Study shows that eye movements decrease while effortfully listening to speech

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Unsplash, Mark Schulte.

After a certain age, approximately 40% of people experience some degree of hearing loss. While age-related hearing loss is most prevalent in adults over the age of 65, it can start occurring far earlier than that,

when people are in their 40s or 50s.

Despite their widespread use, existing diagnostic techniques might be unable to detect earlier signs of hearing loss, such as the loss of the ability to hear speech in crowded or noisy environments. Some researchers have thus been trying to devise viable techniques to detect subtler forms of hearing loss, so that they can be addressed early, before they are irreparable.

To this end, two neuroscientists at the Rotman Research Institute in Canada have recently been exploring the relationship between effortful listening and eye movements. Their most recent paper, published in *The Journal of Neuroscience*, suggests eye movements tend to decrease while young adults are placing greater effort in trying to hear speech.

"We typically diagnose hearing loss using pure-tone audiometry, involving a person listening to pure tones at different sound levels to determine the sound level at which the person can just hear a tone before it is too quiet; we call this point the hearing threshold," Björn Herrmann, co-author of the paper, told Medical Xpress.

"If the hearing threshold is too high, meaning that the level of a tone must be relatively intense for the tone to be heard, we would possibly prescribe hearing aids. However, age-related hearing loss develops gradually over time, often starting when people are in their 40s or 50s."

In their 40s or 50s many people start to experience difficulties in understanding speech in noisy environments, such as crowded restaurants, malls, and other public places. These hearing difficulties are often the precursors of more significant hearing loss that occurs later in life.

"Pure-tone audiometric thresholds are not very indicative of such speech-

in-noise perception challenges at the early stages of hearing loss," Herrmann explained. "As a result, we typically diagnose hearing loss (using pure tone audiometry) a decade or two after first signs of speech perception difficulties emerge."

To identify hearing problems sooner, researchers have been trying to develop additional diagnostic tools that are better at capturing the subtle aspects of a patient's hearing. These include physiological signs suggesting that a person is placing greater effort while trying to discern speech in noisy environments, as this might indicate that they are experiencing early hearing loss. If successfully identified, these measurable physiological indications could help doctors to better assess hearing loss, both in new patients and after in patients who underwent hearing loss treatments (i.e., to evaluate the treatments success),

"Researchers and clinicians would like to measure listening effort objectively, which typically means using physiological responses, because asking a person how effortful they find listening can be influenced by their specific meaning of the word effort," Herrmann said. "People may also find it hard to separate how much effort they exerted from how well they were able to comprehend speech. While it is certainly important to understand a person's subjective experiences, objective measures are seen as advantageous in clinical and research contexts."

Past studies highlighted several different physiological responses that occur while one is effortfully listening. One that is commonly mentioned in existing literature is a change in pupil size, which can be measured using pupillometry, a technique that relies on a camera to record eyes and calculate the diameter of pupils at different points in time.

"We have known for a long time that the pupil size increases when a person is investing cognitively, for example when they have to keep

many numbers in memory," Herrmann said. "A lot of research over the past decade also shows that the pupil size increases when listening to speech is effortful, for example, when speech is masked by background noise.

"The problem with measuring the pupil size is that it is very sensitive to changes in light (i.e., our pupil gets smaller when our environment gets brighter and vice versa). The measurement of the pupil is also affected by the angle of the pupil relative to the camera that measures it, such that pupil size appears to change without actually changing when a person looks to the left or right, which is why participants typically fixate on a fixation point in the middle of a screen while listening to speech."

Ultimately, measuring the size of a patient's pupils during a hearing test does not appear to be ideal, as several factors could confound the results of the test. Therefore, Herrmann and his colleague M. Eric Cui set out to identify an alternative strategy to detect effortful listening.

"There has been a little bit of work in non-hearing related research areas that show that eye movements may indicate when a person is cognitively taxed, for example, keeping many numbers in memory," Herrmann said. "People's eye movements decrease under such cognitive challenges. We thus wondered whether eye movements may also indicate cognitive challenges during listening, that is, listening effort.

