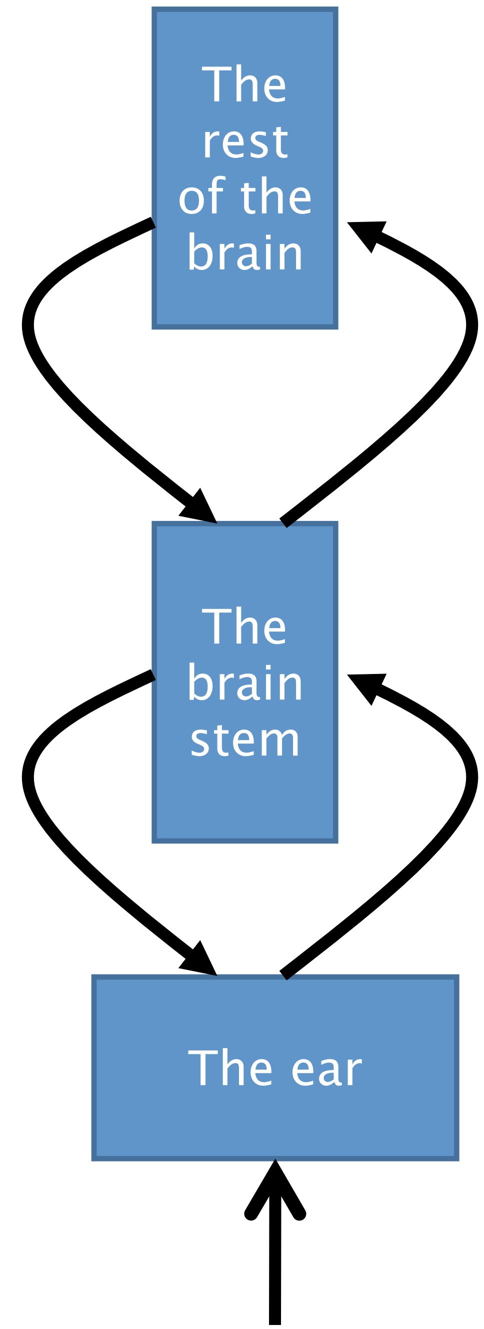
1 Modelling the acoustic reflex and medial olivocochlear reflex.

Summary

The ‘microphone and cable’ image of the auditory periphery is gradually changing to a ‘negative feedback’loop’ conception thanks to recent physiological research.

The acoustic reflex and the medial olivo-cochlear (MOC) reflex act to reduce auditory sensitivity depending, *inter alia*, on the ambient sound level.

A computer model of these processes may help us understand the functional implications of such a system for recognising speech in quiet and in noise and psychophysical measurements such as forward masking.

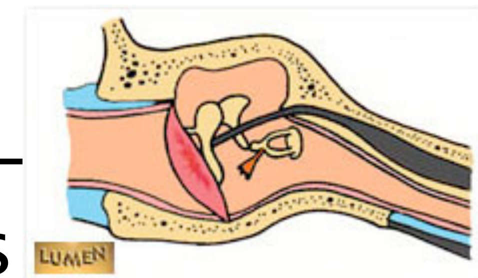


2

Efferent components

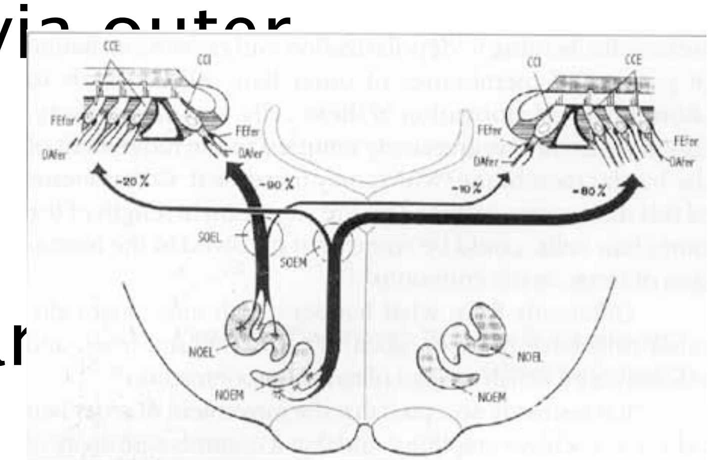
<u>The acoustic reflex (AR)</u>

- works by reducing the stapes response via the stapedius muscle (up to 1 dB attenuation/dB signal level)
- activates at high acoustic levels (>70 dB SPL
- responds most strongly to wideband sounds



