Understanding Emotional Responses in Hearing Loss: From Facial Expressions to Clinical Applications, in partnership with Seminars in Hearing

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Welcome to today's course presented in partnership with seminars and hearing. The title is understanding emotional responses and hearing loss from facial expressions to clinical applications. I'm very excited to welcome to audiology online. Our presenter Soumya Venkitakrishnan completed her bachelor's and master's degrees in India and after working as an audiologist and speech language pathologist in India, she went on to the University of Iowa for her combined doctor of Audiology and PhD degrees. Her dissertation was titled Facial Expressions as a measure of emotional responses and listening difficulty.

She is currently an assistant professor at California State University, Sacramento, working as a researcher and didactic and clinical instructor. Her research areas are improving hearing aid outcomes in older adults, investigating the role of emotional responses, stigma, and bias in audiology, and investigating auditory skills in individuals with long Covid. Wow. Impressive research areas. We'd love to hear more about all of those another time, but we'll start today's course at this time.

Soumya, I'll turn it over to you.

Okay, thank you so much for the introduction Carolyn, and like Carolyn said, I'll be talking about understanding emotional responses in hearing loss. I'm going to discuss a little bit about emotion recognition, the literature and emotional response, and then I'll be discussing part of my dissertation study findings. And then I'll talk a little bit about the clinical applications of facial expressions.

These are my disclosures and the learning outcomes. After this course, participants will be able to describe how hearing loss affects recognition and expression of emotions, explain how facial expressions can serve as indices of emotional response, response and listening difficulty. Sorry list two potential clinical applications of using facial expressions in audiology.

So to begin with, we know and research has also found that emotions are essential for social survival. They help us form social relationships, positive emotions help engage, help us engage in society and and negative emotions also have evolved to help us deal with a problem. And further, negative emotions such as confusion or frustration help increase attention towards a task and facilitate problem solving and learning. So all emotions have a function and have evolved to help us with different aspects of social relationships.

Zhang and Siegel discussed the link between emotions and hearing. They emphasized why we as audiologist must learn about emotional processing of our patients. Firstly, there is an anatomic connection between amygdala, which is the center that processes emotional information, and the auditory cortex that shows that there is a link between emotion and hearing. Further, there is also evidence of links between emotion and hearing in experiments that show stronger activity in the auditory cortex when the stimulus is emotional rather than when the stimulus is just neutral sounds.

We also know about the complex connection between motivation, listening, effort, and affect. When the task is easy or slightly difficult, the participant is found to have good engagement, but when the task gets too difficult, the participant disengages or gives up. So we can see that there is a complex but present connection between all of these constructs.

Further strengthening the relationship between hearing and emotion is the effect of hearing loss on the overall affect or emotions of the individual. We know that hearing loss is also related to feelings of depression, anxiety, social isolation, etcetera. And studies also show that lower affect scores were related to greater hearing handicap scores, which means that individuals with lower moods reported having greater hearing handicap in their daily life. Another area in audiology where affect may be impacted is for patients with tinnitis. One study during the Covid-19 pandemic found that individuals who reported feeling negative states, negative emotional states like anxiety, anger, and pessimism also

reported an increase in self perceived tinnitis.

So all of this shows us the intricate relationship between affect and audiology and warrants further inquiry into the emotional processing of patients.

Now, emotion processing consists of emotion recognition and emotional response. Emotion recognition is identifying the emotions of others, and this could be using verbal cues of others, such as their tone of voice or their prosody, or it could also be using and or it could be using nonverbal cues such as facial expressions and body language. On the other hand, emotional response is the response of an individual to emotional stimulus or how an individual is affected by an emotional stimulus. This could be laughing when someone cracks a joke or feeling sad because of some emotional stimulus. Now, an inability to understand emotions or issues with expressing emotions could both lead to issues with social interactions with social interaction, or problems with conveying information in communication situations.

Hence, it's important to analyze both.

Like I alluded to, emotion recognition can be can be based on either vocal emotion recognition, which in studies has been evaluated using emotional speech or emotional nonverbal vocalization, such as sounds of crying, laughing, and other nonverbal vocalizations. Emotion recognition can also be assessed using visual visual stimulus, and this can be based on facial expressions of individuals and or the body language.

