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Perceiving Auditory Stimuli: Inter-Species Adaptation Differences, Harmonics, and Illusions

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Abstract

Illusions give us insights regarding how physiological systems use and weigh information fromdifferent inputs. Physiological systems interpret data in in such a way that we can understand allof it as a whole concept. We will discuss and understand these processes, as well as thetechnical processes that convert stimuli to electrical impulses in the human auditory system. Wewill propose experiments, explain evolutionary adaptations to improved hearing in other species,explain harmonics and Weber's law relating perception and stimuli[1].

Keywords: Illusions; Physiological systems; Visual inputs; Evolution; Environment; Potential predators; Vibrations; Specific frequencies

Cognitive Improvements

Illusions give us insights regarding how physiological systems use and weigh information fromdifferent inputs. Physiological systems interpret data in in such a way that we can understand allof it as a whole concept.

In some cases, that leads to our brain creating illusions by applying the wrong conceptualgrouping, for example, to the available stimuli[2]. Physiological systems assign more weight tovisual inputs, for example, and the brain groups auditory or visual stimuli based on location andsimilarity to create a virtual model of the perceived world. Attention changes depending on thesituation, as our interpretation of stimuli has developed via evolution.

Illusions can be very artificial and controlled by humans, but some are also common in naturalsettings. An example is that many animal species can camouflage themselves in theirenvironment, giving the illusions to potential predators or preys that the animal is part of thebackground or environment. Some species such as the chameleon can also change the color oftheir skin to adapt to different environments.

The Process of Hearing

When a pressure wave reaches the ear, it transforms to an electrical signal, which leaves theauditory nerve for higher neural levels. First, the pressure wave enters the outer ear, composedof the auditory canal and the pinna, then goes through the meatus, causing tympanic membranevibrations. The eardrum then transmits the vibrations to the cochlea via the ossicles, which aresmall bones in the middle ear[3].

The ossicles in the middle ear are used to decrease reflections caused by a difference inimpedance. The cochlea, which is in the inner ear and is shaped as a spiral filled with a fluid,goes from the base to the apex (the tip), has two membranes (the basilar membrane andReisner's membrane). At the base, there is the oval window, and at the apex, there is anopening between the walls of the cochlea and the basilar membrane, connecting the outerchambers of the cochlea (scala tympani and scala vestibuli).

The physical vibrations wave reaches the basilar membrane, which Von Bekesy discovered thatvibrates and transfers the wave to the apex. As the fluid moves through the endolymph andperilymph, the waves stimulate the receptor cells that send nerve impulses to the brain. In theorgan of Corti, the four rows of hair cells between the tectorial membrane and the basilarmembrane are depolarized by the basilar membrane.

The inner hair cells transform fluid vibrations into electrical signals that are sent through theauditory nerve to the auditory brainstem and the auditory cortex, while outer hair cells are usedto amplify soft sounds in the cochlea. Their electromotility is an amplifier that mechanicallyincreases hearing sensitivity in specific frequencies that are important to hear.

The hair cells release neurotransmitters at synapses with the auditory nerve fibers, creatingaction potentials, which convert the vibrations in the basilar membrane to firing patternstransmitted to the brainstem.

Experiment

It is possible to measure a critical band by masking a sine wave with a white noise band. Bydecreasing the bandwidth of the white noise until the sinewave is identified, the band widthreaches the critical bandwidth. Hereis a graph showing the hypotheticaloutput of this test.By adding another noise band at adifferent critical band, as long as it ismodulated in the same way as thefirst noise band, the brain wouldidentify the pattern and be able toseparate them from the sine wavewhich is not modulated in the sameway. This could further lower thethreshold(Figure 1).

