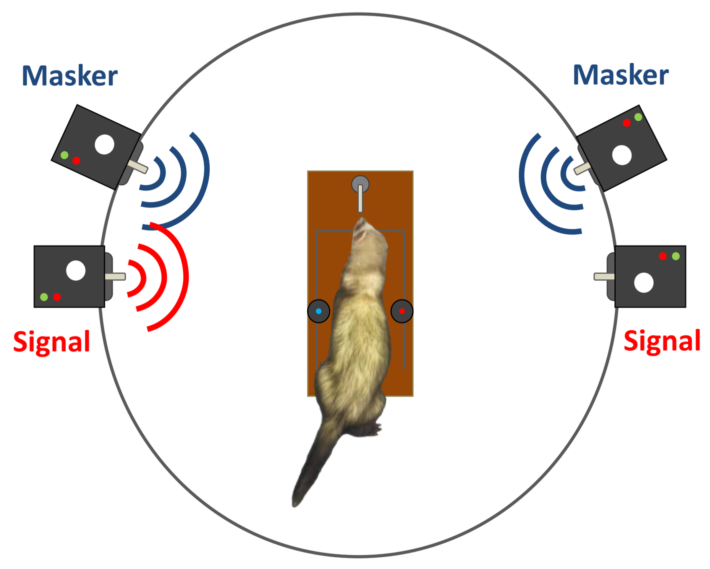
We have made multiple measurements in one species. Here we present a method to flexibly measure AF widths behaviourally using both forward and simultaneous notch noise masking in the ferret.

A preliminary comparison to bandwidth estimates made using auditory nerve (AN) and otoacoustic emission (OAE) data is presented.

2. Methods

- Ferrets were trained to perform a one-interval, two-location discrimination task, in which they had to approach the location of a sound (2s in duration) coming from either the left or right.
- Two speakers placed beside the signal speakers played the masker continuously. The proximity of the speakers ensured the same head related transfer functions (HRTF) for both stimuli.

Figure 1
The behavioural arena.



- Masker is a continuous train of noise bursts, signal a train of 10 narrowband noise bursts.
- Signal bursts can be played in the gaps between masker bursts (out of phase) to measure **forward masking**, or can coincide (in phase) for **simultaneous masking** (figure 2).
- The ferret is not confused by the signal and masker, and not upset by the masker/signal relationship.

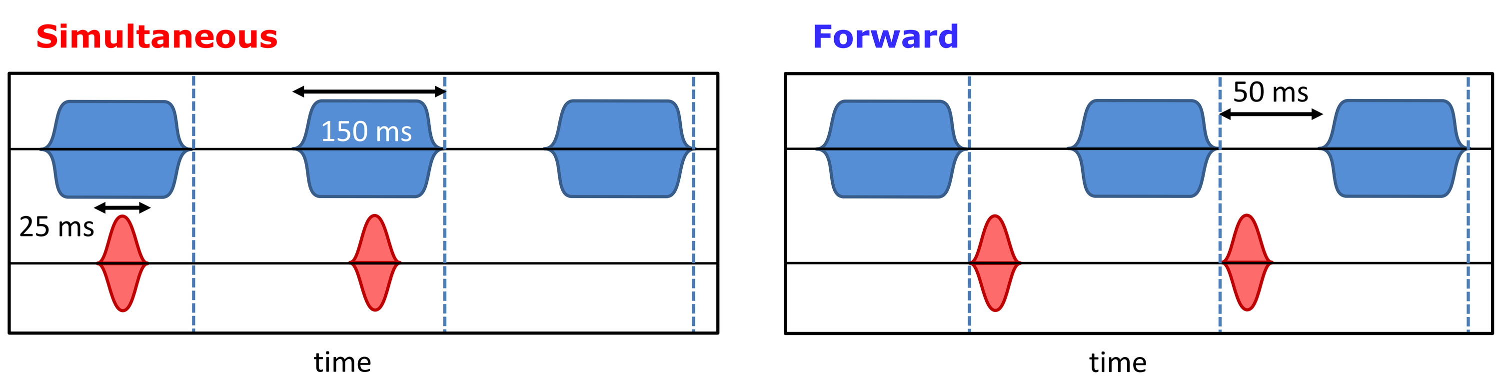


Figure 2
Temporal arrangement of stimuli. Red = signal, blue = masker.