Emotion recognition studies have utilized a variety of these stimulus and have investigated emotion recognition in various age groups, which includes children and adults, and this has also been investigated in hearing aid and cochlear implant users. So I will be reviewing some of the findings of these studies.

Studies in children who are hearing aid or cochlear implant users shows that compared to children with normal hearing, emotion recognition is poor in children with cochlear implants and or hearing aids, and this has been seen both for vocal and visual emotion recognition stimulus. We know that emotion recognition can impact social engagement and ultimately the quality of life of individuals. Thus, considering that emotion recognition is affected in children who are hearing aid or cochlear implant users, it's important to include emotion recognition training as part of oral rehabilitation.

Now, when studies were done in older adults, it was also found that older adults also have poor emotion recognition, and this was also seen for both vocal and visual stimulus, which may also impact these individuals participation in society.

Like with children, it is also seen that hearing devices do not help with recognizing emotions in older adults as well, both hearing aid and cochlear implant users continue to show poor emotion recognition.

However, some studies have also suggested that individuals with hearing loss have better recognition of certain negative emotions, especially those signaling potential threats. So, researchers theorize that these individuals compensate for the auditory deficits by enhancing their perceptual and attentional skills in other domains, which may extend to the effective domain. And the recognition of some of these emotions, such as fear and anger and disgust, better than their peers may be remnant of an evolutionary need to accurately recognize these emotions that can signal danger or that signal the need to be more alert.

Thus, when individuals with hearing loss lose their general emotion recognition, the ability to identify threat related emotions may still be preserved due to their salience.

Recognising emotions is vital for effective communication, and studies have also linked emotion recognition to quality of life. Therefore, researching emotion recognition is essential.

Hence, to summarize about all the studies that we saw regarding emotion recognition, we see that emotion recognition of vocal and visual stimulus are better in children with normal hearing as compared to children using cochlear implants or hearing aids. And the same trend is also seen in older adults with hearing loss compared for both visual and vocal emotion recognition compared to older adults with normal hearing and young adults with normal hearing. We also see that hearing aids or cochlear implants do not help with improving emotion recognition, and further research is necessary to determine the settings that can help with improving emotion recognition in these devices.

So moving on to emotional responses. So, emotional responses are the response of an individual to emotional stimulus or how an individual feels when response to stimulus. Emotional responses also impact daily life in different ways. It is seen that they have an impact on attention and memory processes. Studies also show that memory is better for emotional stimulus than for neutral stimulus, and emotionally charged situations are retained better in memory, and we also discussed a little bit about how negative emotions may also help with decision making.

Negative emotions may also help with vital fight or flight responses. The emotion of confusion promote learning and critical inquiry. In the field of education, this has been studied a lot more where it is seen that learning gains are made when the student is confused because when the student is confused, they tend to devote more cognitive resources to try to resolve this confusion and that helps with learning. Emotions also affect our overall quality of life. Feeling positive emotions promote our engagement in that communication situation, whereas negative emotions may result in individuals giving up and disengaging from communication.

So emotional responses in this way may also affect an individual's likelihood of participation in communication. So it's important to study emotional responses, especially in individuals with hearing loss whose quality of life may already be impacted due to hearing loss and who may already be less likely to participate in communication situations due to their hearing loss. A negative emotional response may emphasize this disengagement.

Most research in emotional responses has used non speech sounds as the stimulus. Example of these non speech sounds are dog bark, sounds of laughing, crying, sneezing, etcetera, and these sounds are classified as pleasant, unpleasent, or neutral based on the emotional responses that they elicit. And looking at the ways to measure emotional responses in audiology, existing research has measured this using subjective rating scales. Generally, this rating measures valance and arousal felt by the participant in response to the stimulus. valance is the extent of pleasantness or unpleasentness that a participant feels while arousal is the intensity of the feeling that is, was the stimulus exciting or calming or between that range and in this literature, it has been seen that compared to individuals with normal hearing, individuals with hearing loss have a reduced range of valance, which means that they report pleasant sounds as less pleasant than someone with normal hearing would, and this tendency is also seen to increase as hearing thresholds increase.

