A hearing aid rechargeable system designed for ease-of-use

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ABSTRACT

Users expect and value rechargeability in today's electronic products, including hearing aids. Advances in lithium-ion battery technology for medical device applications has made it possible to build rechargeable hearing aid systems with good battery performance that can support more than a full day's use from a single charge. Beltone Amaze offers a rechargeable model that has been designed to be convenient, aesthetic and easy to use. The rechargeable solution has been evaluated in field trials with users as well as in a structured usability trial it compared to other systems based on the same battery technology. The Beltone Amaze solution has been found to meet user requirements for battery life and functionality in everyday use. Compared to other solutions, the Beltone Amaze is also the easiest for users to set up and use.

Rechargeable electronic devices are everywhere today. Most of us are surprised to purchase a device that is not rechargeable, and rechargeability is also considered desirable by current hearing aid users and potential users. Until recently, the power supply for hearing aids has not been an area where significant development has been observed. Attempts to introduce rechargeable solutions have not enjoyed much success, as rechargeable battery technologies have not proven able to adequately power advanced functionality in modern hearing aids. A well-conceived rechargeable hearing aid system would not only be able to provide stable power for at least a full day's use of the hearing aids, it would bring numerous user benefits. Most obviously, the user would no longer need to buy batteries for their hearing aids. There would be no need to carry spare batteries or to worry about having to change them during the day. Not having to manage small batteries would also be a benefit if the rechargeable battery was built into the hearing aid. And, depending on the battery technology, a rechargeable solution can also be more environmentally friendly than zinc air batteries simply because so many fewer would end up being disposed of per year.

The Beltone Amaze introduces a rechargeable solution which provides all of these benefits. An enabling technology has been the emergence of lithium ion (Li-ion) batteries that have been designed to meet technical and safety requirements for use in a medical device. This battery type is already being used in many other medical devices such as surgical power tools, robotic cameras, and glucose monitors. Li-ion batteries have high capacity and support low voltages, which means they are suited to miniaturized devices like hearing aids. In addition, they have a very low self-discharge rate of typically less than 2% per month. Li-ion batteries are subject to rigorous testing standards to qualify for use in medical devices. As part of their safety and reliability, this battery features a self-management system that monitors internal values and makes decisions about how it should be treated by an external contact. As such, it protects itself against issues with voltage, current load and too-high internal temperature. Furthermore, it can communicate this information to the medical device and to an external charger. Among other things, this allows the user to get information about battery and charging status from the hearing aid, from the charger and from a smartphone app that communicates with the hearing aid.

The Beltone Amaze rechargeable solution

Figure 1 shows the Beltone Amaze rechargeable solution. It consists of a receiver-in-the-ear (RIE) hearing aid that can be fit with four receiver power levels covering a wide range of hearing loss severity. The hearing aid has a built-in Li-ion battery that is completely encased. An LED on the hearing aid shows charging status when it is in the charger, and LEDs on the charger give further information. The charger can be used as a stationary charger plugged into the mains or as a portable charger. It contains a rechargeable battery that can charge the hearing aids multiple times on one charge. The charger is small and light, and contains two compartments where the hearing aids can be placed for safekeeping and charging. Importantly, charging of the hearing aids is wireless using inductive technology. This means that correct placement of the hearing aids in the charger is easier for the user. From a technical standpoint, the lack of contact points on the hearing aids and charger mean more reliability, as contacts which are dirty or corroded can cause failures in charging. LEDs on the charger indicate power and charge status of the charger, as well as charge status of the hearing aids. A full charge of the hearing aids takes three hours, but there is also a quick charge mode that provides eight hours of use after only 30 minutes of charging. This is practical in cases where the user may have forgotten to place their hearing aids in the charger overnight. Battery status of the hearing aids is also available in the Beltone HearMax app for iOS and Android platforms.



Figure 1.Beltone Amaze rechargeable system features wireless charging in a small charging case that can be used as a stationary or portable charger. Hearing aid battery status can always be viewed in the Beltone HearMax app.

