The many benefits of Edge Mode+: A multiplicity of measures reveal improved performance in hearing aid users

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Introduction

While over 80% of hearing aid users are satisfied with their hearing aids, understanding speech in noise remains one of the greatest challenges for them *(Picou, 2022)*. Modern digital hearing aids have sophisticated adaptive and automatic signal processing algorithms, such as directional microphones and noise reduction strategies, for handling noise in everyday listening. However, listening in certain noisy scenarios can still be difficult. Thus, an on-demand option is desirable to provide additional signal processing to help the listener in these scenarios. Edge Mode+, Starkey's advanced on-demand processing feature, is designed for this request.

Edge Mode+, when activated, prompts the hearing aid to classify the listening environment and apply additional specialized setting changes, which may improve user outcomes in realistic, noisy scenarios *(Fabry & Bhowmik, 2021)*. These specialized setting changes are specific to the listener's current environment as well as the listener's intent if using the My Starkey app for activation *(Figure 1)*. For example, a listener wanting to hear people more clearly might select Edge Mode+ Enhance Speech, while a listener wanting even more comfort in noise might select Edge Mode+ Reduce Noise.

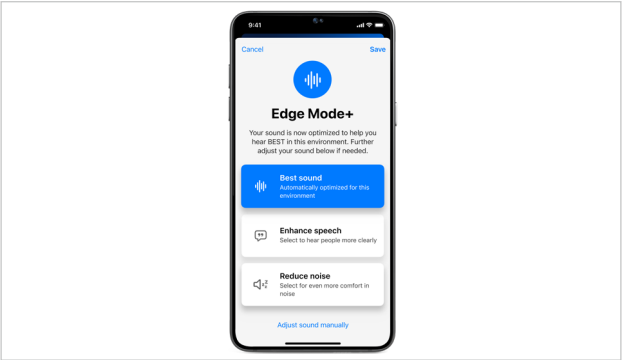

Figure 1: Edge Mode+ with listening intent as displayed in the My Starkey app

These classification and adaptation schemes were derived via machine learning and Deep Neural Network (DNN) processing, in which models were trained on a large number of real-life sound recordings, and further refined via input from both practitioners and listeners.

To understand the benefits of these setting changes in processing to hearing aid users, we completed a laboratory study to evaluate the effect of Edge Mode+ on speech-in-noise performance. Three outcome domains were examined: (1) speech understanding, (2) perceived task demand, and (3) vocal reaction time (VRT).

Methods

Twenty experienced hearing aid users with sensorineural hearing loss (10 female, 10 male) participated in an in-lab study. One additional participant was tested but removed from the dataset for failure to complete demographic assessments.

	Mean *(standard deviation)*	**Range**
Age	70.7 years *(10.5 years)*	42 to 85 years
Four-frequency pure tone average (PTA) of poorer ear *500, 1000, 2000, 4000 Hz*	43.0 dB *(14.5 dB HL)*	11.7 to 61.7 dB HL
Revised Hearing Handicap Inventory (RHHI) score Maximum possible score: 72 points	22.1 points *(12.4 points)*	0 to 48 points

Table 1. Descriptive demographic information for 20 participants

Participants were fit with the Starkey Genesis AI 24 receiver-in-the-canal (RIC) devices with acoustically appropriate coupling (open fits = 9 participants, occluded fits = 11 participants). Descriptive demographic information about the participants is presented in Table 1. The Revised Hearing Handicap Inventory (RHHI) was administered to measure participants' perception of the impacts of their hearing loss on their day-to-day life. The RHHI is scored out of 72 points, with higher scores indicating greater impacts of hearing loss.

Two conditions were tested: listening with default hearing aid settings, and listening with Edge Mode+ Enhance Speech enabled. In each condition, participants were asked to repeat IEEE sentences presented in a noisy restaurant background. The noise, on average, was 63 dB SPL and was presented from 7 loudspeakers encircling the participant from 45 degrees to 315 degrees, at 45 degree intervals. The speech was presented from the loudspeaker directly in front of the participant (0 degrees). For listening evaluations, the speech material was presented at a level such that the participant achieved approximately 70% words correct in the default hearing aid settings condition. At this level of speech performance, listeners would invest a significant amount of effort to understand the speech. Participants' spoken responses were recorded and analyzed offline. After that, participants rated their perceived task demand using a scale ranging from 0 ("Not at all") to 100 ("Extremely") in increments of 10.

