SOARING Rx

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Hearing, Listening, Understanding

...evaluating the strength of the internal representation of speech stimuli in clinical populations believed to have a core deficit in phonological encoding, such as children with hearing loss.

-Rachael Frush Holt, PhD

Mort was happily hovering in the house thermal, beginning a check ride in the club's tandem ship. Suddenly, there was a bang behind him.

What was it? The glider's flight wasn't disturbed. He wiggled the rudders and stick cautiously. They felt fine; the ship responded normally.

Was it the instructor firing a gun in the rear seat? Seemed unlikely, though she was a bit right-wing and an avid hunter. In any case, he didn't feel wounded.

Then he realized that she was talking to him. Between the wind noise from the canopy and wheel well, and the radio chatter over the speaker, he had trouble making out what she said.

The Happiness Quotient suddenly seemed lower. There had been the occasional Marital Discussion at home, "Why don't you listen?!" that, for some reason, came to mind just now.

He concentrated hard, lowered the radio volume, raised the nose to slow down and decrease the wind noise. "What?" he yelled.

"We're high enough," she said, "I'd like to see you demonstrate a cross-control stall. Have you ever done one before?"

Worried, he asked, "What was that bang? Is the ship OK?"

"I was just giving the fuselage a whack," she said, "to get your attention. Have you been in a trance?"

The difference between hearing and listening.

To understand speech – to listen – requires complex processing of complex sound patterns. Hearing – detecting sounds – is merely the first step in this process.

Unfortunately, we have "treatment" only for hearing, not for listening, and we really have only a single tool: loudness. There are many reasons why Johnny might not hearken (listen and respond) to Mom, but she doesn't have any diagnostic tools. In frustration, she will yell, or change her wording, or drag him to the doctor to expensively find out whether his ear canals are stuffed with wax.

We've seen the frustrated tourist shouting, with exaggerated diction, in English, to a street vendor in a foreign country. In fact, everyone's instinctive first response to "Huh?" is to speak louder. Often this works.

Hearing aids are an expensive response to our friends' and spouse's refusal to raise their voices, and unfortunately they amplify ambient noise and distracting conversation at least as well as the speech or music we prefer to hear. They often are effective, but are often unsatisfying.

The newest aides can selectively amplify crucial parts of the sound spectrum, and suppress feedback to eliminate the hated squeal that's never heard by the wearer, but they can never provide missing higher-order sound processing that would actually improve understanding.

What is "hearing?"

Let me expand this definition of hearing as "sound-detection" to include everything about the physiologic processing of sound by the ear and inputs to the brain. I'll reserve "listening" to the processes of attention and understanding: of mapping sounds to linguistic, musical, or mathematical constructs, or any other auditory symbols used in cognition.

What is "listening?"

Listening must, at least, involve comprehension. If we think about this for a bit, it's obvious that several things are required beyond hearing.

– Attention (focusing on it)

– pattern recognition (recognizing, understanding it)

– cognition (thinking about it, responding)

In this regard, over learned responses may not rise into consciousness, or may be displaced from working memory so rapidly that it's not put into permanent memory and thus quickly forgotten.

I'm sure we've all had the experience of continuing to do a familiar, habitual task while distraction occurs – and then discovering, when the distraction ends, that we are further along in the task than we realized, and that we can't recall what we should have observed during the intermediate steps.

Attention

The April, 2014, *Soaring Rx* was a little essay on attention mechanisms. http://tinyurl.com/mk7s3jv

Today, the important point is that listening is not purely a matter of self-will and discipline. There are many powerful distracters in a dynamic environment such as piloting. The most important of these are probably surprise, interruption, and emotion. In this environment, the quality of our systems for speech recognition is crucially important.

Besides this, safe and efficient piloting requires us to keep several threads alive, each of which displaces attention from each other. We may feel proud of our multitasking ability, but while researching the April column on attention, I found that simulation studies have shown performance to degrade when we have several concurrent tasks. That is, multitasking is *possible*, but entails more errors.

