High versus Low Technology Hearing Aids: What Drives User Preferences?

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Partner: Signia

-- [Susan] Hi, everyone, and welcome to today's course on high versus low hearing aid technology and what drives user preferences. My name's Susan Scollie, and I'm a professor in audiology at the University of Western Ontario's National Center for Audiology. And today I'm joined by Hasan Saleh, who is a PhD candidate here at Western and holds a masters degree in audiology from Queen Margaret University in Edinburgh. His research is focusing on the effect of different hearing aid features on users' preferences. In this project, we were also joined by Dr. Paula Folkeard, who was the study coordinator and had analysis help from Dr. Maaike Van Eeckhoutte and Dr. Danielle Glista. So thanks very much, and here we go. We have several learner outcomes that we're gonna try to acheive today. Participants should be able to describe after this course feature differences between currently available premium and entry-level hearing aids, some previous studies of hearing aid technology outcomes, and details of best-practice fitting protocols used in these studies.

After this course, participants should also be able to describe the outcomes that we got in our study, such as speech recognition, sound quality ratings that were associated with each hearing aid model, and also, to be able to describe the factors that drove the user preferences that we found in this particular study for either an entry-level or a premium hearing aid. So without further ado, we'll get going with the content. So as background, looking at high- and low-tech hearing aids, we know that today's consumer has a lot of choices when they're choosing hearing aid technology for themselves. And in this project, we wanted to try to understand that a little bit better. So we wanted to look at hearing aid outcomes, whether or not those are different between entry- and premium-level hearing aids when both are fitted following best practices. We wanted to look at hearing aid users' preference for one device over another if both of those devices have been set to provide good outcomes. So it's not that the entry-level device is doing a poorer job as a hearing aid, but what are the actual differences in the technology levels? We also wanted to understand the reasons behind user preferences and what is important to the people whom we serve. So in

terms of today's agenda, we are gonna go through some past studies. We're gonna tell you about the hearing aids and the technology levels that we used in this study. We'll give you a little bit of information on our fitting protocols and the results from our laboratory outcome measures. We'll then move on to talk about user preferences and a kind of analysis of that that gives us user preference maps that are pretty interesting, and the clinical implications for your practice at the end of this talk. So thanks for joining us again today, and we'll get going with all that. So looking at premium hearing aid features in terms of today's hearing aid products in 2020, there's a number of features that we know. This isn't everything, but it's certainly most of the factors that have to do with premium hearing aid technologies. So we know that people will pay more for hearing aids that have a smaller form factor, whether that's because the hearing aid is a RIC and the casing of the behind-the-ear hearing aid is smaller or whether it's an extended-wear device or a very small device that's meant to fit inside the canal. In addition, if we've got improved signal processing, so there's been advances to have the adaptive behavior be smoother and have better sound quality perhaps. There might be new technologies that we hope might improve noise reduction or that might improve the sound quality of hearing aids.

There might be a greater suite of accessories or advanced methods for compatibility and linkage with premium hearing aid features that have remote microphones, that have TV adapters, that have remote controls, and then in more recently introduced hearing aids, Bluetooth connectivity, direct link to smartphones. This can allow us to have one hearing aid linked to one another for bilateral linking. This can improve our ease of use by having the user just have to adjust volume control or program controls on one aid, and they get the changes in both. But it can also make meaningful improvements to directional microphone and beamforming capabilities by having the two hearing aids work as a team. Bluetooth connectivity can also allow smartphone or tablet connectivity, so access to audio streaming and stream phone calls directly to the hearing aid, but also can include having connectivity to apps that can provide more

sophisticated user controls beyond just a basic volume control and can also allow things like remote communication with the hearing healthcare provider. So these are a range of functions that are outside of how the hearing aid has set to provide basic amplification that might enhance the functionality of the device, the convenience of the device, the user experience with the device. But we don't really have a lot of information around how people see that in terms of whether they would prefer to have a hearing aid that includes those particular features. So if we look to the literature, there have been a few recent studies of high- versus low-tech hearing aids. Here's just a couple examples of studies like that that we'll just talk about today. So there's a set of three papers from the Memphis group, Cox et al. and two papers from Johnson et al., that are all papers from the same set of 45 adults who all had hearing loss, and they completed four trials. So they had two different brands, and all of these people completed trials with the basic level and a premium level from each of those two brands for a month each and a washout period in between.