"Moreover, research investigating the auditory cortex in animals—that is, the brain region responding to sound—found that when animals reduce their movements, the auditory cortex becomes more sensitive to sound. We thus thought that reduced eye movements could also be associated with higher auditory sensitivity to speech."

To test their hypothesis, Herrmann and Cui conducted a series of experiments involving 26 young adults, between the ages of 18 and 35.

Their objective was to determine whether these participants' eye movements decreased while they were listening with greater efforts.

"Participants who came to our lab sat in a comfortable chair inside a sound booth," Herrmann said. "They rested their head in a chin rest, which helps stabilize the person's head, and faced a computer monitor. They also wore headphones over which we played spoken speech. We used an eye tracker, a camera-based device that can track a person's eyes, to determine where participants looked on a computer screen."

The researchers' experiment spanned across different trials. Throughout these trials, the participants listened to sentences and spoken stories on a set of headphones, yet in every trial they observed something different on the screen in front of them, such as a stationary dot, a moving dot, several moving dots, or a blank screen. By changing their object of focus, the team hoped to determine whether changes in the participants' eye movements occurred irrespective of what they were looking at.

"Participants were told that they could look wherever they liked on the computer screen," Herrmann said. "The critical manipulation was the degree of speech clarity. Sentences and stories were played either with very minimal background noise that would require little effort for the participants to understand what is said or with severe background noise for which speech comprehension required a lot of effort. While participants listened to the speech, we recorded their eye movements."

In their analyses, Herrmann and Cui focused on two different aspects of eye movements, known as fixation duration and gaze dispersion. The first is a measurement of how long a person's eyes remain fixed on a given object or point, while the second quantifies how often a person moved their eye across the screen.

"We found that under the more effortful listening conditions, that is,

when the degree of speech masking through background noise was high, individuals' eye movements decreased as reflected in longer fixation durations and reduced gaze dispersion, compared to more favorable listening conditions," Herrmann said.

"We show this for simple disconnected sentences, the type that is commonly used in clinical contexts, as well as for spoken stories, which reflect more naturalistic speech we encounter in everyday life. We also show the reduction in eye movements when listening is effortful for the different visual presentation conditions."

Overall, the findings gathered by the researchers highlight the potential value of using eye movement recordings to determine how much effort one is placing on listening under different conditions. In the future, this measure of effortful listening could be used to create new tests to detect hearing loss in clinical settings.

"Our study and another study published around the same time as ours are the first to show that listening effort is associated with reduced eye movements," Herrmann said.

"However, we still need to better understand how changes in eye movements relate to changes in pupil size under listening effort. Perhaps both measures capture different facets of listening effort, for example, a more automatic vs. a more voluntary physiological effort response. This would enable us to capture listening effort more exhaustively."

In their next studies, Herrmann and Cui would also like to explore the mechanisms underpinning a reduction in eye movements, to better predict challenges that would promote such a reduction. In addition, they plan to further explore the link between eye movements and effortful listening, so that they can identify and account for differences in "listening efforts."

Effortful listening, in fact, might not always be linked to hearing loss. For instance, people might place greater effort while listening to speech in a language that they do not speak fluently, or while processing syntactically complex or ambiguous sentences.

"In our initial work we only investigated eye movements in younger healthy adults," Herrmann added. "From a clinical perspective, the next steps are certainly to investigate whether eye movements also indicate listening effort in older adults, because this is the population for which our new approach may be most useful. Moreover, we plan to investigate whether eye movements indicate reduced listening effort when individuals are treated with hearing aids; as this could help to assess how much a person benefits from their hearing-aid prescription."

More information: M. Eric Cui et al, Eye Movements Decrease during Effortful Speech Listening, *The Journal of Neuroscience* (2023). DOI: 10.1523/JNEUROSCI.0240-23.2023

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