When stressed, we tend to lock in on the event causing stress. This causes "tunnel vision," improving performance on that single task but neglecting all others, decreasing safety and degrading overall performance.

This fact is a reason that repetitive practice for emergencies is important, and why it's helpful to practice unusual situations so that they're familiar when they show up uninvited.

Pattern recognition in listening

I think that we may easily undervalue the key role of pattern recognition in successful listening. Its importance is highlighted when we listen to professional jargon, regional accents, and small children. The nearly incomprehensible quotation at the top of this column demonstrates that we can neither "listen" nor understand unfamiliar patterns.

This quotation is saying that language patterns in the cerebral cortex can't be built when there are defects in sound-processing neural mechanisms, whether in the ear or in the pathways to the cerebral cortex. This creates defective "listening" mechanisms. Understanding language is far more than hearing the sound.

We visit family friends, and discover chatty three-year-old Morty to be half incomprehensible, yet his five-year-old sister Jennifer understands him well and when she perceives our discomfiture, steps in unasked to translate. She has learned his patterns; we have not. Regional speech is the same, except that in addition to unique pronunciation, letters, syllables, or even whole words, and words familiar to us may have peculiar meanings.

Instrument-flying air-traffic control chatter is something that many of us use. When we began work on the rating, what controllers said was hard to understand and remember. With training and experience, we learned the jargon. Perhaps just as important to understanding was the fact that we learned what to *expect*, which allows our brain to fill in the gaps that our ears don't catch.

When I tell the consulting dermatologist that our patient has for three weeks had a pruritic, bullous, non-inflamed centrifugal eruption, she understands exactly what I am seeing. You, as a pilot, should find this just as incomprehensible as if the dermatologist came to the gliderport and heard you complain that your new total-energy vario is too sensitive to lateral gusts.

Cognition.

The processes involved in the understanding and production of speech are located in various parts of the cerebral cortex, the outer layers of the brain. It was interesting to read that cortical speech-processing physiologic changes begin only 175 milliseconds after sound vibrates the eardrum. The complex acoustic analysis and pattern recognition required for listening is completed very quickly.

To see maps showing the complexity of speech understanding and processing and brain areas for speech recognition and production, search for images of "phonemic organization of the auditory cortex."

What we glibly call "learning" involves building a set of enduring physical networks at all levels of the brain – and once these are in place, they work with astounding rapidity. I'm sure we've all had the experience of thoughts flowing so fast that our mouth gets behind. Whole sentences and paragraphs are suddenly *there*, and we can't push them out as quickly as they form. In the jargon, this is called "pressured speech."

From hearing to understanding

The entire system by which we understand language is wonderfully complex and highly organized. The physical patterns of sound are analytically mapped, from the inner ear to the brain, where the bits of words we call 'phonemes' are physically arrayed. These are linked via memory to language and abstract concepts.

Sound entering the ear is first reduced to pitch, loudness, and duration. ☛

Differences in these, between the ears, permit localization of sound. The successive levels of the auditory system are designed to find and then to respond to patterns.

For example, the nerve leading from the cochlea, the auditory nerve, is organized like the rings of a tree – the fibers carrying low-pitched sounds are at the center and high-pitched sounds at the rim. (Search for images of "tonotopic organization" to see maps showing how this carries through to the cerebral cortex.)

For the engineers, it may be interesting that the auditory processing from the inner ear upward does a frequency analysis – essentially a Fourier Transform – at least at each of the first 3 levels.

The characteristics of a pattern determine whether it's mapped to a word, music, or an event. We instantly and concurrently parse the sounds in the kitchen to conversation, to the music playing, and to the soup boiling over.

Much of this patterning is built into the auditory system. But sound's "meaning" – its abstract and emotive qualities – are learned. In the physiological sense, music, language, abstract thought, and recognized events are built through learning, engraved biochemically in the brain's structure.

