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DIFFERENTIAL DIAGNOSIS OF AUDITORY NERVE DAMAGE THROUGH AMPLITUDE MODULATION TESTS

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ABSTRACT

Auditory nerve fibres (ANFs) are classified into low, medium and high spontaneous rates (SRs). Hearing impairments caused by the loss of these different types of ANF are difficult to differentiate. We estimated the impact of different types of ANF loss on processing of amplitude modulation (AM). A physiologically inspired computational model and hearing loss simulator, MAPsim, was used to simulate the impact of different types of ANF loss on the encoding and perception of AM signals. All modelled ANFs shifted their dynamic range to adapt to the prevailing sound level, but the low- or medium-SR ANFs showed much better phase locking to AM than high-SR fibres. Furthermore, psychophysical measures and computational modelling of AM perception showed that removing high-SR fibers had little impact on supra-threshold AM perception, but removing low-SR fibers significantly degraded performance on tasks that rely on AM cues; AM detection and understanding of unvoiced speech in noise were only degraded by loss of low-SR fibres. However, natural speech in noise, which provides fine-structure information, showed smaller deficits from the loss of low-SR fibres. The study illustrates the potential of using AM-based tasks as a differential diagnostic tool for different types of auditory nerve damage.

Keywords: *hearing loss, modulation, auditory nerve fibres.*

1. INTRODUCTION

Auditory nerve fibers respond to sound differently based on their spontaneous rates. Fibers with high spontaneous rates (HSRs) are sensitive to low-level sounds and encode near-threshold intensities due to firing rate saturation at about 40 dB SPL. Fibres with low spontaneous rates (LSRs) show relatively higher thresholds and levels of saturation and encode sound intensity at supra-threshold levels, while high spontaneous rate (HSR) fibres tend to be saturated at moderate sound levels at which suprathreshold listening tasks, such as speech perception are often performed. However, using a detailed physiological model of the peripheral auditory system, Grange et al. [1] showed that the acoustic reflex (AR) and the medial olivocochlear reflex (MOCR) may be able to provide substantial adaptation of HSR-fibre responses in order to widen their dynamic range.
The current study examines the potential relationship between loss of LSR fibers and the psychophysical manifestation of temporal envelope processing, even when the AR and MOCR are activated.

2. METHOD

The AM responses of simulated AN fibres to were analysed by measuring their synchronisation index for the envelopes of sinusoidally amplitude modulated tones. Different context levels were established by presenting precursor sounds.
The perceptual effects of the loss of specific auditory nerve fibre types was simulated using the MATLAB Auditory Periphery Simulator (MAPsim) [1]. The simulator reconstructs the input waveform from the AN responses, thus incorporating in the output any deficit in information encoding at the AN level.
The simulator was used to pre-process amplitude modulated tones in an AM detection threshold experiment and unvoiced speech in a speech reception experiment. Precursor sounds were employed in all the stimulus

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preparation in order to capture the benefits of the AR and MOCR.

3. RESULTS AND DISCUSSION

Fig. 1 shows the degree of synchonisation (vector strength) to the amplitude modulation envelope displayed by the three different types of nerve fibre at different context levels. Consistent with the results of [1], the range of input levels over which a given class of fibres is able to synchonise well to the stimulus envelope is shifted by the context level for each of the fibre types. However, the LSR fibers continue to show superior phase-locking to the envelope at the highest sound levels, suggesting that the two mechanisms (neural adaptation and variation in spontaneous rate), work in concert to produce an extended dynamic range).