Emotional responses have also been found to be related to isolation and disconnectedness, so this reduced range of valance may have implication for individuals psychosocial well being because this means that individuals are perceiving emotions at a less range than individuals with normal hearing, which may further cause them to disengage in communication situations.

In emotional response research similar to emotion recognition, the usefulness of hearing aids and or cochlear implants has also been assessed, and this was similar to emotion recognition research. This benefit was also found to be limited. It was found that using hearing aids or cochlear implants or even

bimodal devices did not help with improving emotional responses. However, more research is needed to determine how to restore these emotional responses with device use so similar to what we saw with the emotion recognition research.

So, to summarize the research reviewed on emotional responses, individuals with hearing loss show a reduced range of emotional responses or reduced in that range of emotional valance. Further, hearing devices don't help restore the range of emotional responses and there is not as much research done on emotional responses as there is in emotion recognition. So definitely further research is needed in this area.

Like we talked about, existing studies have used non speech sounds, such as laughing, crying, sounds of animals, environmental sounds as the stimulus to assess emotional responses. However, study of emotional responses in response to speech stimulus is also critical because of the ubiquity of speech in daily life and because difficulty in understanding speech and noise is one of the most common complaints of individuals with hearing loss.

Hence, in our study that I'll be discussing later, we used speech stimulus to elicit emotional responses. Existing studies of emotional responses also use subjective rating scales where they asked participants to subjectively rate their emotional response in response to the emotional stimulus. Subjective rating scales may be problematic due to a few reasons. Individuals may have difficulty with identifying their own emotions because sometimes they may reflect emotions that others project. They may also hesitate to give their honest emotional ratings or evaluate stimulus or provide ratings based on their evaluation of stimulus.

For example, they may evaluate stimulus based on what they think others should feel in response to that stimulus rather than rate based on their own emotions that they felt. Hence, in the study that we did, we objectively measured emotional responses using facial expressions without. So this helped in

identifying facial expressions without the participants having to report it. We also measured these in response to speech in quiet and speech and noise, thus utilizing a more realistic scenario and utilizing that speech stimulus.

So in the next few slides, I will be describing using facial expressions for measuring emotional responses and how we did this. In our study, one of the most apparent ways of expressing emotional responses is using facial expressions. Strong links have been found between facial expressions and affective states and we can all attest to it when we feel a facial. When we feel a certain emotion, most of the time it may be displayed through our facial expressions.

Facial expressions of emotions facial expressions of emotion also can affect an individual's communication partner and their own behavior and also affect the entire communication situation, and that makes it more important to study these facial expressions.

Facial expressions can be measured using different electromyographic methods, that is, by attaching electrodes to the face. This method has been found to be more cumbersome because it involves placing electrodes on the face, on specific muscles of the face to determine how the facial muscles move in response to stimulus. Participants also find that this affects their facial expressions because they are very aware of the electrodes on their face. Recently, facial expressions have also been measured using a more non invasive method, such as by using automatic automatic facial expression algorithms. These algorithms work because of the principle of universality of facial expressions.

This means that all facial expressions, regardless, all individuals, regardless of their race or cultural origins, express emotions in the same manner with respect to their facial expressions. And these automatic facial expression recognition algorithms are trained using faces of individuals from different ethnicities and cultural groups, so that the facial expression algorithm can then be able to recognize the facial expressions from all of these groups. However, just a note that this principle of universality is also

still widely debated by researchers. Some of these researchers believe in the appraisal perspective, where they postulate that facial expressions consist of components which differ based on the appraisal of the situation or the context in which they are seen, and they cannot just universally be identified just based on facial movements.

So, in our experiment, we used an automatic facial expression detection software to detect emotional responses in an objective way. Like I mentioned, we used speech in quiet and speech and noise because we wanted to use speech stimulus and we wanted to capture the listening environment that is challenging for a lot of individuals with hearing loss. Previous literature shows that when individuals encounter difficult situations that require problem solving, they show emotions of confusion, frustration, anger, anxiety, etcetera. However, these results have been obtained in the field of education where. In the field of education where researchers evaluate emotions that arise when the student is trying to learn a new concept by tracking their facial expressions.