Throughout our entire life, we continue to learn and to forget, continuously revising the patterns we've built. In the jargon, "*plasticity*" describes the fact that our brains are continually remodeling as we learn and train, respond emotionally, and forget.

The brain's plasticity is greatest when we are young, yet is always present, even when we're senescent. (Though after stroke or with dementia, the damage may overwhelm this plasticity.) After the deaf are provided hearing with a cochlear implant, they cannot "listen" until the patterns of sound are learned, which takes a long time, just as any complex learning does.

It is not only the cortex that changes. The auditory pathways themselves are subtly altered through experience and learning, and even the responsiveness of the cochlea to sound frequencies can be somewhat adjusted.

What we do listen to affects what we are *able* to listen to, and even what we are able to hear.

Degradation and loss

Many things can damage our ability to listen. The best recognized is the loss of hearing acuity – earplugs, for example. Or ear wax, or a ruptured ear drum. These decrease the apparent loudness of sound, altering its characteristics only a little.

Hearing is *damaged* by loud noise. Sound is physically parsed by frequency in the helical and spiral cochlea of the inner ear, where vibrations cause cilia – hair cells – to move in response to particular frequencies.

It's traditionally taught that noise-induced hearing loss involves destruction of the hair cells responding to the predominant frequency of the loud noise, and this is often true. Yet it's interesting that less-intense damaging sound may create reparable damage to the hair cells and yet, for some reason, destroy the nerve-ganglion cells that innervate them and relay signal to the brain.

The result of such damage is that *patterns* are incomplete, and thus more difficult to process and recognize. Even if we make the speech louder, by shouting or with an aide, the notch in the pattern remains. In this situation, distracting or irrelevant sounds degrade the pattern more than if our hearing were normal.

Even if we can amplify only the frequencies that are degraded, if the auditory ganglion cells are kaput, the increased volume can't help: you can't flog a dead horse.

This is why hearing aids don't always help understanding.

Training and practice for listening

The most effective way to prevent hearing loss is to avoid loud noise, and to wear effective hearing protection when we cannot.

Regardless of whether we have hearing loss, the best way to improve our ability to *listen* is to practice. The act of listening engages the brain's plasticity – it self-improves the brain. We learn a language or professional jargon by listening repetitively. If we do have hearing loss, the best compensation is to seek out repeatedly the conversations and messages that we need to hear.

Going into a shell is more comfortable, but without practice (due to the brain's – shall we call it *negative* plasticity?) we lose pattern-recognition ability. Practice improves skill at everything we do; at work, at play, in the air, or using language. Listening and speaking are truly different skills, and both need practice.

Factors that contribute to listening

To summarize, here's a list of some of the most important contributions to understanding:

– brain plasticity (training, experience)

Familiar words and phrases are understood well with fewer cues

– Brain injury and degeneration (e.g., "semantic dementia")
– Loss of acoustic ganglion cells
– Loss of hair cells
– Genetic differences
– Nurturant-experience differences

Further reading
(Highly technical.)

Cochlear Hearing Loss: Physiological, Psychological and Technical Issues, Second Edition, Brian C.J. Moore, 2007, John Wiley & Sons, Ltd.

Print ISBN: 9780470516331
Online ISBN: 9780470987889
DOI: 10.1002/9780470987889

This work focuses on problems of the inner ear and the utility of hearing aides and cochlear implants. It does not review the cortical organization of speech-processing or music.

Clinical Neurophysiology of the Vestibular System, 3rd ed. R. W. Baloh and V. Honrubia.

2001. New York: Oxford University Press.

This is the classic work in the field. There are more recent texts with the same title.

Handbook of Clinical Neurophysiology, Vol. 10.

Disorders of Peripheral and Central Auditory Processing

Ed. Gastone G. Celesia. Elsevier, 2013
ISBN: 978-0-7020-5310-8

A recent academic review of the physiology and disorders of hearing.