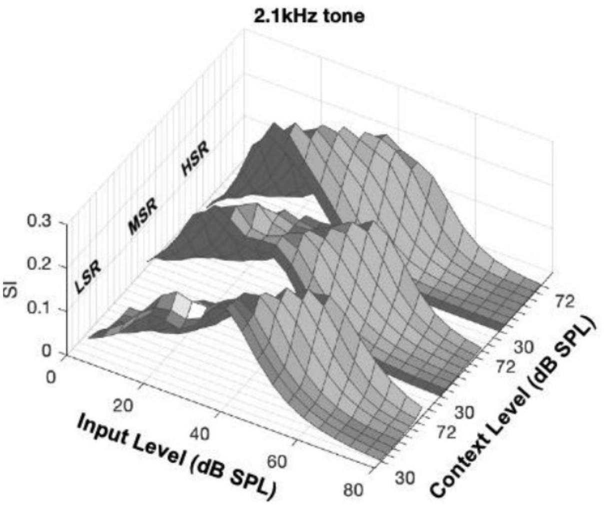

Figure 1. Example analysis of the encoding of amplitude envelopes on the AN by fibres with different spontaneous rates, and at different context levels.

Fig. 2 shows the results in human listeners of the AM detection threshold experiment. The normal (all 3 fibre types) and noHSR conditions were indistinguishable and showed a small deficit in comparison with the normal condition. That deficit reflects some degradation caused by the processing. In contrast, the two conditions that lacked LSR fibres were both substantially elevated, suggesting that LSR fibres are critical to good performance in this suprathreshold listening task.

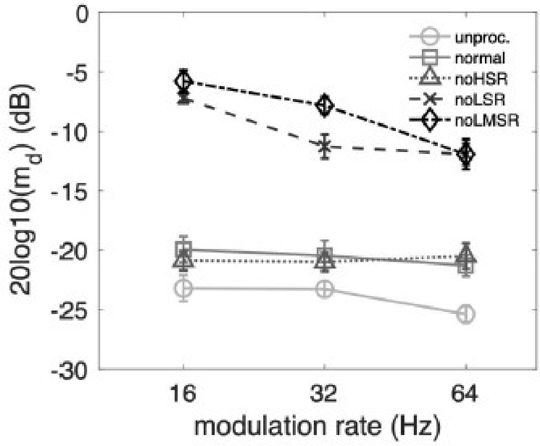

Figure. 2. AM detection thresholds measured under different conditions. The conditins were a full simulation of the AN (normal), simulations with no LSR fibres (noLSR), with no HSR fibres (noHSR), no Low or Medium Spontaneous Rate fibres (noLMSR) and unprocessed (unproc.).

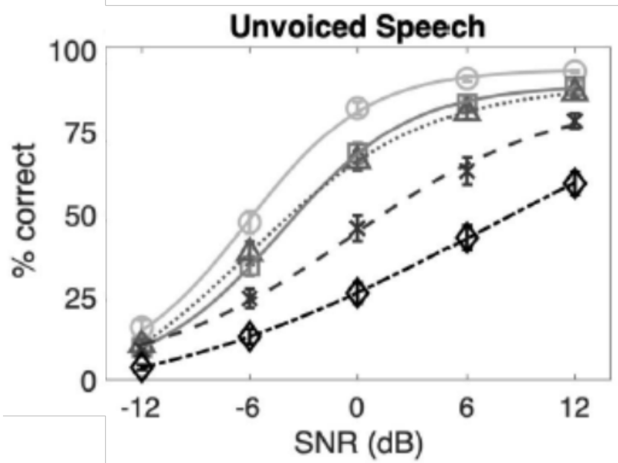

Figure 3. Percent words correct as a function of signal-to-noise ratio for the same condition as in the AM-detection experiment. Line colours and symbols are matched to Fig. 2.

Fig. 3 shows the results of the speech reception experiment. The pattern of results is similar to that from the AM detection experiment, in that there is a small deficit for the normal and noHSR conditions, but a more substantial one for the two conditions in which LSR fibres were removed. In this instance, there is a more substantial difference between the noLSR and noMLSR conditions.

These results reinforce the conclusion that the widening of the dynamic range produced by the AR and MOCR are likely insufficient to facilitate many suprathreshold tasks using HSR fibres alone. From this simulation, fibres with lower spontaneous rates and higher thresholds remain essential to normal suprathreshold performance.

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4. ACKNOWLEDGMENTS

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5. REFERENCES

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