TECHNICAL COMMITTEE ON PSYCHOLOGICAL AND PHYSIOLOGICAL ACOUSTICS: AN ADJUSTABLE AUDITORY SYSTEM

Elizabeth A. Strickland

and

Skyler G. Jennings

Department of Speech, Language, and Hearing Sciences, Purdue University
West Lafayette, Indiana 47907

If a person is said to have "cat-like reflexes," one might envision a star athlete or martial artist. Although reflexes are often associated with automatic neural feedback to muscles in the arms or legs they can also appear in the most unlikely of places, such as the ear. For several years neural feedback from the brain to the ear has been well understood from a physiological perspective; however, from a psychophysical or "hearing" perspective it remains a mystery.

"In general the temporal effect seems to be consistent with a behavioral effect that could be caused by the medial olivocochlear reflex."

The auditory system not only sends information to the brain, but also receives feedback from it. This is also true of other sensory systems. For example, feedback to the visual system adjusts pupil diameter in response to changes in light. In the auditory system, one feedback loop projects from the brainstem to the outer hair cells in the cochlea, and is called the medial olivocochlear bundle (MOCB). MOCB neurons in the brainstem are activated by afferent neural fibers from the cochlea. When activated by sound or electric shock, MOCB neurons send neural impulses to the cochlea's outer hair cells, which control cochlear amplification (or gain) and are related to the "active process." The anatomy of the MOCB involves two fiber pathways, which vary in size and projection. The largest branch of the MOCB feeds back to the same ear from which the afferent fibers came. A smaller branch goes to the other ear. Physiological evidence in animals suggests that this feedback loop responds to sound by decreasing gain in the cochlea in a frequency-specific way, an effect called the medial olivocochlear reflex (MOCR).[1]

In addition to the physiological data from anesthetized animals, there is some evidence of the activity of this feedback loop in awake animals and humans. Otoacoustic emissions (OAEs), a byproduct of the active process in the cochlea, are backwards-propagated disturbances measured in the ear canal in response to sound. OAE level decreases with the duration of a sound, or with the addition of a contralateral sound.[1] This decrease largely disappears when the MOCB is cut, and is correlated with vulnerability to acoustic injury in animals, suggesting that the MOCR may function to protect the cochlea.[2]

Another possible role for the MOCR is to improve hearing in noisy environments. Evidence for this hypothesis comes from a psychophysical phenomenon called "the temporal effect." The temporal effect refers to the fact that a short signal presented at the beginning of a longer masker is easier to detect if it follows a precursor (a separate sound or an extension of the masker). Quantitatively, the temporal effect is the difference between thresholds measured with and without the precursor. Although the temporal effect was first described over 40 years ago,[3] it received renewed interest when studies tied it to the active process in the cochlea. For example, the temporal effect is reduced in adults with temporary hearing loss caused by excess noise exposure or aspirin ingestion, both of which decrease the gain of the active process.[4,5] Interestingly, the temporal effect decreases with hearing loss because threshold improves in the no precursor condition. The improvement suggests that reduced cochlear gain (as seen with hearing loss) may enhance detection in some circumstances. It follows that the large temporal effect seen in normal hearing listeners may be caused by a precursor-induced reduction in gain; thus leaving thresholds (and gain) high in the no precursor condition while lowering them in the condition with a precursor. This gain reduction effect by the precursor may be mediated by the MOCR.

Although the temporal effect appears to be related to outer hair cell function, additional evidence is necessary to link it to the MOCR. For example, a precursor intended to activate the MOCR should decrease gain and frequency selectivity. Moreover, the magnitude of this reduction should increase with increasing precursor level. In an effort to tie behavioral findings to the MOCR, studies have been designed which allow the results to be analyzed in terms of these expectations. These have shown that the presence of a precursor does appear to decrease the gain of the input-output function, and that this effect increases with the level of the precursor. The presence of a precursor at the signal frequency also decreases frequency selectivity.[6] If the precursor is off-frequency, the results support the idea that another byproduct of the active process, suppression of one sound by another, is decreased.[7] This would seem to be consistent with a decrease in gain at the suppressor frequency, although it does not fit with current theories of suppression. Thus in general the temporal effect seems to be consistent with a behavioral effect that could be caused by the MOCR. To show this conclusively, physiological and behavioral measures need to be obtained from the same subjects, either humans or animals.

In animals, the MOCR has also been shown to be active during a visual attention task.[8] This suggests another role, turning down input from one sense when paying attention to another. This suggests that the MOCR is active in auditory attention, in addition to the reflexive response to sound discussed above.

Why would it be beneficial for the auditory system to decrease gain in response to sound? The basic temporal effect is the ability to detect a signal at a lower signal-to-noise ratio (SNR) after a precursor. In certain conditions, decreasing gain may improve the SNR at the output of the cochlea because cochlear amplification decreases with sound level. For example, if the noise output is lower than the signal output, a decrease in gain will turn down the noise more than the signal, thus increasing the SNR. The MOCR may adjust the auditory system to maximize the SNR in varying levels of background noise. Thus our person with the cat-like reflexes may be a star athlete not only because of muscle feedback, but also because auditory feedback allows communication in background sound levels ranging from the quiet of practice to the roar of a game.**AT**

References for further reading

1 J. J. Guinan, Jr., "Olivocochlear efferents: Anatomy, physiology, function, and the measurement of efferent effects in humans," Ear and Hearing **27**, 589-607 (2006).

2 S. F. Maison and M. C. Liberman, "Predicting vulnerability to acoustic injury with a noninvasive assay of olivocochlear efferent strength," J. Neuroscience **20**, 4701–4707 (2000).

3 E. Zwicker, "Temporal effects in simultaneous masking by white-noise bursts," J. Acoust. Soc. Am. **37**, 653–663 (1965).

4 D. McFadden and C. A. Champlin, "Reductions in overshoot during aspirin use," J. Acoust. Soc. Am. **87**, 2634–2642 (1990).

5 C. A. Champlin and D. McFadden, "Reductions in overshoot following intense sound exposures," J. Acoust. Soc. Am. **85**, 2005–2011 (1989).

6 E. A. Strickland, "The relationship between frequency selectivity overshoot," J. Acoust. Soc. Am. **109**, 2063–2073 (2001).

7 E. A. Strickland, "The temporal effect with notched-noise maskers: Analysis in terms of input-output functions," J. Acoust. Soc. Am. **115**, 2234–2245 (2004).

8 P. H. Delano, D. Elgueda, C. M. Hamame, and L. Robles, "Selective attention to visual stimuli reduces cochlear sensitivity in chinchillas," J. Neuroscience **27**, 4146–4153.

Elizabeth A. Strickland received her PhD in experimental psychology from the University of Minnesota in 1994. Following a year of postdoctoral work at the University of Florida, she joined the faculty of Purdue University. She is currently an associate professor in the Department of Speech, Language, and Hearing Sciences, as well as the Chair of the Technical Committee on Psychological and Physiological Acoustics of the Acoustical Society of America. Her research focuses on temporal processes in normal and impaired hearing.

Skyler G. Jennings is an Au.D./Ph.D. student at Purdue University and a Doctor of Audiology extern at the Indiana University Medical Center. In addition to his clinical responsibilities, he holds a half-time National Institutes of Health pre-doctoral research fellowship and is a resident assistant in the University's residence halls.