So the general differences in that particular set of studies between the basic and the premium included things like more versus fewer channels, but all of them had directional microphones and noise reduction. They might have had more versus less binaural streaming capabilities and more versus less automatic adaptation. All of them had the same form factor. They were all mini BTEs with slim tubes. The fittings in these studies followed best practices. So they were all fitted to the NAL and NAL2 prescriptive target with real-ear measurement to verify and fine-tune. And all of the hearing aids were fitted with three manually available programs. There was one that was described as an everyday program, one that was described as a look-and-listen program, so the directionality was set to be fixed so that the person should look at what they wanted to listen to. And the third program would be more of an adaptive strategy with that that was described to the end users as a speech-finder program. So they tried to really standardize across these four hearing aids how the hearing aids were configured, how they were set up, and also to match them for the provision of

basic audibility. In this particular study, what we see is that, because they were all set using best practices, the aided benefit for speech recognition was similar and the performance was high across all of the hearing aids. So we had about 90% speech recognition for all four of those hearing aids. So that's good, that regardless of the technology level, we oughta be able to provide good basic audibility through best practices. There was a small improvement for localization in quiet for the premium version of brand B. So there, some evidence there that perhaps there's some improvement due to advanced signal processing in that brand. In terms of the real-world outcomes on questionnaire ratings and diaries and that sort of a thing, all of the hearing aids provided real-world benefit. So they worked as hearing aids in the real lives of these users. And they reduced listening effort, but there wasn't a measurable difference among the hearing aids on the measures used in this study. The use rates were nice and high, with more than nine hours a day of hearing aid use. And everybody reported improved quality of life with the hearing aid use versus without hearing aid use. So good outcomes in general. When they asked people if they preferred one of those four hearing aids versus the others, 42 preferred one or more of the hearing aids but their preferences were mixed and small.

So there was not really an overall message of preferring one brand or preferring one premium or one basic version of any of the brands. People had preferences, but they weren't a consistent message across this group of people out of the 45. A more recent study from Wu et al., and this was using 2013 hearing aids, so a little bit more recent than the 2011 hearing aids that were used in the previous set of three studies. They looked at one brand. They looked at two technology levels, so again, an entry level and a premium level, and in terms of lab measures, found a few differences. There was a little bit more benefit with premium features for speech in noise and for localization in those lab measures. So that's encouraging to see that there's some sensitive measurement of the technology advancements in this particular study. But it was a bit mixed, so paired comparisons found no difference between premium and basic on

most measures of listening effort and sound quality. But there were higher ratings for premium features for wind noise and higher ratings for basic and premium features in noise in general. So when we have noise management features turned on in either the basic or the premium devices in this study, we're seeing higher ratings there. They also performed real-world assessment of outcome using a smartphone-based method called ecological momentary assessment, which is really in-the-moment querying of the end user to say, how is this working for you now, and what would you prefer to be using right now, using the person's smartphone. There was preference for noise management features to be activated rather deactivated. And that was at either the premium or the basic level. So people have a measurable preference to have real-world use and activation of noise management.

So in summary, looking at those and other studies, it looks like we're not seeing a lot of results from premium versus entry level. And some of the things that we were talking about in planning this study was, does technology level really not matter that much? Or is it maybe how we're measuring it? So we see that lab measures are showing equivalent benefit on most but not all measures. We know from the literature that even the developers of the APHAB and others would say that it wasn't really designed for between-aid comparisons. It was really designed to look at benefit of getting a hearing aid versus not having a hearing aid. And the real-world questionnaires that are starting to emerge may help remove the effects of having to remember, or memory issues, in terms of using recall-based questionnaires. But what questions should we really be asking? So there's not a lot of questionnaire-type measures out there or that have been designed to say, which hearing aid do you prefer, one over the other? And we wanted to have a little bit of a better understanding of how people who use hearing aids themselves view those features. So we decided to embark on the study that we'll tell you about today, where we're looking at patient outcomes and also preferences with entry- versus premium-level hearing aids. And we know from the literature looking at user preferences that user choice decisions in hearing aid selections are typically

affected by a wide range of factors, not just the gain and compression and directionality and those types of things in the hearing aid but other factors as well. So we know that appropriate fitting practices and lab outcomes are still important. We wanna make sure that we've provided good hearing with the hearing aids that we're fitting. But non-audibility factors such as the form factor may actually matter a lot. And newer wireless access and apps are common features of today's premium hearing aids, and they haven't really but studies all that much yet. So our primary aim in this study was to look at these outcomes and these user preference factors for entry versus premium, using product profiles that actually generalize to the real between-product selections that users are making today when choosing hearing aids. So it may be the case that availability of an app or different form factor is part of what drives a hearing aid being considered an entry-level versus a premium-level hearing aid. And if we're standardizing those in our studies, we don't really get to see whether or not those matter to people. So our research questions included, will appropriately-fitted entry-level and premium hearing aids provide different perceptual outcomes? Can we actually produce better fittings with those premium hearing aids? And will appropriately-fitted devices that differ widely in overall product profile, what factors are related to user preferences for one aid or another?