The question was, "How mentally demanding was the speech task?". Participants circled or marked their answer. This subjective effort rating scale was based on the NASA-Task Load Index (TLX) developed by Hart and Staveland (1988).

In addition to speech understanding and perceived task demand, another outcome of this study was vocal reaction time (VRT). VRT is a behavioral listening effort/speech processing measurement where faster participant responses to stimuli may indicate less cognitive effort used to complete speech processing *(Meister et al., 2018)*.

Results – Speech Understanding

The percentage correct scores were computed and subsequently transformed into rationalized arcsine-transform units (RAU) to allow for parametric statistical analysis *(Studebaker, 1985)*. RAU scores align closely with the respective percentage correct scores within a score range spanning approximately 20 to 80. With default processing, mean speech understanding scores were 62.7. With Edge Mode+ Enhance Speech enabled, mean speech understanding scores increased approximately 8 points to 70.8 RAUs.

Thus, Edge Mode+ Enhance Speech resulted in an improvement in speech understanding over default hearing aid settings *(Figure 2)*. When RAUs were analyzed statistically, this increase was found to be significant (one-sample t-test of differences from default condition, $t(19)=2.55$, $p=0.02$).

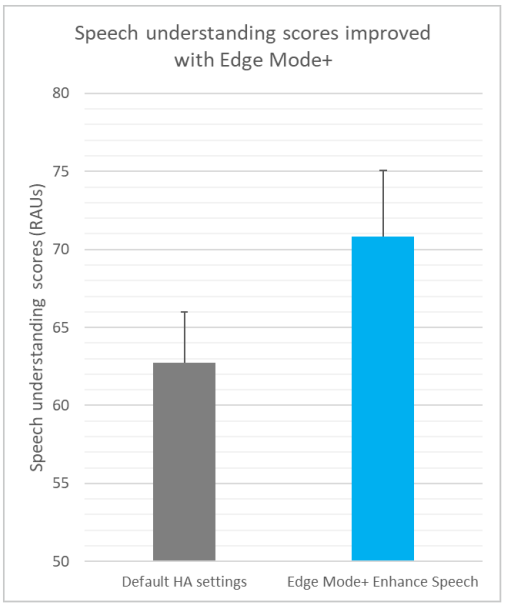

Figure 2: Mean speech understanding scores (transformed into RAUs) for the two listening conditions. Speech scores significantly improved when Edge Mode+ Enhance Speech was enabled. Bars indicate standard error.

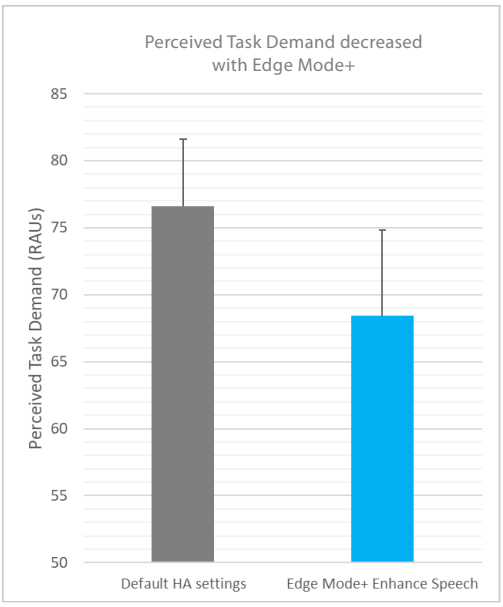

Figure 3: Mean perceived task demand ratings (transformed into RAUs) for the two listening conditions. Mean rating decreased when Edge Mode+ Enhance Speech was enabled. However, this difference was not statistically significant. Bars indicate standard error.