Evaluating the rechargeable solution

In designing the rechargeable system for Beltone Amaze, the goal was to create a solution of great utility and a high degree of usability. Utility refers to whether the product does what the user needs it to do, while usability refers to how easy and pleasant the product is to use. The classic example of the product with good utility but poor usability was the typical video cassette recorder (VCR), which was commonly used in homes in the 1980s through the 1990s. Anyone old enough to have had personal experience with a VCR will recall that, although most models offered a wide range of recording capabilities, many people found that programming them to record was difficult and ended up mainly using them for playback. To avoid the situation that users don't take full advantage of the capabilities of the rechargeable hearing aid system, great care was taken to specify usability requirements and to validate with users that these requirements were met.

One of the ways that the Beltone Amaze rechargeable system was tested was in the context of field trials, where users were fit with the hearing aids, and used them in their daily lives for a period of weeks. The data collected in this way was subjective in that users reported on their opinions on the usefulness, ease of use, and performance of the system. In one trial, 28 participants wore the hearing aids for two months. All strongly agreed with the statement that "The battery lasts all day". Several participants added the comment that the batteries lasted two or even three days on one charge. Based on technical measurements of battery performance and current drain, two days of use per charge would be usual, even including a significant amount of streaming from wireless accessories or Apple devices. However, since most participants placed the hearing aids in the charger each night, they did not experience how long the hearing aids would have run per charge. Regarding ease-of-use, 89% strongly agreed and 7% agreed that the rechargeable system was easy to use, while one person responded "neutral" to that statement. In general, users were very pleased with the rechargeable Beltone Amaze. Spontaneous comments that illustrate both benefit and performance included:

> "I got 2 days per charge on the hearing aids and the charger could go 8 days without having to plug it in."

> "Sometimes the hearing aids lasted 3 days."

> "I was skeptical but am won over. Loved not having batteries run out in the middle of a meeting or phone call!"

Testing for usability

Another way that the rechargeable system was validated was via more formal usability testing. This testing focused particularly on the charger and how well users could figure out how to set it up and use it. Because there is no user maintenance of the hearing aid battery itself, the charger and hearing aid/charger interface are the most difficult parts to consider in terms of designing for ease of use. Usability testing differs from the subjective evaluations done in the field trials in that participants are asked to perform representative tasks

with the product. The investigator observes what the participants do, where they succeed and where they have difficulties interacting with the product. The participants are not instructed or helped by the investigator in a usability test.

Methods

Three rechargeable hearing aid systems with integrated Li-ion batteries were evaluated. Apart from Beltone Amaze, two systems from other manufacturers were included as an industry benchmark for state-of-the-art rechargeable solutions. All three systems are portable with a built-in battery within the charger.

Ten adult hearing aid users participated in the test. None were owners of rechargeable hearing aids nor had they participated in Beltone Amaze field trials. This was important in minimizing bias and the strong learning effects there would likely be in using a rechargeable hearing aid system. The test was completed in one visit. Participants did not take hearing aids or chargers home to use them. Because it would be impractical to wait for hearing aids to charge and discharge, the tasks focused on setting up and using the charger. Participants were also asked about their expectations to feedback regarding charging status.

Test participants were administered the basic and advanced handling subscales of the Measure of Audiologic Rehabilitation Self-Efficacy for Hearing Aids (MARS-HA)[1] to get an impression of their self-efficacy in terms of managing hearing aids. They completed subjective ratings of each system's perceived ease-of-use and indicated which of the three systems they thought was easiest to use and which one was most difficult to use.

Usability tasks

The usability test was based on the "Hearing Aid Management Test" from Caposecco et al[2] but without access to user documentation and with tasks related to using the chargers. These tasks included setting up the chargers for use, placing hearing aids in the chargers, and removing the hearing aids from the chargers. Performance on each task was scored based on efficiency and effectiveness in completing them. Points were awarded for each task depending on the outcome:

- No difficulty: 2 points – test participant successfully completes the task within 30 seconds.
- With difficulty: 1 point – test participant successfully completes the task in less than 120 seconds but more than 30 seconds.
- Fail: 0 points – test participant fails to complete the task or takes longer than 120 seconds to complete the task.

Participants were not provided with any instruction from the investigator or any user materials such as operation manuals or brochures.

Participants were also asked the following questions regarding their expectations about charger function and status of charging:

- How do you know the charger is ready?
- How do you know the hearing aids are charging?
- How do you know the hearing aids are charged?