So our participants were 23 people in total. And they were self-identified as smartphone owners so that they would be able to make use of the smartphone features of the premium aids in this study. And they had an average age of 62 with a wide range of ages and average experience of six years with hearing aids in a wide range of experiences. And their audiograms are shown here on the right. And the hearing aids that we used in this particular study were one premium set of hearing aids and one basic set of hearing aids. And the differences between them are listed here. One thing to be aware of is the form factor difference between the two. So in this particular product line from Signia, a normal product difference is that the basic hearing aid is a BTE that can be fitted with a slim tube or an earmold versus the

premium hearing aid, which would be fitted with a RIC. And the premium is also, it's fitted with a rechargeable battery system. So there are some really different form factor features of these two hearing aids that have necessarily to do with how we would program them what prescriptive method we might use with them but make them different to handle, make them different to use. But that's a real generalizable difference in this particular product family with, that's how the basic hearing aid is, and that's how the premium hearing aid is. So we wanted to keep that represented so that we could measure later whether or not there was a preference around those things. Internally to the hearing aids, the premium hearing aid has more channels. It offers Bluetooth linkage and binaural linkage. It has more microphone settings. It has more noise reduction settings and smoothing. It also has apps that provide an enhanced user control over the hearing aid and also a tele-practice access that are not available in the basic hearing aid. In terms of accessories, they're both available with a remote control. But the premium device includes TV adapter and remote microphone as well, if you want them, and as I said before, is rechargeable.

So there's a number of differences between these two different hearing aids over and above the signal processing capabilities. The study design is that after the people were assessed, they would be allocated to either the, to start the study on either the basic or the premium, which we called X or Y in this study. So we didn't label them to the participants as a premium or a basic. We just called them X and Y. They had three-week trials with each. They came in for outcome measures, and then a preference interview. And then they crossed over to the other aid, repeated all of that. And then in a final stage, they did a preference-mapping exercise that Hasan will talk to you about in a little bit. In terms of fitting, we did follow a best practices protocol. So we used insert phones for audiometry. We measured the real ear to coupler difference to assess ear canal acoustics. We used a set of validated targets in the form of DSL version 5 adult. And we verified and fine-tuned with the hearing aids fitted on the ear using calibrated speech signals and an Audioscan Verifit2 real-ear measurement

system. So an example of one of the actual fittings is shown on your right. What we did see is that, electroacoustically, there is an advantage to the premium device in this particular study. So remembering that the premium device was a receiver in the canal instrument, which, in theory, should provide an enhanced high-frequency response, there was a difference in the high-frequency response as follows. So there's a general smoothness to the blue curve that you see here, that is the RIC curve, compared to a little bit peakier, especially in the 1500 and 20, let me think, about 2700-hertz regions. You see a couple little peaks in the gray curve that are, that's the BTE fittings on average. The blue curve, which is the RIC fittings on average, is a bit smoother and extends further out into the high frequencies with about five more dB output in the four to six-k region. So there is a slight enhancement of the high-frequency response of the hearing aid fittings that we got at best fit to targets from this particular set of hearing aids that, it's consistent with even basic textbook information on the differences between BTEs and RICs. We measured a wide range of hearing aid outcomes with these particular studies. So that included consonant recognition in noise, sentence recognition in noise with a noise surround, sound quality ratings and loudness ratings, and that preference interview that we'll talk about in a little while. So just to go through the basic outcomes, we saw nice high speech recognition performance for a pretty challenging task of consonants in noise. So we had more than 75% recognition of consonants in noise with both hearing aids. And we had no differences between the basic and premium aided results.

So remember that both were set to have the same and good audibility. So perhaps that's not surprising. And that small increment in bandwidth from the RIC, although it's there, electroacoustically, it was not enough to cause a significant change in speech recognition between the two devices. We looked at sentence recognition in noise. And this was better with both aids when directionality was enabled. So on this type of test, low scores are good. So the lower the bar goes, the lower the score is. And on your left is the performance with the omni conditions. Here, and... So performance with omni

conditions here, directional conditions here, adaptive conditions here, and performance from normal-hearing listeners just for comparison over here. So what we see is, in the omni category, we've got full-on omni compared to some slightly different omni, like pinna-matched omni conditions, within the premium device. And those are giving us a slight benefit for sentence recognition in noise. And the directional conditions all outperform the omni-directional condition as expected. So we're seeing that both the entry-level and the premium-level device are giving us good speech-in-noise performance, with best performance in a directional mode. We also see that both hearing aids provided loudness within the normal range. So on the graph to your right, you see input level on the x-axis. And loudness ratings from zero to 100% on the y-axis. The slight dash lines are normal loudness range. And you see that with both the entry- and the premium-level hearing aids in this study, that their loudness ratings are right in the middle of the loudness range, meaning they have normal loudness perception. There was no significant in loudness growth results between the two technology levels. And the average matched-input level difference between the two was only .7 dB, meaning they were very, very similar. And recall that both these hearing aids were fitted, in fact, to the same target and verified for soft, average, and loud in our best practices protocol.