Results – Perceived Task Demand

As with the speech understanding outcomes, perceived task demand ratings were transformed from the 0-100 scale into RAUs to allow for parametric statistical testing. With default processing, participants provided an average rating of 76.6 RAUs for the perceived task demand. With Edge Mode+ Enhance Speech, participants provided an average rating of 68.4 RAUs. Thus, Edge Mode+ resulted in an approximate 8-point decrease in perceived task demand over default hearing aid settings. Figure 3 depicts the difference between the two hearing aid conditions. When RAUs were analyzed statistically, this decrease in perceived task demand was found to be not significant (one-sample t-test of differences from default condition, $t(19)=1.58$, $p=0.13$).

Results – VRT

VRT was measured as the time (in seconds) between the offset of the stimulus and the onset of the participant's response *(Meister et al., 2018)*. Prior to analysis, trials in which participants reported zero keywords correctly were removed (n=83 of 800 trials, 10.4% of the data). Removing incorrect responses is typical for reaction time analyses. Of these removed trials, approximately 45% were from the Edge Mode+ Enhance Speech condition, and 55% from the default processing condition. The average number of trials removed per person was 4 trials.

With default processing, mean VRT was 1.048 seconds. With Edge Mode+ Enhance Speech, mean VRT was 0.963 seconds. Thus, Edge Mode+ resulted in an 85 ms decrease in VRT compared to default hearing aid settings *(Figure 4)*. When analyzed statistically, this decrease in VRT was found to be significant (one-sample t-test of differences from default condition, $t(19)=2.92$, $p=0.009$).

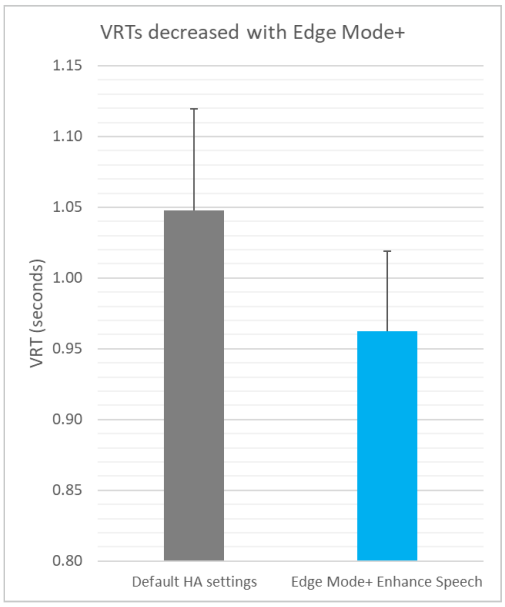

Figure 4: Mean VRTs (in seconds) for the two listening conditions. VRTs significantly decreased (i.e., speeded up) when Edge Mode+ Enhance Speech was enabled. Bars indicate standard error.

Results – Multiplicity of Measures

How do the three outcome measures relate to one another, within each participant? The three measures were mapped onto one another using a color-coded grid *(Figure 5)*. The x-axis plotted change in speech understanding accuracy with Edge Mode+, with 0 indicating no change from default settings, a positive value indicating improvement in speech understanding, and a negative value indicating a decrement. The y-axis plotted percent change in VRT with Edge Mode+, with 0% indicating no change from default settings, a positive percentage indicating an increase in VRT (indicating greater consumption of cognitive resources toward processing speech), and a negative percentage indicating a decrease in VRT (indicating a freeing of cognitive resources). Four colors were utilized: a gray circle indicated a participant for whom no change in perceived task demand was reported across conditions.