<u>The medial olivo-cochlear (MOC) system</u>

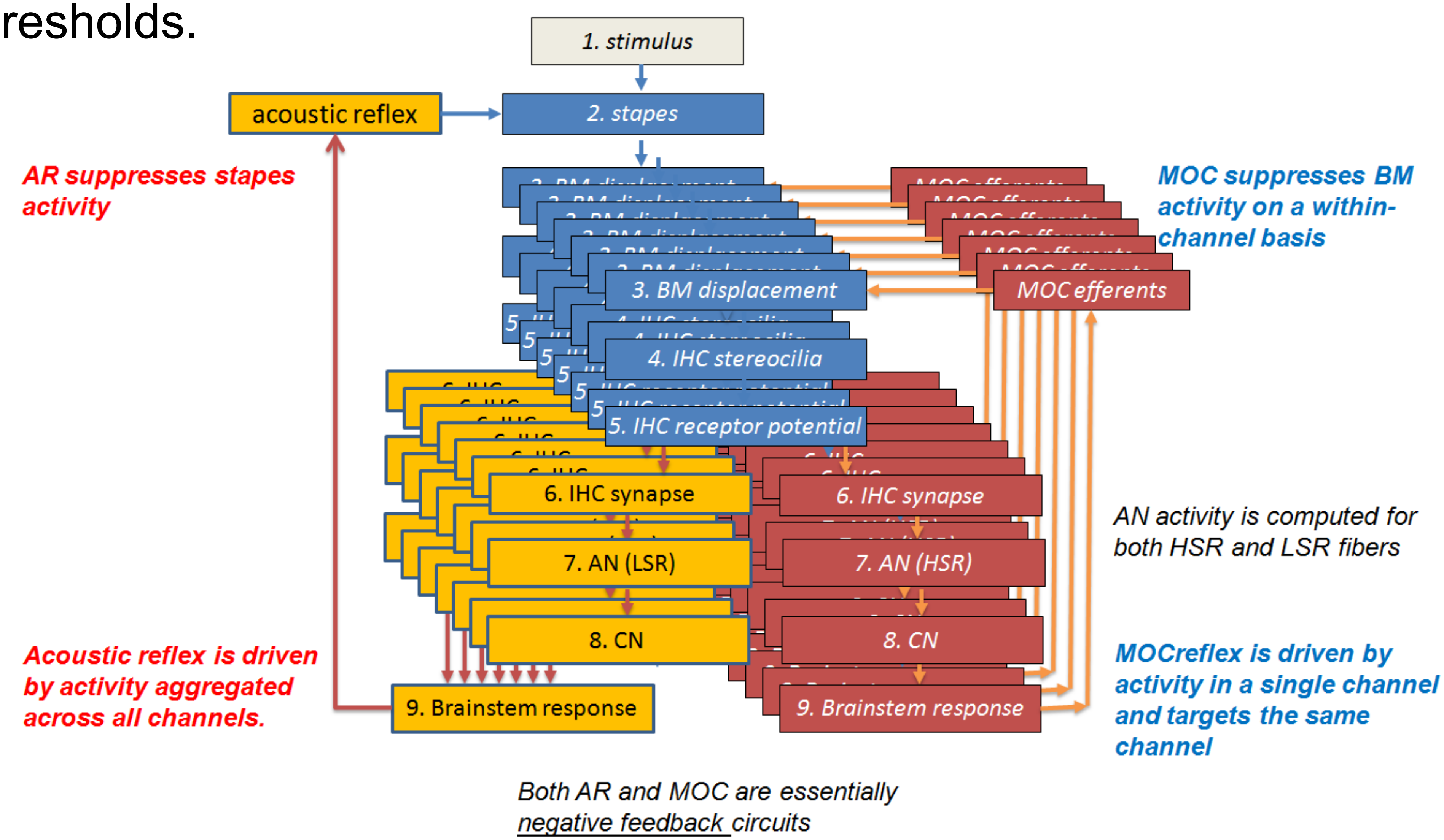
- reduces basilar membrane (BM) response via outer hair cells (up to 30 dB attenuation)
- activates near absolute threshold
- responds to narrow-band sounds on a char channel basis



Computer models of the auditory periphery have generally ignored both systems even though they are likely to be very influential at all supra-threshold signal levels

3 Multi-channel auditory model

<u>AR feedback</u> is controlled by brainstem activity innervated by auditory nerve low spontaneous rate (LSR) fibers across all BFs. The use of LSR fibers is speculative but guarantees high thresholds.



<u>MOC feedback</u> is controlled by brainstem units; one per channel each activated by a narrow range of frequencies. These units are driven by AN high spontaneous rate (HSR) fibers.