So again, perhaps this is not surprising that we actually matched the audibility between the two devices. In terms of sound quality ratings, or for clarity specifically, these were very high for speech in quiet for both aids. So notice on the y-axis, the ratings go from very unclear to very clear on a zero to 10 scale. And these hearing aids were all rated at a nine for omni-directional processing for speech in quiet. So they were rated as very clear in this particular study. And that was true both for omni and for directional. And then when we move on to omni and directional in noise, the sound quality ratings drop, because we've added to the stimulus, so it just doesn't as good. But it's still rated as a little bit higher than rather clear for both devices. So that ratings in noise being lower was expected. So again, we're seeing decent outcomes for both. And

we're seeing that noise brings down the overall sound quality as expected. So despite all those near-equivalent lab outcomes that I just showed you, the majority of participants, when we asked them, had a strong preference for the premium hearing aid. So on this graph, preference is shown on the x-axis. Number of participants is on the y-axis. And the tall blue bar on the left is the majority of our participants preferring strongly, or, in the next bar over, moderately the premium hearing aid. In fact, only four of our participants preferred the entry-level hearing aid. And we just noted that all of our entry-level choosers were all aged 68 years or older. So we decided to keep an eye on the role of age in this particular study. So we know that the gains were set to be similar between the two hearing aids, slight increase in high-frequency gain for premium. Speech recognition is essentially equivalent for consonants, for sentences. Loudness is equivalent and sound quality is equivalent between these two well-set hearing aids. But nonetheless, we're seeing a significant preference. So obviously, it's not about audibility. We controlled for that. So we asked them why. So with that, I'm gonna pass the torch over to Hasan to take over. And he'll talk to you about that stage of this.

- [Hasan] Now, in order to better understand and better answer the question of why there is a difference in preference between the hearing aids, I'd like to first discuss a little bit about how we assessed this difference in preference between the hearing aids and the hearing aid features. So we used a process, a methodology called group concept mapping. And group concept mapping is basically a process that uses statistical, quantitative methods to assess complex, intangible concepts. So in this case, what we did is that we used it to create a statistically derived visual representation, or a map of what it was that drove hearing aid preference in our participant group. So the first step of concept mapping is the brainstorming or statement generation stage. Now, during our trials, participants were actually recorded when they discussed what it was that they liked, disliked about the different hearing aids after each of their hearing aid trials. And they were also recorded when they were

discussing which hearing aid they preferred. So participants were then allowed, or encouraged, actually, to listen to the recordings of the previous appointments in order to refresh their memory and try to remember what it was that they liked and disliked about each of the different hearing aids. They were then given the focus prompt, "one thing that influenced my preference "for model of hearing aid was," and asked to complete that statement with as many ideas possible. So basically, they were given that prompt to read out, and then completed that statement with many different ideas. So each participant did this individually. So as you can imagine, there were quite a few duplicate statements. All of the participants, a lot of them gave similar statements. So the research team actually worked together in order to try to remove the duplicate statements to end up with only unique ones. And we ended up with 83 unique statements that finished the sentence, "one thing that influenced "my preference for one model of hearing aid was." Now, out of these 83, here are some of the example statements. So I'll start off with the prompt. One thing that influenced my preference for one model of hearing aid was how it makes my voice sound, hearing aid size, simplicity of use, the smoothness of sound, and the ability to contact the hearing professional through the app. And that's actually one of the premium features that's available through the smartphone tablet app available on the premium hearing aid. So now that we know a little bit of the statements that were provided, the next step is the sorting stage, or the sorting activity.

Now, the sorting activity is basically a drag-and-drop activity done by each participant individually, where they're asked to group statements based on common ideas. So what we asked them to do is to take statements that have a similar underlying meaning and place them together into a category, and then to name that category based on the meaning of the statements within. So an example that we like to give during the activity was based on cars, in order not to bias them with a hearing aid-based example. So in terms of the car example, we said that, let's say the focus prompt is, "one car feature which influenced my preference "for one car over another was," and the three

statements were soft leathered seats, comfortable padding on the seats, and a nice catchy color of a car. So out of those three statements, the first two, which is comfortable leather, soft leather and a comfortable seat, would likely be able to be placed into a comfort category, maybe, whereas a nice color could probably fit well into an aesthetics category. Now, moving on from there, any other statements that might fit into a comfort category would be placed in comfort, and anything aesthetics-based would be placed into aesthetics until all of the statements are categorized. So now that we've talked a little bit about the things to do, let's talk about the sorting don'ts. So participants were recommended not to group statements based on value or importance. While we are interested in the importance of the different statements and of the features that they represent, that's actually something that we're going to be looking at in the next step. So right now, in terms of this activity, what we want is to group statements based on their underlying meaning. As well, participants were asked not to group statements into miscellaneous or not applicable categories. Because that would place statements that are entirely unrelated to one another in the same category, and that would actually decrease the quality of our data going forward. So that's in terms of the sorting stage.