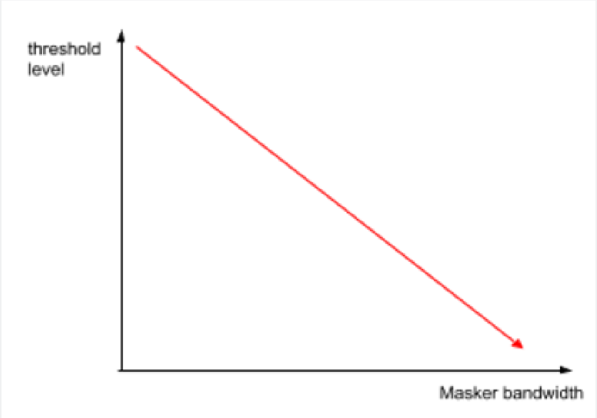

Figure 1: Masking graph.

There are multiple types of masking: Simultaneous masking, when a sound is maskedby another sound that is played during the entirety of the first sound. Non-simultaneousmasking is when a sound cannot be interpreted by the human brain because another soundhas been played very soon before or after, and it causes the illusion of having been part of thesame group and is therefore masked[4].

Evolutionary Adaptations

There are species with evolutionary adaptations that have enabled them to hear in remarkablyunique ways. Dogs have evolved in such a way that they can move their ears in differentdirections to capture and amplify sounds from those directions[5]. Some owls cannot move theireyes, which means they can more easily map vision to hearing, and thus have a stronger spatialconnection between vision and audition[6].

Bats have evolved to the point of being able to echolocate their preys and environment[7]. Somehumans are also able to achieve this. Some insects have also learned to hear these sounds thatbats emit. For example, some butterflies can sense these vibrations in their wings, which makethem drop to the ground and avoid being captured[8].

Harmonics

The perception of a 100 Hz Sawtooth wave, if all the odd harmonics are removed, will remain asawtooth wave but in the next harmonic (200Hz), because all the even harmonics for 100Hz areALL of the harmonics for the 200Hz wave.Therefore, it will be exactly an octave higher.

In order to create the 60 phon curve, for exampleone would have to play a 60dB tone at 1kHz, andthen play tones at other frequencies and measurewhich volume intensity in dB would perceptuallymatch the 1kHz 60dB initial tone. Thus, the curve will always provide 60phons at anyfrequency (Figure 2). The A level weighting was made for under 40phons, so a regular classroom wouldneed to be measured with an A-level meter. For a rock concert, C-level would be moreappropriate since it was designed for louder sound, around 100phons.

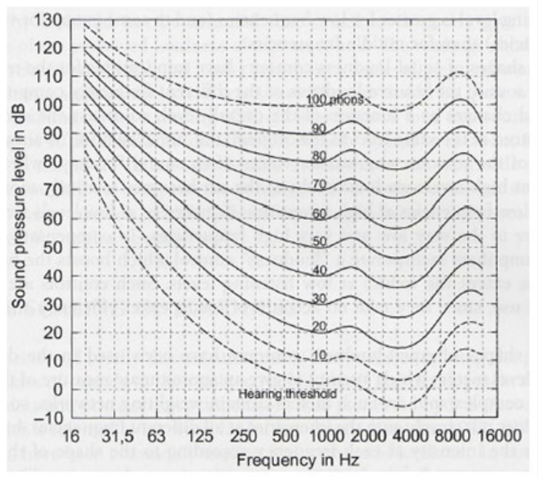

Figure 2: Harmonics.

Near Miss to Weber's Law

The Near Miss to Weber's law is when at high frequencies, the law doesn't apply anymore[9]. Itprobably occurs because at high frequencies, loudness perception differences converge. This islikely to be an effect of the nonlinear scale of sound perception. For example, there is a higherfrequency separation between C3 and C4 than C4 and C5, and that could create a smallerdifference in perceived volume difference, according to Steven's Power Law[10].

Conclusion

In conclusion, illusions can help shed light on the systems and mechanisms that our brain usesto understand the environment, by combining multiple auditory and visual clues into a coherentrepresentation of the world.

We analyzed some of these systems and gave examples on how the ear mechanism works,with the cochlea, going from the base to the apex, hair cells and auditory nerve fibers. Finally,we proposed future experiments to measure critical bandwidth for masking of auditory cues.

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