- Temporal characteristics (figure 2) were chosen, to maximise forward masking while keeping the ferret engaged with the task.
- Here, either **signal or masker level was varied**, in the range 0-80dB SPL. The traditional approach is to vary the signal level but recent human experiments vary masker level (Rosen and Baker, 1994).
- **Signal** : 1/32th of an octave around either 1, 3 or 10 kHz.
- **Masker:** 2 bands of Gaussian noise, 0.25 × the signal frequency (SF). Notches were symmetric 0, 0.1, 0.2, 0.3, 0.4 × SF and asymmetric 0.2/0.4 × SF and 0.4/0.2 × SF (Oxenham and Shera, 2003).

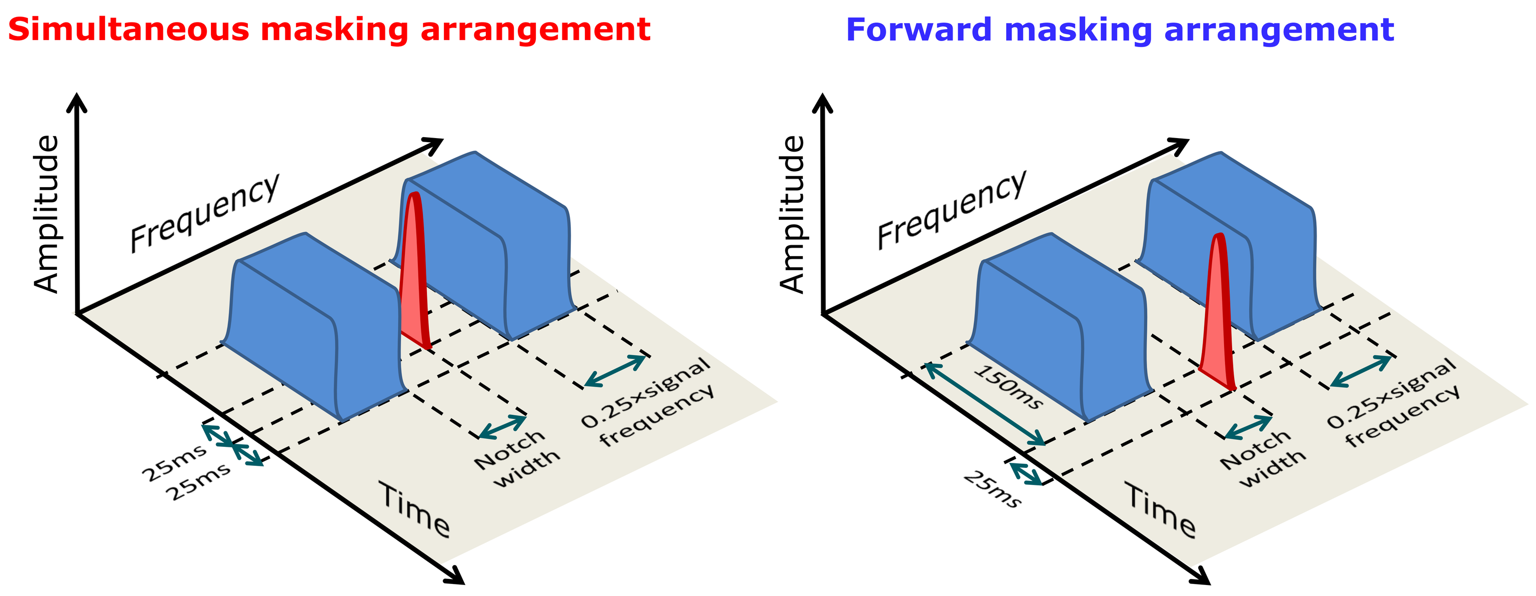


Figure 3 Spectro–temporal properties of stimulus bursts.

Narrow band signal   Masker

3. Data analysis

- $p(c)_{max}$ was calculated, an unbiased measure of proportion correct.
- Logistic functions were fit to each notch condition. Slope of each function was fixed for a given filter measurement.
- Threshold was taken at $p(c)_{max} = 0.75$.
- The roex(p,r) function (with a single parameter governing both slopes) was used to model the auditory filter.
- Bandwidth is measured as the Equivalent Rectangular Bandwidth (ERB).