Now, for the rating stage, this is where we actually want to look at how important each of the statements, and thus the features that they represent, how important those were for each of our participants. So each participant was asked to rate all of the statements, and to rate them on a Likert scale, answering the question, how important is this factor when choosing a hearing aid? Now, the Likert scale can be seen down here. It's rated from one to five, one being not important and five being very important, or extremely important. So using the sorting information, the concept mapping software is actually able to create a two-dimensional point map. Now, the point map is basically a map that uses how likely they were, how likely the different statements were to being placed together during sorting in order to determine where they fit on the map and how far each of the points are from one another on the map. So let's take a look at

the map. And this is our point map. This has all 83 statements on it. And upon first glance, you might not get that much information from it. But there are a few observations that we can make. It's definitely clear to see that there are definitely statements that are more closely linked to one another, which would imply, according to the sorting stage, that these are statements with more similar underlying meanings. And thus, these statements have been grouped together more often in the sorting stage, as opposed to statements from across the map from one another, which would not have been sorted closely together during the sorting stage, or might have been sorted very rarely together. But as you can see, there's really not that much that you can get from the point map in its center form. So the next step would be to create the cluster map. Now, the cluster map is basically the statistical software partitioning the point map in order to better highlight the different clusters that we saw in terms of the point clusters. Now, once these clusters are partitioned, those clusters are presumably filled with statements that share an underlying meaning, because that's why they were clustered together to begin with.

So in the creation of the cluster map, researcher interpretation or researcher input is actually required, because there's many different cluster solutions that are available. And the researchers in this study actually unanimously decided on a cluster solution that was most appropriate for our data set. Now let's take a look at the cluster map. So as you can see here, these are the nine clusters that our data provided. You can see that the statements within, so all of the statements that were in the point map can be seen in this cluster map. And the statements within each of the clusters, you might be able to recognize the statements clusters that we saw earlier in the point map and how they made their own clusters here. So the clusters that we ended up with, the nine, are comfort and appearance, feedback, sound quality and intelligibility, multi-environment functionality, streaming, user-controlled DSP, which app-based, convenience and connectivity, ease of use, and complex factors. I'm going to go into all of the clusters a little bit more in depth and discuss what some of the example statements within each

are. But I'd like to draw your attention to the complex factors cluster, which is, as you might notice, centrally located and does not have that many points in it. So just remember that it is centrally located, because I'm going to be discussing this cluster a little bit more in depth than the rest as well. Now let's take a look at, and sorry, let me actually put a marker on the complex factors. So this is the one that I'd like to point your attention to. Now let's move forward and take a look at the comfort and appearance cluster and some example statements within. So the comfort and appearance cluster is quite a straightforward cluster. It's related to physical comfort caused by the hearing aid and how the hearing aid looks, pretty much. So a couple of example statements from within this cluster are how well it sits in the ear and the ease of putting the hearing aids into the ears. Moving on to the feedback cluster, the feedback cluster is related to the auditory feedback caused by the hearing aid, how it the participants feel, and management of that auditory feedback. Now, some example statements here are less embarrassment from feedback at work and how much feedback is caused by my hair. Next up, let's take a look at the sound quality and intelligibility cluster, which is related to how clear or how good sound is from the hearing aids and how well the hearing aids allow the user to hear speech.

Some examples here are better music quality and the audibility of high-pitched sounds. Now, moving on to multi-environment functionality, multi-environment functionality is a cluster that's related to, the underlying meaning of this cluster is pretty much that the hearing aid works well in many different auditory environments, so it's quite reliable in these different environments. Now, some example statements from this cluster are the default adaptive program gave better understanding in noise, the directional microphones of the hearing aids worked well, and having a live music program. The live music program is one of the multi-memory programs that is available to the premium hearing aid, which is designed for listening to live music being played. Now let's take a look at user-controlled DSP. So the user-controlled DSP app cluster is actually one of the mainly premium hearing aid clusters, which revolves around having

a smartphone/table app that allows the user to modify or change their digital signal processing. So they're able to adjust volume and clarity through the app, as well as they have access to the phone app's directionality steering feature, which is a feature on this app that allows the hearing aid user to change the directional microphones that are in use in order to change how the hearing aid's directionality performance is. Now, another primarily premium hearing aid-related cluster is the streaming cluster. And this cluster is related to streaming sound, be it music or phone calls, directly onto the hearing aids through Bluetooth. So some example statements here are the ability to listen to music directly into my hearing aids, and the ability to rely on hearing with the hearing aids when streaming phone calls. Now let's move onto the convenience and connectivity cluster. Now, this cluster has two primary focuses. One is convenience caused by accessory compatibility. And the other is connectivity through the smartphone tablet app to the hearing professional, which, in this case, was us, the researchers. So some examples of this cluster are Bluetooth compatibility, having remote control compatibility, the ability to contact the hearing professional through the app, which is a feature that we mentioned earlier, and the ability to have a fitting done remotely with remote changes.