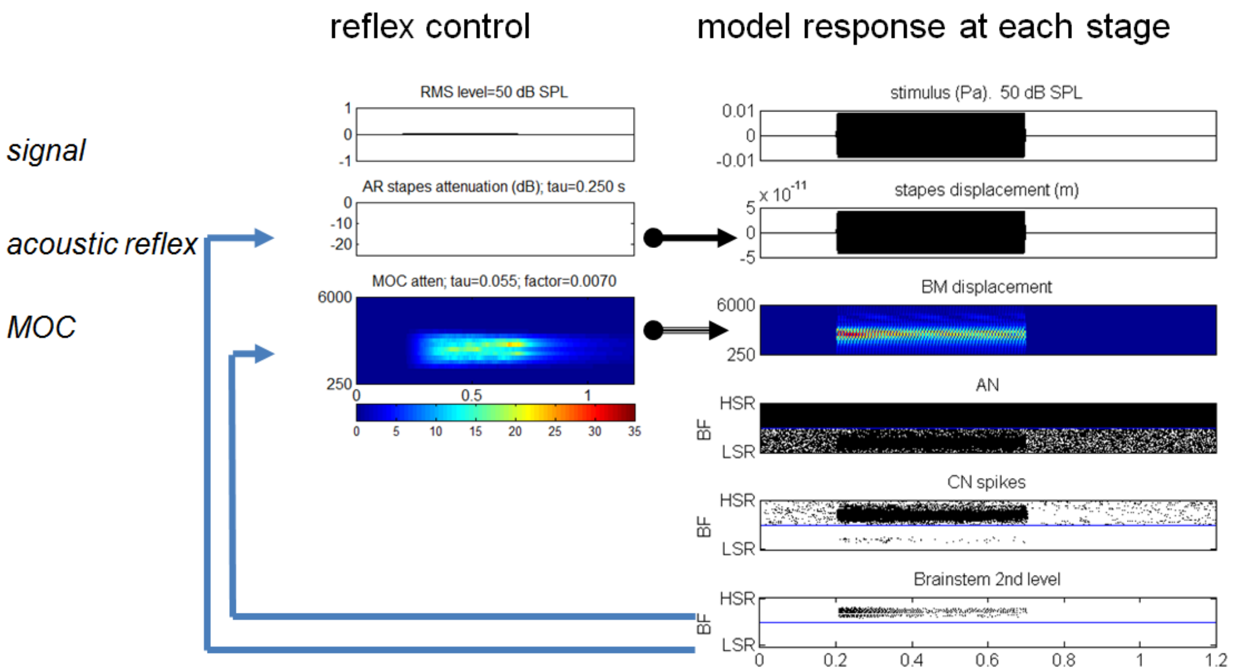
notes

To study the role of the peripheral efferent system, we have extended a model of the auditory periphery to include both acoustic reflex and MOC patheways.

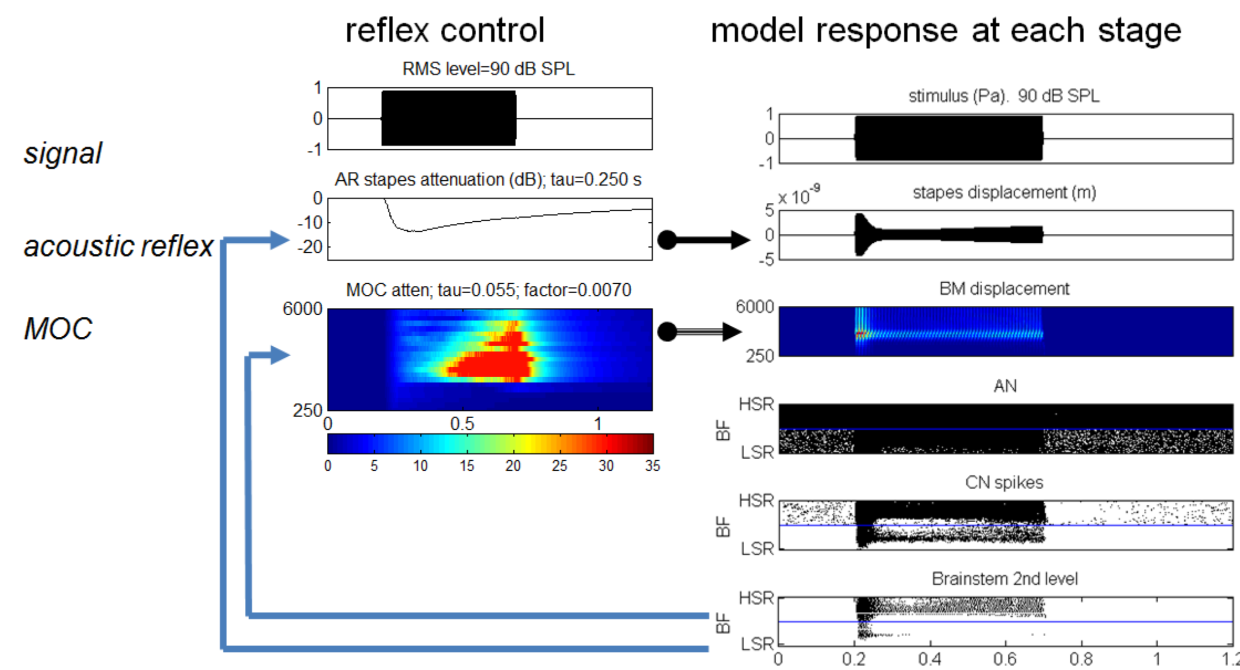
Model in action

1-kHz pure tone

65 dB SPL



95 dB SPL



Points to note:

1. At moderate signal levels only the MOC is operative and BM displacement is reduced.
2. The MOC continues to operate after the end of the tone and produces forward masking

Points to note:

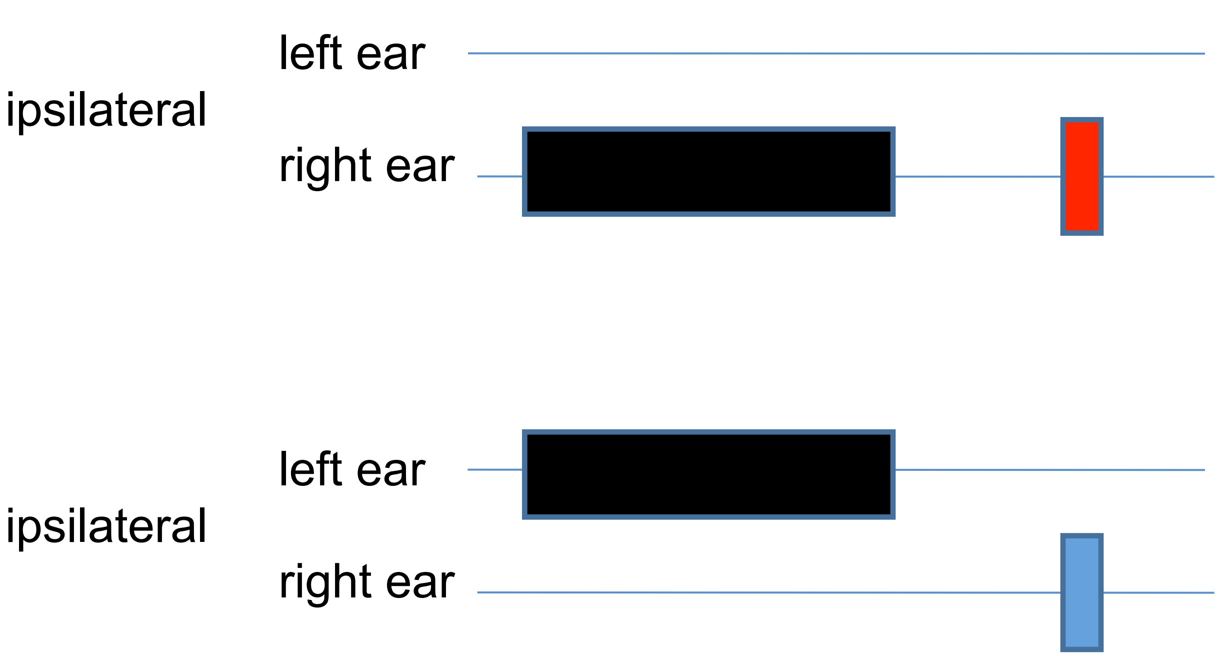
1. At high signal levels the AR is a major contributor and reduces the MOC effect
2. The AR continues to operate after the end of the tone and produces forward masking
3. The AR generates negative feedback oscillation in the stapes response.

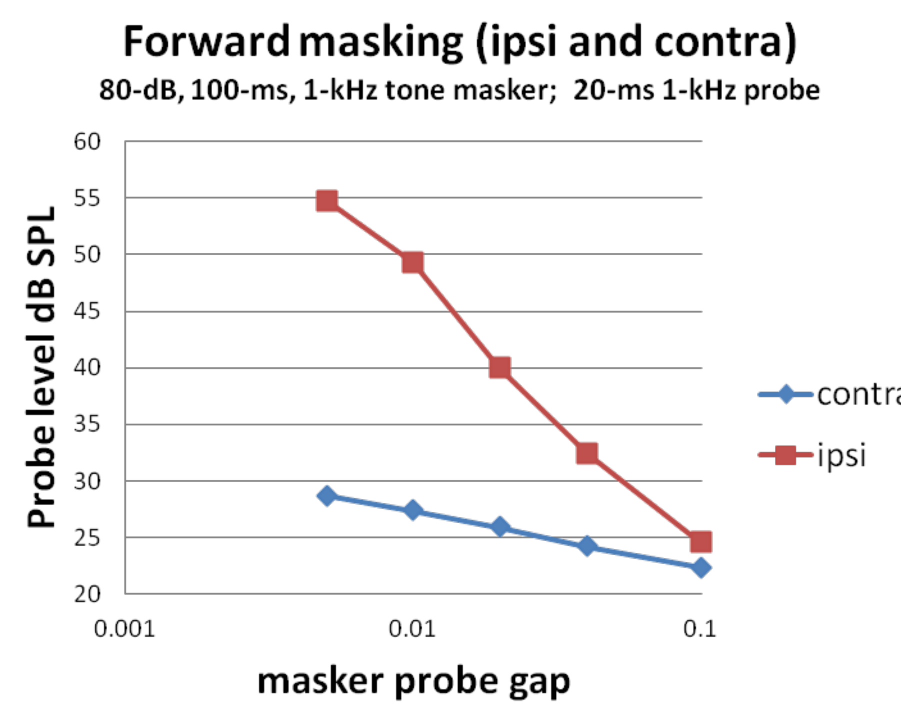
notes

This slide shows the graphical representation of the model output at different processing stages. The input signal is the word ‘twister’. This is processed at two different levels, 65 and 95 dB SPL.