Results and Discussion

Figure 2 shows the averaged results of the MARS-HA, which is a measure of self-efficacy relative to using hearing aids. Self-efficacy is a type of self-expectation that refers to an individual's belief in his or her competence to perform a specific task or perform in a specific situation[3]. An individual with high self-efficacy believes that he or she will be able to succeed at a specific task or in a specific situation. Enhancing self-efficacy has been shown to produce better treatment outcomes within vision, arthritis, obesity, cancer, drug addiction and more[3]. On the MARS-HA questionnaire, participants are asked to state a percentage of certainty that they could perform certain hearing aid related tasks. The average scores were found to be high on all items, although there were several items where at least two of the participants indicated a low level of certainty that they could perform the task. These items were the top four on the list shown in Figure 2. Naming the make and model of a hearing aid was the item that participants were least certain that they could perform. Half of them indicated a certainty of 50% or less that they could do this. Based on these results, it was expected that participants should easily handle the usability tasks for all of the rechargeable systems evaluated. Furthermore, the consistency of the responses among the participants suggested that individual differences in self-efficacy would not complicate interpretation of the usability results.

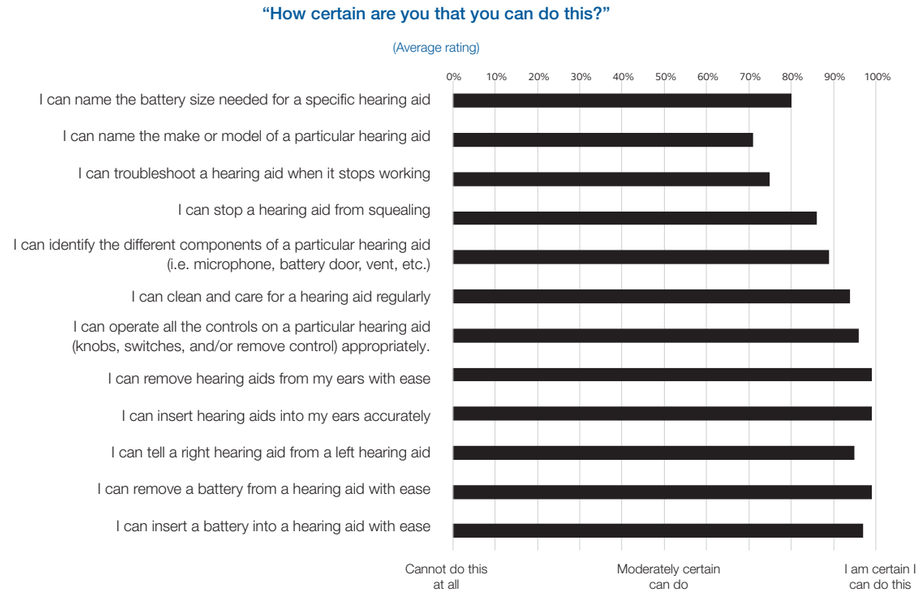


Figure 2. In general, participants in the test showed a high degree of self-efficacy relative to hearing aid tasks. There was most uncertainty regarding naming the make or model of a particular hearing aid.

Perceived ease-of-use

All three systems were rated highly in terms of ease-of-use, with Beltone Amaze and system A being the highest (Figure 3). Beltone Amaze and system A were selected as the easiest to use by an equal number of participants, while only one participant selected system B. In contrast, no participants selected Beltone Amaze as most difficult, whereas seven pointed to system B as the most difficult to use.

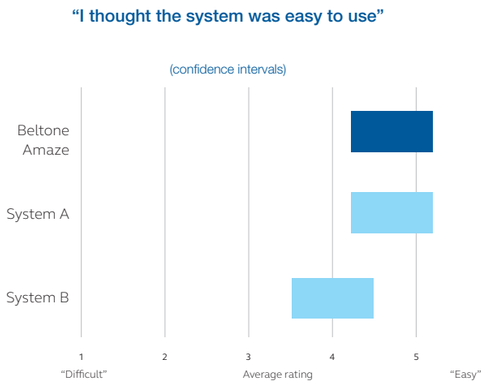


Figure 3. System B was rated significantly poorer in perceived ease-of-use. System B was named by seven participants as the most difficult of the three systems tested. Beltone Amaze was not named as most difficult by any of the participants.