So that's a premium hearing aid feature where we were able to actually send changes to the person's phone through the app, and then through Bluetooth, those are downloaded onto the hearing aid. So quite interesting stuff. Now, the ease-of-use cluster is quite straightforward as well. It's mainly related to quality of life and just general ease of use. So some example statements here are having a recharging feature and overall ease of use, that the hearing aids are not too technically complex to use. Now let's move on to complex factors, which is the cluster that I drew your attention to earlier. Now, if you remember, it is quite centrally located. And upon first glance, you might notice that, hey, this cluster is different than the others, because it doesn't have as many statements in it. And the statements don't, at first glance, have any inherent connection between them. So let's talk about what the statements are, and then I'll

discuss why, what the content of the statements really dictates why it is centrally located and why it is a complex factors cluster. So the statements here are the amount of frustration caused by the hearing aid, not having to try and physically find the right place to hold the phone to the ear during phone calls due to Bluetooth streaming, noticeable changes when switching programs, and the ability to wear a helmet within feedback. So taking a look at the amount of frustration caused by the hearing aid, one thing to note is that this cluster, or this statement, sorry, can easily be placed in many different clusters, depending on the participant's own experience with hearing aids and their own interpretation of the statement. For example, one participant might think, "I find feedback quite frustrating, "so I'm going to sort it, "during the sorting stage, with feedback." Another might think that, "I find physical comfort important "and physical discomfort frustrating, "so I'm gonna sort it with physical discomfort." Now, statements that are heavily sorted with different clusters or different areas of the map tend to move towards the middle. It's because they are linked to many different statements that actually places them into a central location on the point map. So as you can see with this example is that because this statement is easy to place in different areas of the map, it would have been placed centrally based on, and choosing where to sort it is dependent on user experience. It is a complex factor.

So let's move on to not having to physically try to find the right place to hold the phone due to Bluetooth streaming. This is very similar to the previous statement, because some participants might place it in Bluetooth streaming, or streaming, in the streaming cluster, whereas other participants might place it in feedback, because the lack of this feature might cause feedback. So again, this is a feature that is not quite as easy to place. It's quite more complex. So its placement is more centrally located. The ability to wear a helmet without feedback is another such statement, where some participants might place it in the feedback cluster, whereas other participants might find that the ability to wear a helmet is a physical feature, so it is placed, it can be sorted into the physical comfort cluster. Now, the fact that it's heavily sorted to both places it centrally

as well. Lastly, let's take a look at the noticeable changes statement within this cluster. So noticeable changes when switching programs upon first glance might seem like it's a positive, but actually, interestingly, the participant who suggested it to us suggested it as a negative, because they found that those noticeable changes were quite distracting, and they preferred it to be a bit soother. So this statement, again, could be placed within maybe speech intelligibility. It could be placed within the multi-environment functionality cluster. Or it could be placed within the ease-of-use cluster. So knowing that, you can see that the link, the link and meaning between these statements that put them into this cluster that is centrally located is that their interpretation is really dependent on hearing aid user experience and what the hearing aid users interpret from each of the statements based on their experience. So that's what makes them complex factors. That is really dependent on the hearing aid user. So now that we know a lot about the clusters and what's in the clusters and our cluster map, let's see if we can make the map a little bit more informative. It is quite interesting as it is, but we still haven't incorporated any of the importance rating information onto it. So by incorporating importance information onto the cluster map, we get something called a cluster rating map. Now, a cluster rating map, which I'll show you in a second, looks very similar to the cluster map, except the importance rating is also displayed. Now, this can be conducted on either the entire group of participants, so overall, or you can select different subgroups in order to assess visually the differences between them. So let's take a look at our cluster rating map.