Forward masking

- AR and MOC have suppressive effects that outlast the stimulus. They must contribute to forward masking in addition to AN synapse transmitter depletion. But by how much?
- We gain some insight by studying contralateral forward masking where transmitter depletion cannot be a factor but MOC is at work because of crossed-MOC fibers
- Contralateral maskers produce a small but dependable amount of forward masking.
- NB from anatomical considerations (more fibers) we expect the ipsilateral contribution to forward masking to be greater than the contralateral effect.





notes

This is a psychophysical demonstration of forward masking that cannot be explained in terms of auditory nerve fatigue. This is because the masking tone is played in the contralateral ear. Masking is considerably less in this case. It is possible that this kind of masking shows the effect of the MOC system at work.

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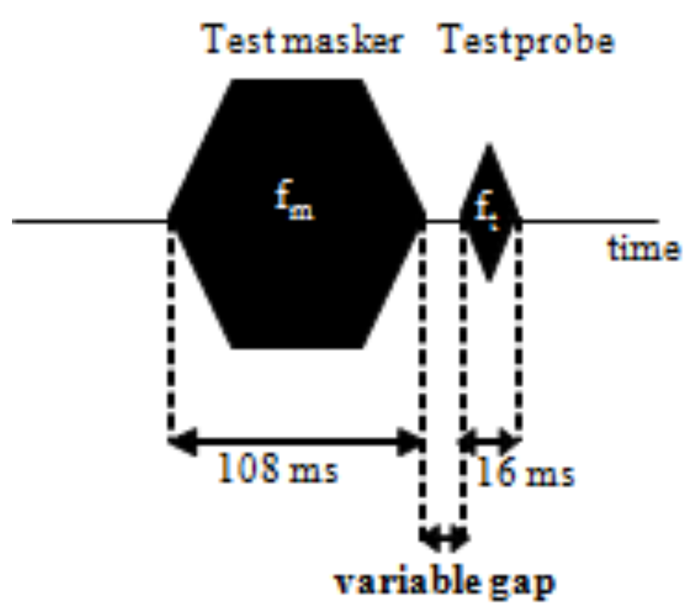
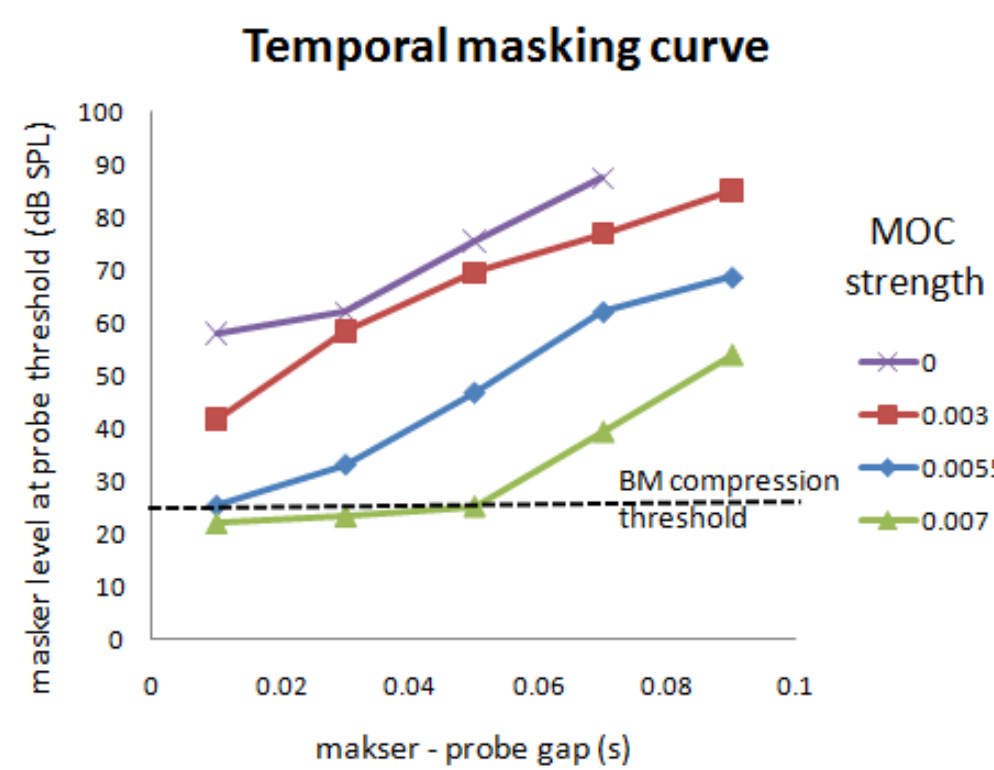
Model application to temporal masking curves

Temporal masking curves (TMCs) measure the level of masker required to just mask a probe as a function of the gap between the masker and the probe.