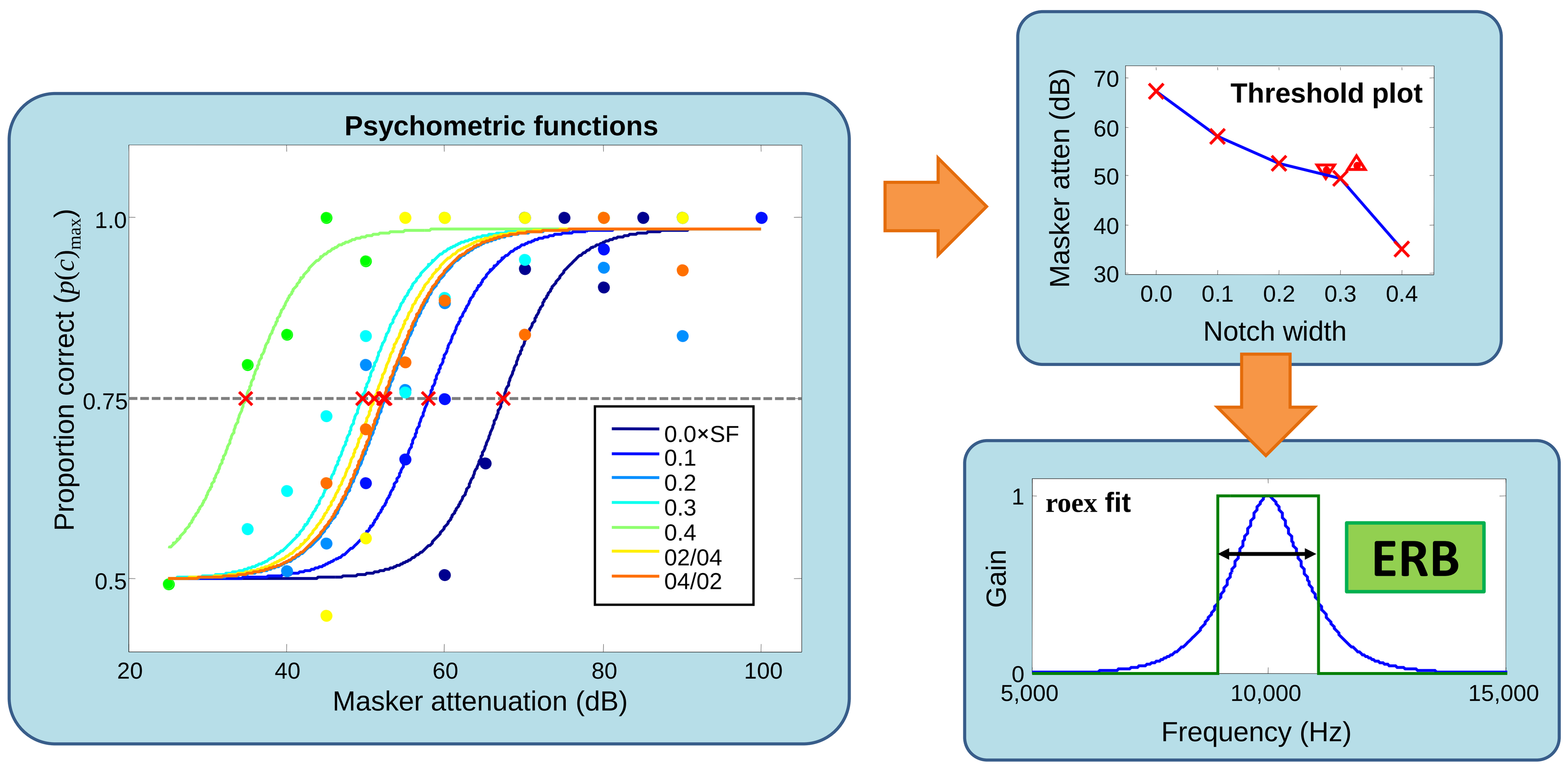


Figure 4 Data analysis to obtain a single bandwidth estimate.

4. Psychophysically measured ERBs

- Linear increase (in log-log space) of ERB with SF.
- **Vary–signal** vs. **vary–masker** level: no significant difference.
- **Forward** vs. **simultaneous** masking: no significant difference (possible trend for simultaneous giving narrower ERBs).
- **New** vs. **traditional** method: no significant difference (potentially broader measurements with new method at 10 kHz).