So as you can see, it looks very similar to our cluster map. It's got the same clusters when you compare the overall participant group. But you might notice that some of the clusters are thicker than others. Now, this is our legend here. The cluster ratings each have an average between one to five based on the average of the statements within the cluster. Over here, they range from 3.12 to 4.31. So one thing to note is that thicker clusters are more important. So for example, in this case, the sound quality and intelligibility cluster is more important than the feedback cluster, whereas the comfort

and appearance cluster is also more important than the multi-environment functionality cluster. Now, as I discussed, you're actually able to make subgroup comparisons, each with their own cluster rating map in order to be able to visually compare them. So let's take a look at our two main groups, the people who chose the basic hearing aid versus the people who chose the premium hearing aid. So the basic hearing aid up here, and the premium hearing aid down here. Now, you can make a few visual comparisons. You might notice at first that the feedback and ease-of-use clusters seem to be quite a lot thicker, thus more important to the basic hearing aid choosers than to the premium hearing aid choosers, whereas other clusters are quite similar. But again, you might notice that it's not that easy to actually make this comparison. Visually, it's, you might notice anecdotally that there is a difference, but you don't if it's statistically significant, and you're not really sure by how much. So you might ask, is there a better way to do this? And I'm happy to say that there is, and it's called a pattern match. So a pattern match take really a lot of the same information that is in cluster rating map and puts it into a different visual medium. Let me orient you to what we have here, thus so I am better able to describe what the results of this pattern match is.

So over here you've got the basic choosers on the left and the premium hearing aid choosers on the right. On each scale, the scale goes up in terms of average importance of the cluster. So on the very bottom is 2.49 out of five, and on the top is 4.39 out of five. And on both sides, you've got the same nine clusters. So each cluster is repeated on each side. Now, from what we know about the rating scale is the higher up a cluster is on each side is the more important it is on that side. So for example, here, let's take comfort and appearance. Comfort and appearance is the most highly rated cluster in terms of importance for basic choosers, but it's slightly less important for the premium hearing aid choosers. Even though it is still quite up there, it's less important. Now, the connection between the two is just there for us to be able to more easily see where the cluster is on both sides, as well as to better be able to determine how different it is in terms of importance by looking at the slope of the line. Now, now

that we know what we're looking at here, let's talk a little bit about the statistical differences between them. Now, the software actually allows a statistical test to be done to determine which clusters are statistically different in terms of average importance rating between the two groups. These three clusters are shown here, and they each have stars on them. So these clusters are the user-controlled DSP app cluster, the streaming cluster, and the convenience and connectivity cluster. So one thing you might note is, yes, and these clusters are all actually significantly more important to the premium hearing aid choosers than to the basic hearing aid choosers. So some things you might note at first are that these three clusters are all actually primarily linked to features that are present only in the premium hearing aids, which is an interesting finding, but it also supports the idea, it makes sense that the people who would more highly value these clusters or the features that they represent are people that would prefer a premium hearing aid. So as we said, a lot of the oldest participants are people that chose the basic hearing aids. So the inclusion of a few people that are in their 20s, there are three participants in their 20s that also all chose premium hearing aids, you might think maybe that that skews it a little bit.

So let's actually look a little bit more into age and investigate that. So taking out the all younger participants and looking only into participants aged 60 years and older, we made the same comparison where we compared the basic hearing aid choosers to the premium hearing aid choosers. And we found, very interestingly, that it was the same exact three clusters that were significantly more important to the premium hearing aid choosers than to the basic hearing aid choosers. So that indicates that for people that prefer these hearing aids, or for people that preferred these, that found these clusters important, it was regardless of age, really. Even participants over 60 years old who preferred the premium hearing aids found these clusters to be significantly more important than their basic hearing aid-choosing counterparts. So looking a little bit more into age, we thought an interesting comparison would be to compare the oldest group of adults to the youngest group of adults. So these are the adults aged 60 and

above. And these are the adults aged 25 and below. And this is within only premium hearing aid choosers. So we thought, okay, let's take all of the people that preferred premium hearing aids, and let's see if there is a difference in age group. Now, the two clusters that we found were significantly different and which were significantly more important to the older adults than to the younger adults were the comfort and appearance cluster and the user-controlled DSP cluster. Now, that is quite interesting, and it might and then be what you'd except. Because you might expect that the younger, more, quote, unquote, tech-savvy adults might appreciate this type of hearing aid technology, which is app-based, and might appropriate the freedom that they gained from that. But actually, it just goes to show that older adults also have a, they do value these details, and they value this feature, and the access to that feature. Now, one thing to note is that there were only three younger adults. So in terms of generalizability, we might need more data in order to make these more generalizable claims. But in terms of statistical significance, the results are clear. So next up, now that we've seen a couple of pattern matches, let's take a look at one of these clusters, let's say, comfort and appearance. And let's take a more in-depth look, and let's investigate it. We can do that through a process called a go-zone analysis.