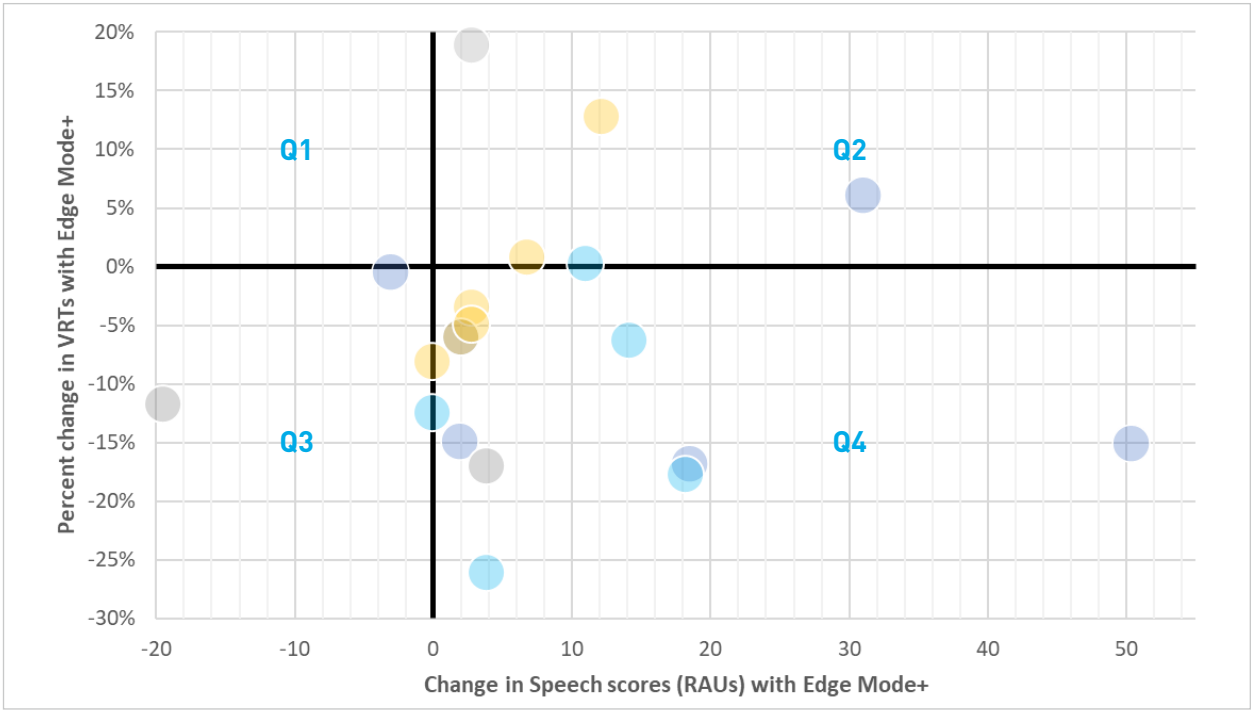

Figure 5: Visualizing the three outcome measures' relationships to one another. Change in speech understanding scores (in RAUs) and perceived task demand ratings (in RAUs), as well as percent change in VRTs, between default hearing aid settings and Edge Mode+ Enhance Speech were calculated. Change in speech understanding scores is plotted against percent change in VRT, while color indicates change in perceived task demand ratings. The four quadrants of this plot indicate Q1: No Benefit (reduced speech, increased effort); Q2: Mixed Benefit (improved speech, increased effort); Q3: No Benefit (reduced speech, reduced effort); and Q4: Benefit (improved speech, reduced effort).

A yellow circle indicated a participant who perceived task demand as increased with Edge Mode+. A light blue circle indicated a participant who perceived task demand as somewhat decreased with Edge Mode+ (reductions between 10 and 21 RAUs), while a dark blue circle indicated a participant who perceived task demand as strongly decreased with Edge Mode+ (reductions between 27 and 49 RAUs).

Q1: No Benefit (reduced speech, increased effort). If mapped to this quadrant, then one would have experienced increased VRT and decreased speech accuracy with Edge Mode+, indicating that less speech was understood with more cognitive resources used. This is a poor result. No participants in the present study were mapped to this section of the grid.

Q2: Mixed Benefit (improved speech, increased effort). If mapped to this quadrant, then one would have experienced increased VRT and increased speech accuracy with Edge Mode+, indicating that more speech was understood with more cognitive resources used.

