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Getting a Little Batty for Audiology

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This is a scenario that may occur once or twice a day to you: Pretend you are an insect flying around, minding your own business, and a bat decides that you would be a tasty meal. You quickly have to review your audiology training and knowledge of a bat's echolocation signal (11 kHz to 212 kHz depending on the species) and come up with a survival strategy.

One obvious approach is to match and emit an identical signal that is 180° out of phase with the bat's echo-locating signal, just like modern digital hearing aids do with feedback cancellation. This innovation, first appearing in the literature in 1933, would work long enough for a moth to take cover. It is questionable whether this approach offers any evolutionary advantage, however. Because the echo location signal can range from 11kHz to over 200kHz, the selection of one frequency provides protection from only one species of bat, but not other species—not a very effective approach.

Another solution would be to "jam" the bat's signal. Aaron Corcoran, a post-doc fellow in biology at the University of Maryland discovered that some insects may use a jamming signal to block a bat's echo location of its prey (http://www.sciencemag.org/content/346/6210/745). This is the first indirect evidence that insects study audiology.

According to Dr Corcoran's research, some moths—specifically, Grote's tiger moth—emit a high pitched clicking that masks the signal of the bat's echo location signal. Short of matching the exact signal and then flipping its phase 180°, this moth seeks to create a clicking that has a broadband high frequency biased spectrum, sufficient to mask some or all of the bat's signal. In many cases, this would have its energy at a lower frequency than the echo-location signal, but thanks to upwards spread of masking in the mammalian bat's ear, this would be sufficient to mask, or otherwise confuse where the moth was.

Dr Corcoran also found that Mexican free-tailed bats emitted similar sounds to the tiger moth, but this time designed to distract other hungry Mexican free-tailed bats from their meal. When he aimed recorded sounds of a Mexican free-tail bat directly at another bat about to eat a tasty moth, the bat was up to 85.9% less likely to catch its prey. And to think that, at one time, a definition of a human was a "tool user"! We can't even say that humans are the only ones to know about upwards spread of masking.

Upwards spread of masking is related to the asymmetry of the travelling wave in the mammalian cochlea. Even though the cochlear tuning curves of individual hair cells are most sensitive at their characteristic or best frequency, they also respond to lower frequency sounds if they are of sufficient sound level. This is true of all mammals, as well as some non-mammals.

You can think of the upward spread of masking as a necessary aspect of normal hearing function;

without a sufficiently asymmetric cochlear hair cell tuning curve, speech and all other acoustic stimuli would sound quite odd.

A salient feature of speech is that it is sequential—lower frequency vowels and nasals are followed in time by other low frequency sounds or other high frequency consonant sounds. Rarely do two or more speech sounds occur at the same time. This has allowed upwards spread of masking to remain a relatively minor phenomenon when it comes to speech perception, at least in quiet.

In contrast, music is co-incident, meaning that two or more notes tend to occur simultaneously and also closer together. The creation of musical notes are not limited by the mundane neuroanatomy of the vocal mechanism. There can be 16th or even 32nd notes where temporal masking from one moment in time can occur next to another, one a small fraction of a second later.

Music would sound very odd indeed without upwards spread of masking rearing its important head. Each note, and its harmonics, would create a significant upwards spread of masking, and this is why music sounds as good as music does. Too much masking can be as deleterious as too little.

And in the case of moths, there are more of them because of their innate knowledge of upwards spread of masking. Perhaps that fly on the wall in your first-year Audiology class was really a moth learning about bat-evasion.