We can simulate this using the model, varying the strength of the MOC suppression to examine its influence on the shape of the curve.

Result: strong MOC suppression increases forward masking and reduces the level of the masker needed to mask the probe. Otherwise there is no change to the slope of the function except below compression threshold.





notes

Temporal masking curves can be obtained from the computer model of the auditory periphery. The masker can suppress the response to the probe if it is close enough in time to the probe. When the gap is increased the masker must also be increased in level to compensate. The resulting function is strongly affected by the strength of the MOC effect.

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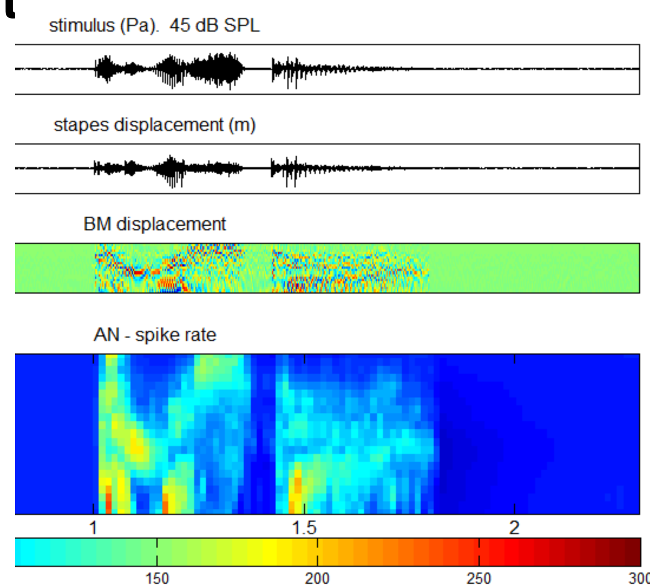
MOC improves speech representation in quiet and in noise

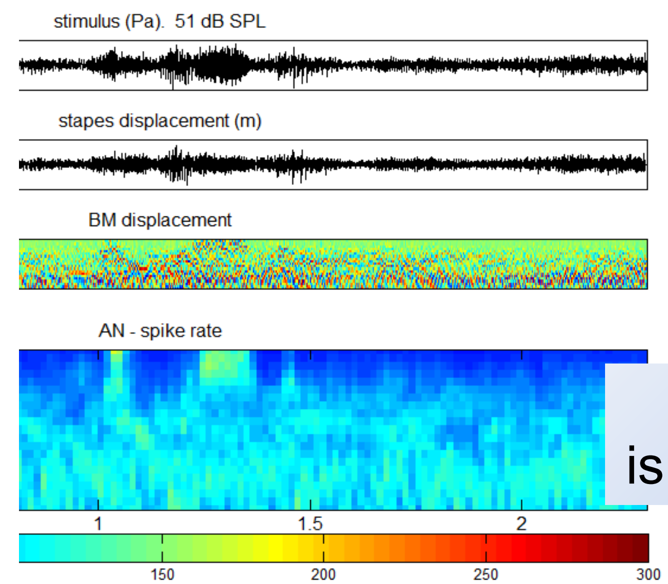
without efferent

clean speech



AN representation is fuzzy

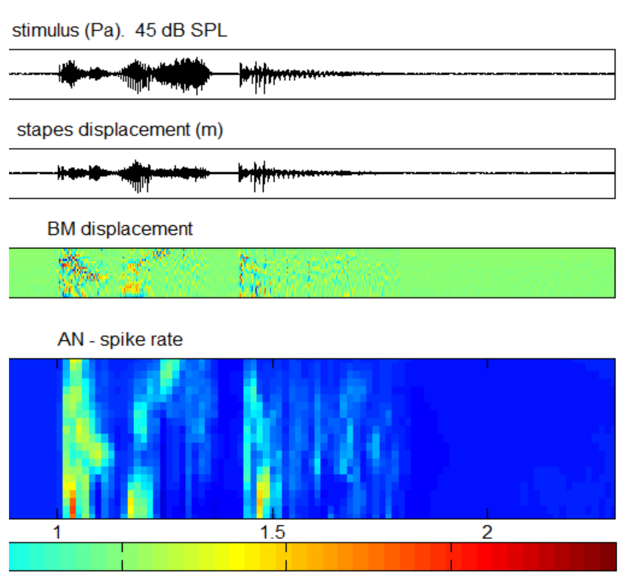
in babble (10 dB SNR)