This result indicates a mixed benefit; while participants are understanding more speech in noise, they must work harder, cognitively, to do so. Five of the 20 participants (25%) were mapped to this section of the grid. Interestingly, perceived task demand did not neatly align with increased VRT: only two of the five participants reported perceived task demand as increased. The remaining three participants reported either no change in, or a decrease in, perceived task demand.

Q3: No Benefit (reduced speech, reduced effort). If mapped to this quadrant, then one would have experienced decreased VRT and decreased speech accuracy with Edge Mode+, indicating that less speech was understood with fewer cognitive resources used. This result may indicate "giving up" on the part of the participant, another poor result, as it could indicate that processing provided by Edge Mode+ did not provide an opportunity to engage fully with the task.

Two of the 20 participants (10%) were mapped to this section of the grid. One participant reported no change in perceived task demand, and one participant reported decreased perceived task demand.

Q4: Benefit (improved speech, reduced effort). If mapped to this quadrant, then one would have experienced increased speech accuracy and decreased VRT with Edge Mode+, indicating that more speech was understood with fewer cognitive resources used. This is the most desirable result for any new processing strategy. Eleven of 20 participants (55%) were mapped to this section of the grid. Again, perceived task demand did not neatly align with VRT outcomes: in this quadrant, six participants reported decreased perceived task demand; three participants reported increased perceived task demand; and two participants reported no change in perceived task demand. (Note: a yellow circle and gray circle lie directly on top of one another in this quadrant).

On boundaries. Two of 20 participants (10%) experienced no change in speech accuracy across conditions, and thus were located on the y-axis itself. Both participants experienced a decrease in VRT, indicating that the same amount of speech was understood with fewer cognitive resources used. This is an encouraging result. Although the processing provided by Edge Mode+ did not boost speech understanding scores, it made the speech that was understood easier to process (used fewer cognitive resources). One participant reported an increase in perceived task demand, and one participant reported a decrease in perceived task demand.

Overall, perceived task demand ratings did not align with changes in VRT. Per Pearson correlation analysis of each participant's VRTs in each condition with their perceived task demand ratings, there was a positive but weak, non-significant relationship ($r=0.203$, $p=0.21$), in that slower VRTs tended to be associated with higher perceived task demand ratings.