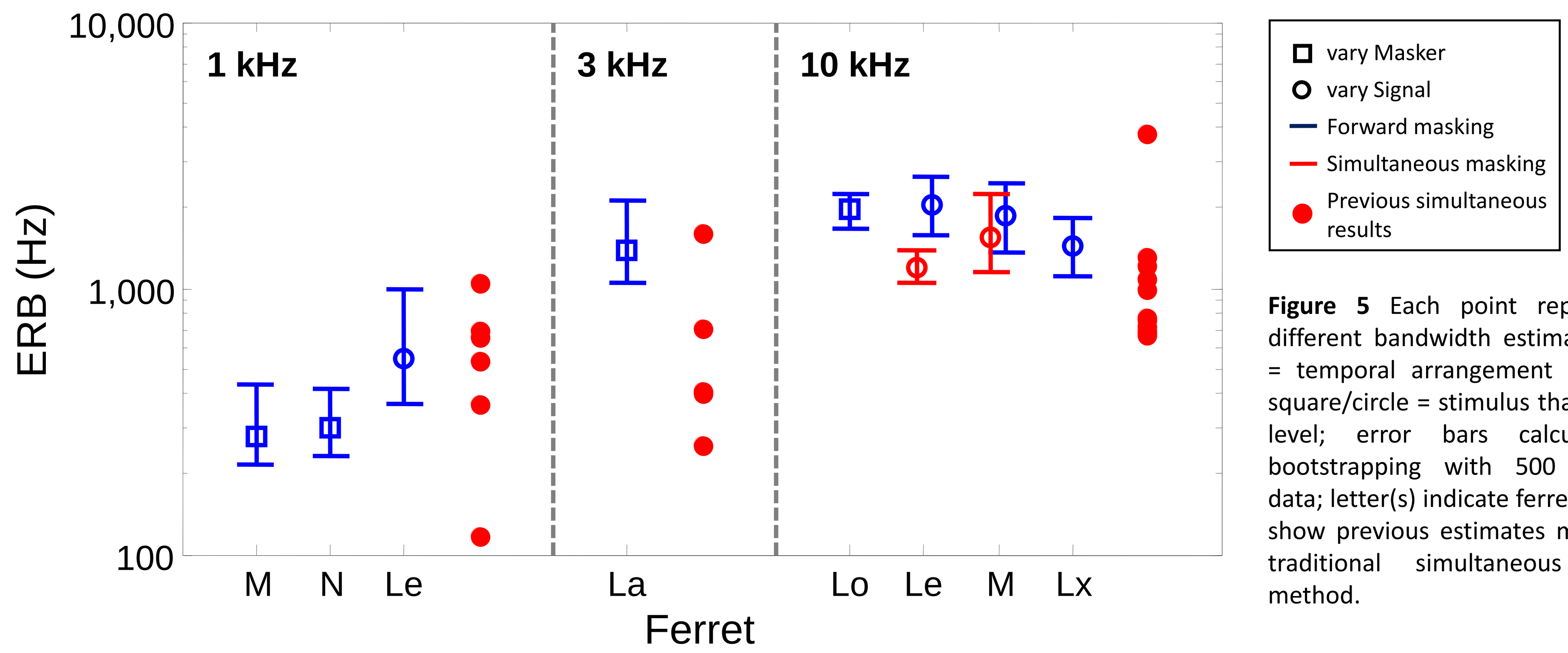


Figure 5 Each point represents a different bandwidth estimate: colour = temporal arrangement of stimuli; square/circle = stimulus that varied in level; error bars calculated by bootstrapping with 500 simulated data; letter(s) indicate ferret. Red dots show previous estimates made using traditional simultaneous masking method.

5. Comparison between psychophysical and physiological ERBs

- Auditory nerve tuning (124 units) measured by calculating an ERB from the pure-tone frequency response area (Sumner and Palmer, 2012).
- OAEs measured using a suppression paradigm (Shera and Guinan, 1999). Data was collected and analysed by Bergevin, Shera, Palmer and Sumner (18 ferrets).
- At 1 and 10 kHz all measurements in close agreement.

N.B. 3kHz data probably attributable to poor ferret behaviour.