AN representation is dominated by babble

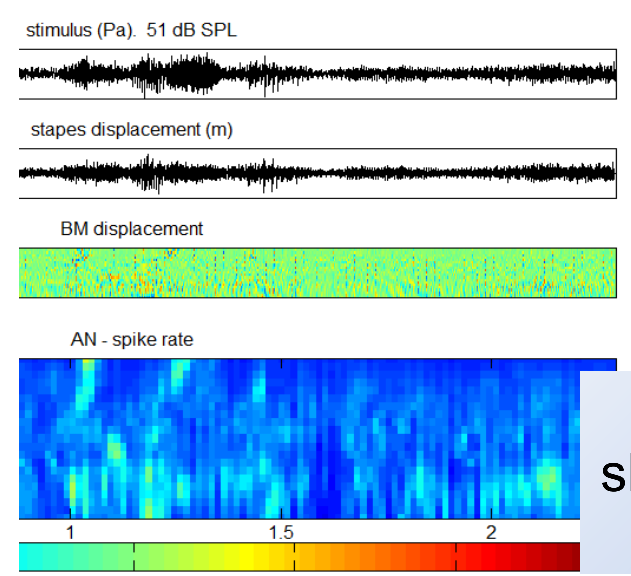
with efferent (best)

clean speech



AN representation is sharp

in babble (10 dB SNR)



AN representation shows original features more clearly

notes

The MOC may be very important in helping us understand speech both in quiet and against a background of interfering talkers. This slide shows how the representation at the level of the auditory nerve is improved when the MOC is active.