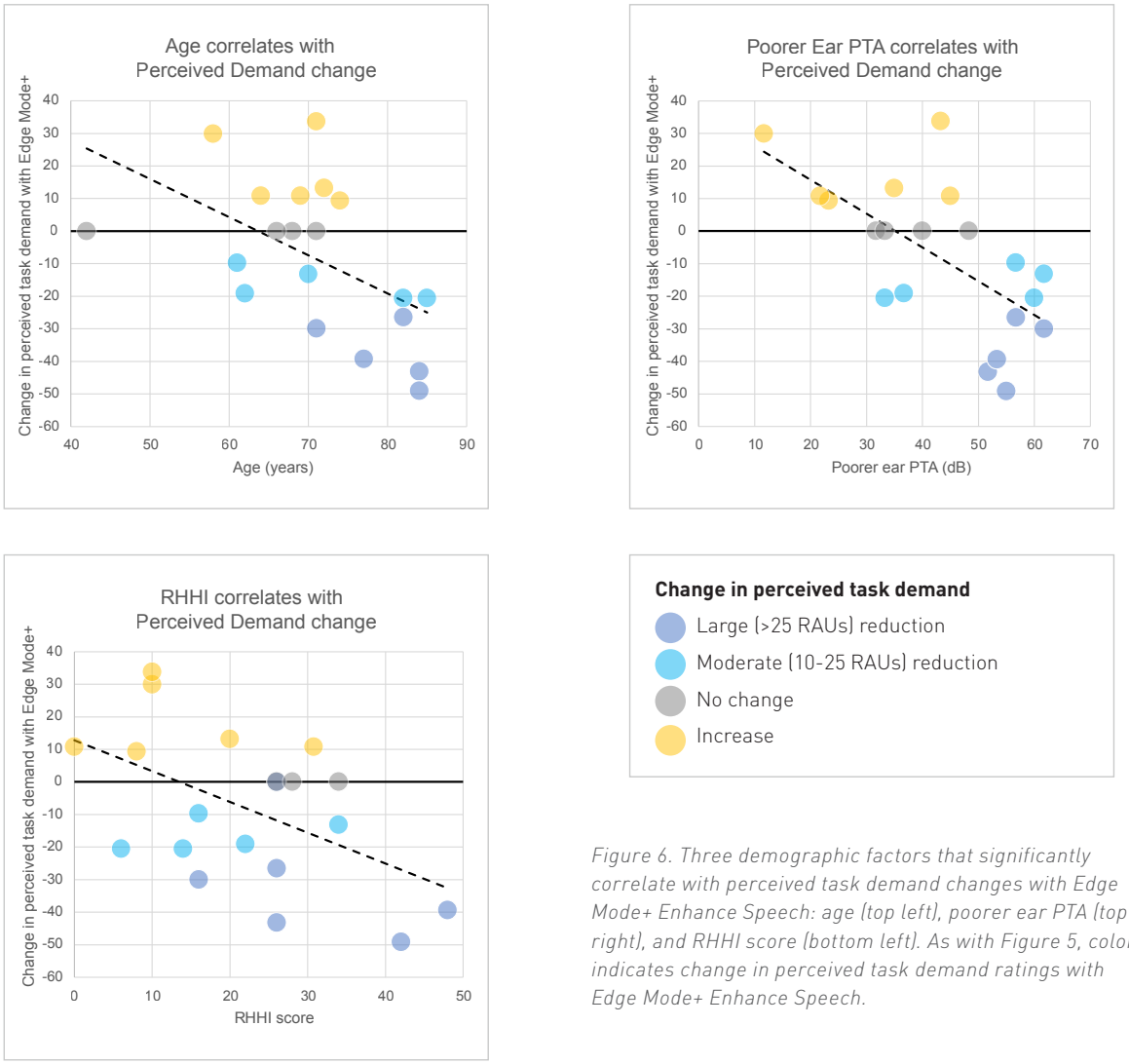

Figure 6. Three demographic factors that significantly correlate with perceived task demand changes with Edge Mode+ Enhance Speech: age (top left), poorer ear PTA (top right), and RHHI score (bottom left). As with Figure 5, color indicates change in perceived task demand ratings with Edge Mode+ Enhance Speech.

Impact of demographics

Whether demographics were associated with any of the outcomes of interest was assessed. Age, four-frequency pure tone average (PTA) at 0.5, 1, 2 and 4 kHz of the poorer ear, and perceived hearing handicap scores derived from the RHHI were found to correlate significantly with changes in perceived task demand with Edge Mode+ Enhance Speech *(see Figure 6)*. The largest decreases in perceived task demand ratings with Edge Mode+ Enhance Speech were among older participants (n=20, r=–0.534, p=0.015), participants with the largest hearing losses in their poorer ears (i.e., highest PTAs) (n=20, r=–0.652, p=0.002), and participants with the highest perceived hearing handicap scores (n=20, r=–0.508, p=0.022). No demographic variables correlated with changes in speech accuracy or changes in VRT across conditions. When it comes to listening effort, it is possible that changes in VRT are less related to demographic factors than subjective measures of effort like perceived task demand.

Conclusion

To summarize, on-demand processing like Edge Mode+ in realistic environments may provide broad benefits for listening effort and speech understanding in hearing aid users. That said, specific sub-groups may see larger benefits than others, specifically those with greater hearing losses and older ages. In addition, these results support using a multiplicity of measures when evaluating outcomes to gain a fuller picture of each participant's listening experiences.

References

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Author Biographies

Brittany N. Jaekel, M.S. Ph.D., joined Starkey as a research scientist in 2021. She earned her master's degree in Communication Sciences and Disorders from the University of Wisconsin-Madison and her Ph.D. in Hearing and Speech Sciences from the University of Maryland-College Park. Her research has focused on speech perception outcomes in people with hearing prostheses and the impacts of aging on communication.

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