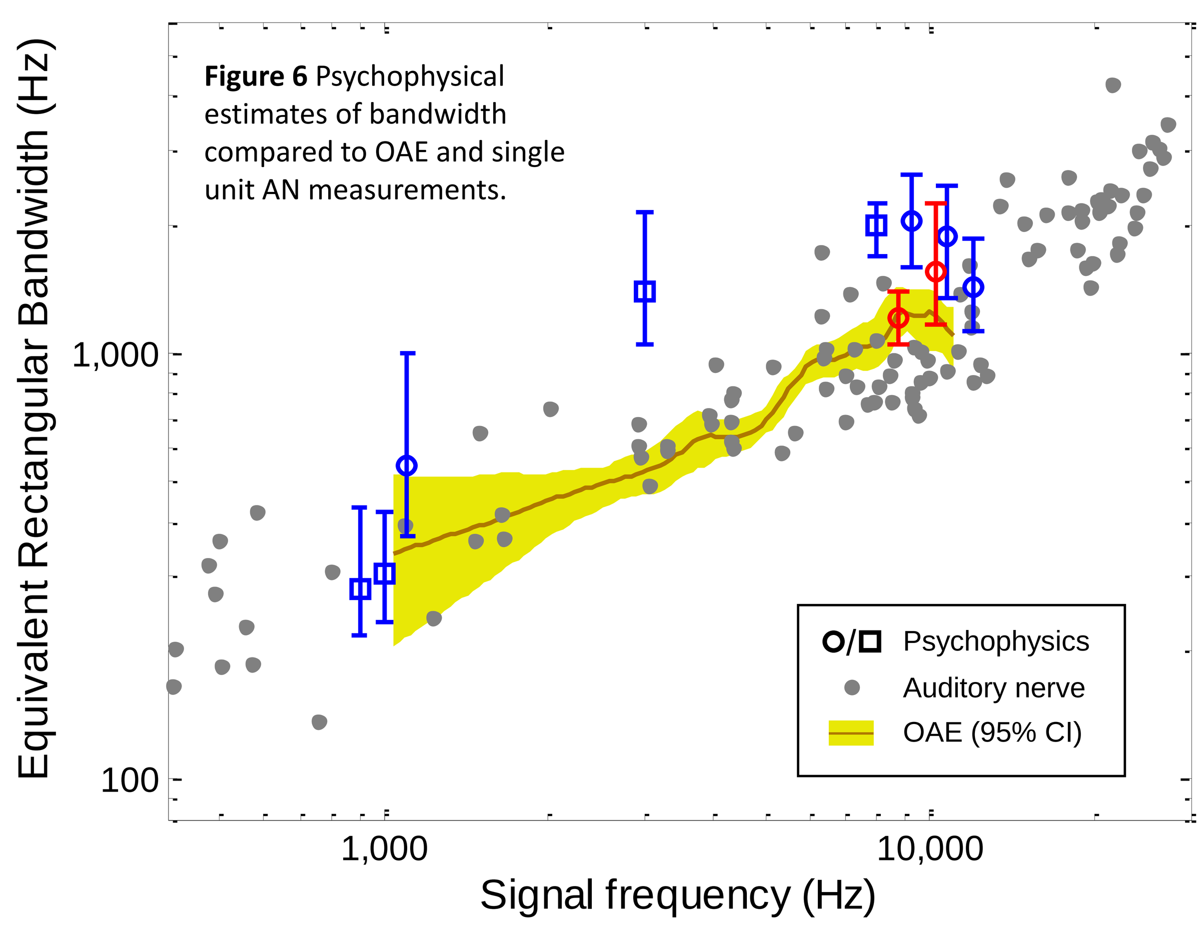


Figure 6 Psychophysical estimates of bandwidth compared to OAE and single unit AN measurements.

6. Summary

- We have successfully developed a method to measure auditory filter widths in the ferret using both **forward and simultaneous** masking, **fixed and varied** level masker.
- Bandwidth estimates made using different behavioural methods do not differ significantly.
- *Most* psychophysical estimates of bandwidth match up closely with auditory nerve fibre and otoacoustic emissions measurements.
- So far, data appear to support the validity of otoacoustic measuments made in humans, and suggests that humans may indeed have narrower auditory filters than other mammals.

References

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Acknowledgements

I would like to thank Joe Sollini and Ana Alves-Pinto for providing previous ferret psychophysical results. Chrises Bergevin, Shera and Sumner, Andy Oxenham and Alan Palmer for the ferret OAE and AN results.