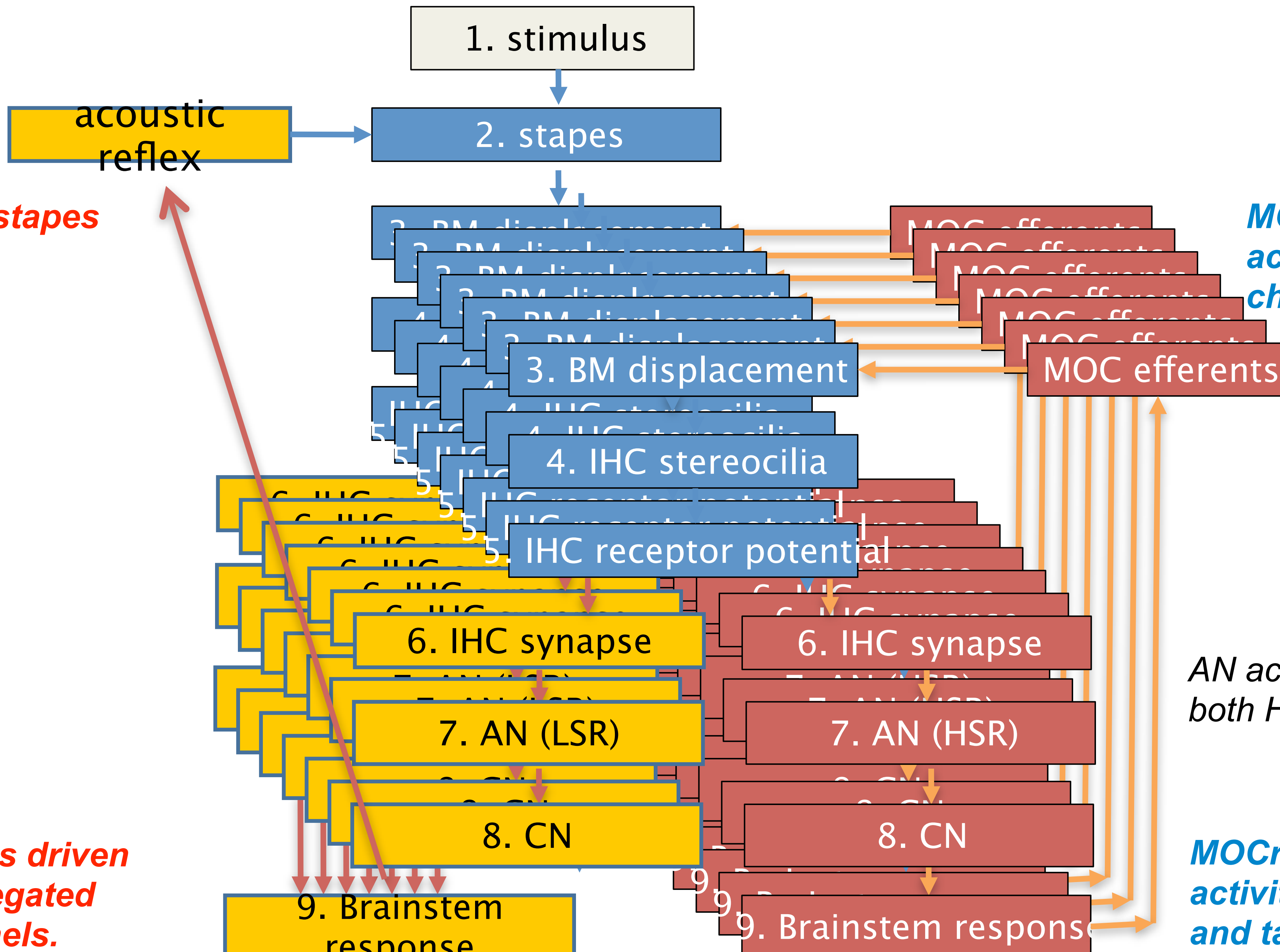
Working slides

3

Multi-channel auditory model incorporating AR and MOC feedback

AR suppresses stapes activity

MOC suppresses BM activity on a within-channel basis

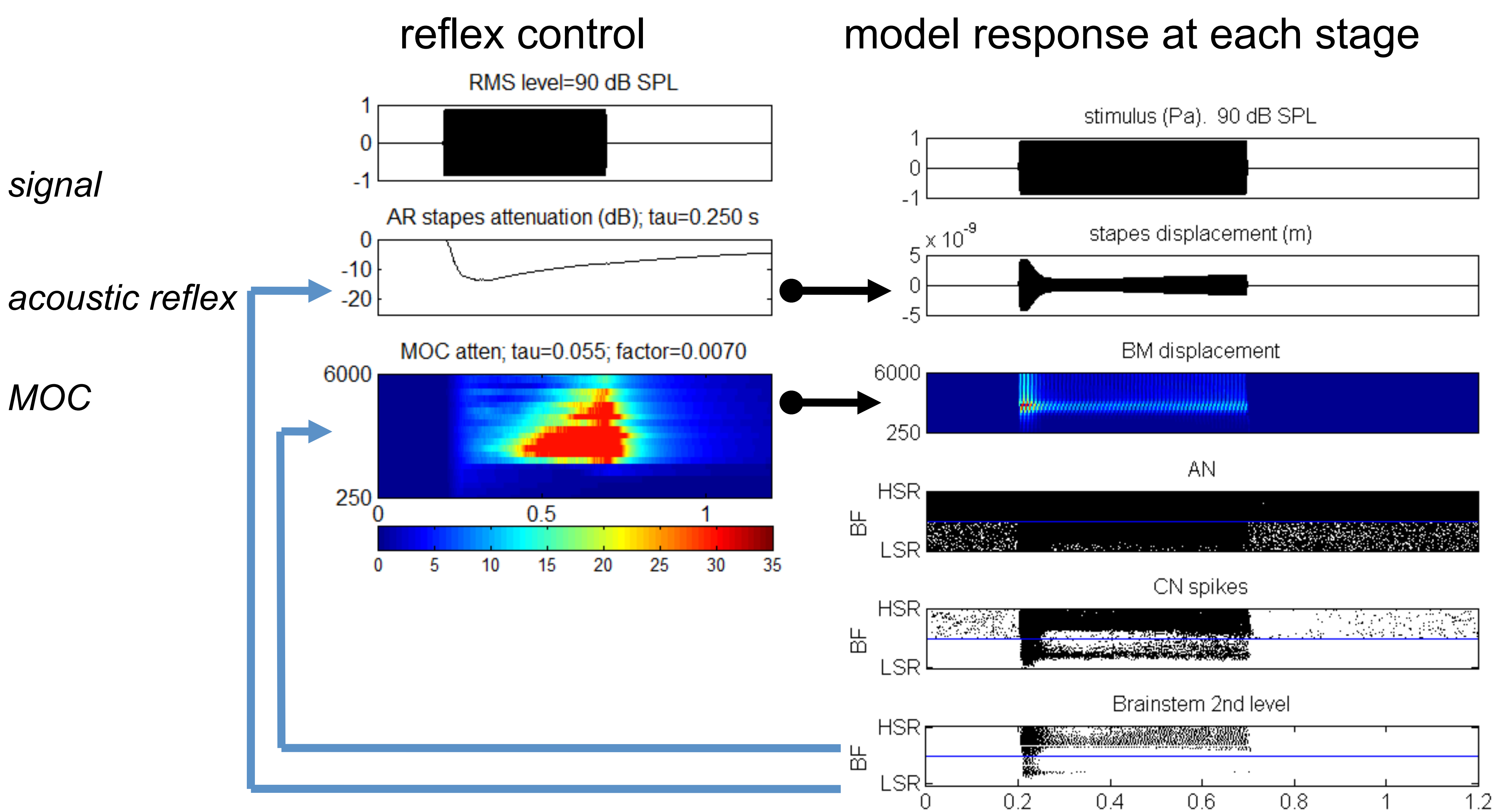


AN activity is computed for both HSR and LSR fibers

Acoustic reflex is driven by activity aggregated across all channels.

MOCreflex is driven by activity in a single channel and targets the same channel

Both AR and MOC are essentially *<u>negative feedback</u> circuits*



reflex control
model response at each stage
signal
acoustic reflex
MOC
RMS level=90 dB SPL
AR stapes attenuation (dB); tau=0.250 s
MOC atten; tau=0.055; factor=0.0070
stimulus (Pa). 90 dB SPL
stapes displacement (m)
x 10-9
BM displacement
AN
CN spikes
Brainstem 2nd level
HSR
LSR
BF
6000
250