Now, a go-zone analysis is basically just a graph that allows a within-cluster importance rating comparison between two groups. So we're sticking with the same groups being the oldest group of adults and the youngest group of adults that all chose the premium hearing aid. Now, different areas on the map indicate different levels of importance for each of the groups, and I'll show you exactly what I mean. Again, let me orient you to our graph and what we're seeing, and that way I can explain the results. So we're looking at all of the different statements within the comfort and appearance cluster. And we are comparing younger adults, so the youngest group of adults versus the oldest group of adults in terms of their average importance for the statements within the cluster. So again, it's comparing it based on the importance rating scale, which was from one to five. It's from one to five for the youngest adults and from 1.93

to 4.86 to the oldest adults. Now, the line in the middle is the average. So three is the average for all the statements in the younger adult group. 4.1 is the average for all the statements in the older adult group. So let's take at the sections of this graph. Now, the orange section contains statements that are above average importance for the younger adults but below average for the older adults. And an example statement here is the ease of putting the hearing aids into the ears. The green section here contains points that are above average importance for both groups. And an example here is how well the hearing aid sits in the ear. The yellow section contains points that are above average importance for the older adults but below for the younger adults. So this section contains points that might contribute to this statement or this cluster being significantly more important to the older adults. And an example here is the fitting compatibility with glasses. Lastly, the gray section contains points that are of below average importance for both participant groups. And an example here is an aesthetic appearance, which, personally, I wouldn't have thought would rank so low, but that's quite interesting. So the go-zone actually lets us look more in depth into this cluster, and into all of the clusters really, in order to better investigate why that cluster differed the way it did. So for example here, maybe a way to explain why there's quite a few more points that contribute to this cluster being more important to the older adults, for example, is the fitting compatibility. Now, a way to explain that might be that older adults are more prone to needing glasses. It might be that older adults are less likely to wear contact lenses when they need eyesight correction. So those are just some of the things that you can take into account, and it helps us maybe better understand the differences in terms of cluster importance. So I'm going to pass it back to Susan now to discuss the take-home messages from our study.

- [Susan] Okay, thanks very much. So trying to put that all together in terms of implications for your practice and what this all means, we wanted to try to pull together some take-home messages for you and what we feel like we learned from this interesting study. So one thing to bear in mind is keeping an eye on the basics. So

there were some features that mattered to everyone regardless of whether they preferred the premium aid or the entry-level aid. The participants rated these things as being really important. So physical comfort of the hearing aid, appearance of the hearing aids, and sound quality and speech intelligibility of the hearing aids were in clusters that were important for all users regardless of their preference. So it's just a reminder to us to, even when we're dealing with really advanced and interesting features of hearing aids, to keep an eye on those basics and make sure that we've got good basic audibility, clean signal processing and good sound quality, and that the hearing aid fits the person's ear physically in a really good way. And those are things that show up in study after study, not just this one, as being important to people making their way through becoming a new hearing aid user or getting used to getting a new hearing aid is getting those basic things down, so making sure that we have those covered regardless of the technology level. Another take-hame message is that there's some features that may matter more to people who might become premium hearing aid users and that who would choose a premium level of technology. So these are things like the ability to stream calls and stream music onto their hearing aids.

So asking people maybe if that's something that would be important to them might be relevant, having access to an app where the directionality or other settings can be modified so that they've got some really advanced control over noise management in the real world, and overall convenience and accessory compatibility. So those are things that are gonna matter more to your premium choosers and are worth having a conversation about in terms of how an individual patient values those particular features. Some clinical implications of all of this are that the premium choosers did value having streaming and remote support access through their apps. But being able to use those things requires some coaching time. So the app needs to be installed on the person's phone, and you have to show them how to use it if you wanna be able to take advantage of remote support capability, for example. In this particular study, a 30-minute appointment was scheduled for most of the participants in order to go

through all of that, so specific dedicated time was incorporated into the design of this study to get our participants to be successful in using these features so that they could later on tell us whether or not the use of those features mattered to them. So we actually scheduled in dedicated time to get those apps working with people. So that's our 30-minute coaching session. We were able to successfully get these devices working on a wide range of phones with those apps, iPhones, Androids. Occasionally, but not very often, we did have to schedule a longer appointment or a rescheduled appointment if there were technical difficulties arose. So it's worth anticipating that. But just, we thought would note that it didn't happen much in this particular study. Physical comfort and hearing well were valued highly regardless of technology level, so remembering good fit to ear and good audibility using best practices including real-ear measurement. And older and younger user groups contained individual people who valued premium or entry-level features. So in terms of those premium features, don't assume a lack of motivation to use new or advanced technology based on age. Assess the individual. Just 'cause someone's older doesn't mean they don't wanna use that technology. So we also saw that hearing aid users valued having access to remote support, and they liked that convenience. So it's worth taking advantage of those new features when they are available. With that, we'd like to say thank you for your time. And we hope that this information is of use to you in your clinical practice. And have a good rest of your day. Thanks very much.