Usability tasks

Figures 4 and 5 show the average points scored by participants in the tasks related to setting up the charger and placing the hearing aids in the charger. All participants scored maximum points for removing the hearing aids
from all of the chargers. Performance on setting up the chargers was equivalent for Beltone Amaze and system B. Performance for both of these chargers was better than system A. However, when placing the hearing aids for charging, participants did best with Beltone Amaze and system A. Performance with both was significantly better than with system B, although performance in general was more variable. This suggests that placing the hearing aids for charging was a more difficult task than setting up the chargers for use. The results for placing the hearing aids is also interesting considering the charging technologies. Both Beltone Amaze and system B have inductive charging whereas system A charges via metal contacts. Thus, although wireless charging should theoretically be the easiest for users, the actual design of the charger may make it more or less difficult. Performance with system A and Beltone Amaze was equivalent. However, because Beltone Amaze charging is inductive, there are likely to be fewer issues in real-world use, where corrosion or debris on the contacts might cause unreliable charging with system A. These results strongly support the usability of the Beltone Amaze system. Of

the three, it was the one where participants easily performed all three tasks with no instruction or guidance.

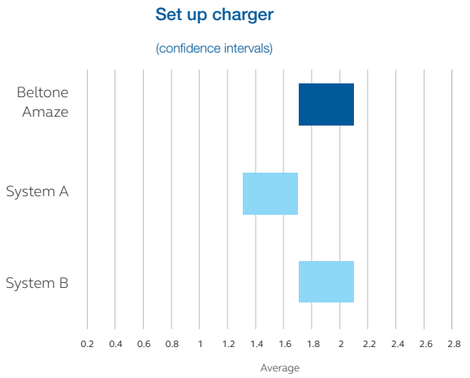


Figure 4. Beltone Amaze and system B were the easiest for participants to set up for use.

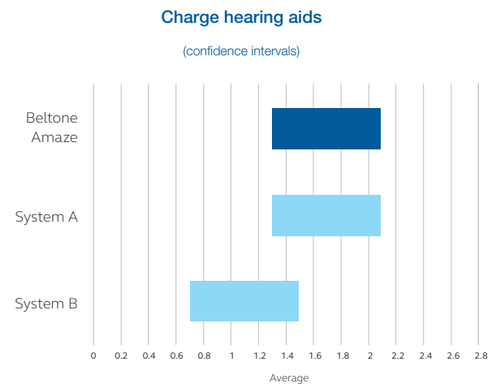


Figure 5. Participants had the most difficulty placing the hearing aids in the charger of system B.

Expectations on charger functionality and charge status

Regardless of the rechargeable system that was tested, participants gave similar responses to what visual feedback they would expect to tell them about charger and charging status. Nearly all expected a solid light on the charger when it was ready to use, a blinking light on either the charger, hearing aids or both when the hearing aids were charging, and a solid green or blue light when charging was complete. For Beltone Amaze, these expectations are in line with the actual LED indicators, which suggests that users would have minimal need to refer to the user documentation in order to successfully use the system.

Summary

Rechargeability for advanced hearing aids is enabled by medical grade Li-ion batteries that can be sealed in the hearing aids. This offers multiple user benefits and excellent battery performance. Furthermore, it provides better protection of vulnerable electronic parts and contacts in the hearing aids. Because of the smart battery technology, users get feedback on battery and charging status from the charger, from the hearing aid itself, and from the Beltone HearMax app for iOS and Android smartphones.

The rechargeable Beltone Amaze solution has been very positively reviewed by participants who used it in field trials. This is both in terms of battery lifetime as well as the functionality of the rechargeable system. Usability of the rechargeable system was also evaluated compared to two other Li-ion based rechargeable hearing aid systems. Participants were unfamiliar with rechargeable hearing aids and were not provided with user documentation to help them figure out how to perform the tasks. They demonstrated high performance on all usability tasks with the Beltone Amaze system, while performance varied depending on task for the other two systems. System A's charger was more difficult to set up but easy in terms of placing the hearing aids in the charger. In contrast, system B's charger was easy to set up but participants showed more difficulty in placing the hearing aids in the charger. The participants reported what their expectations would be in terms of visual feedback from the hearing aids and charger regarding status, and these were consistent with the product design. Taken together, these results point to Beltone Amaze as the most user-friendly rechargeable system.

References

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