We don't have an evidence. We don't have evidence yet of facial expressions that occur in difficult listening situations.

However, we know that understanding speech and noise is also a complex process that requires problem solving. It requires peripheral and higher level processing. It's a complex process involving segregation of information, maintaining attention, etcetera, and breakdown at any of these levels could cause what is called cognitive disequilibrium. And this cognitive disequilibrium is caused when obstacles to goals are faced or when there are discrepancies or gaps in knowledge. And this may give rise to similar emotions, emotions of confusion and frustration.

And the automatic facial expression algorithm that we used in our study had the ability to detect the emotions of the facial expressions of confusion and frustration.

So, information about emotions felt in difficult listening situations using self report shows that individuals reported feeling fear, frustration, stress, embarrassment, and doubt in communication situations. And these emotions are probably due to increased effort expended by individuals in these situations. As well as the feeling of missing out on parts of conversation in these challenging listening situations. This suggests that emotional responses could be present in these difficult listening situation situations, and Francis and Oliver show a model where they emphasize these interactions between effort motivation and effective systems. They emphasize the role of affect systems in speech perception in challenging listening situations.

Hence, measuring emotional responses at different difficulty levels may provide an index of the affective component present when listening effort is experienced by individuals.

Complex listening situations may have components of effect as well as listening effort given the complex relationship between these constructs, and studies also show that listening effort increases as the signal to noise ratio reduces or as the situation becomes more challenging. While we measured affect or emotional responses objectively, we also recorded listening effort using a subjective reading scale. Negative emotional states, along with increased listening effort may cause reinforcement of the negative moods that individuals feel individuals feel in these difficult listening situations, and there is a probability that this might have further increase the social isolation or may reduce the engagement of these individuals in social activities.

Measuring both emotional responses, that is, the affect and listening effort, will provide a more comprehensive picture of the speech perception process in challenging listening environments. So we measured in our study, we measured emotional responses using facial expressions and listening effort using a subjective rating scale.

So, the research questions of our study were to investigate the effect of signal to noise ratio or by changing the difficulty levels on facial expressions of emotion, and to also investigate the effect of hearing loss on facial expressions of emotion.

We hypothesized that the facial expressions of confusion and frustration will increase with worsening signal to noise ratios and compared to the normal hearing condition, the condition in which the condition with hearing loss will increase likelihood of emotions of confusion and frustration depicted by individuals facial expressions.

So 33 young adults with normal hearing participated in our study. We use speech in quiet and speech and noise at various difficulty levels.

For our hearing loss condition. We used a hearing loss simulator to simulate a mild to moderate hearing loss. So when I talk about the hearing loss condition, it's nothing in. It's not including individuals with hearing loss, but it's the same individuals with normal hearing who listen to a filtered stimulus that simulates mild to moderate hearing loss. And this hearing loss simulator simulated effects of cochlear hearing loss such as threshold elevation, loudness recruitment, and reduced frequency selectivity.

Our outcome measures included looking at the objective measure of emotional response, which is facial expressions of confusion and frustration. I'll also be discussing our speech recognition scores and the listening effort self rating.

So before I talk about some of these results, I wanted to discuss a little bit about how the facial the automatic facial expression detection algorithm works the automatic facial expression detection algorithm that we used was developed by the company emotions and we use their face set algorithm. So for the experiment, we recorded participants facial expressions using a camera that was directed at them and the camera recorded the participants facial expressions. Throughout the experiment, I will

describe how the emotion face software used this recording to detect facial expression. So firstly, the software detected the face of the participant.

It then identified various parts of the face such as eyebrows, eyes, mouth, corner of the mouth, cheeks, etcetera. And this was detected before the stimulus is presented so that the participant has a neutral expression and that served as a baseline of the participants facial expressions. Sorry, I'm not sure why the slide is moving on its own.

After observing that the neutral facial expression this was then the algorithm then monitored how each of these parts of the face move in response to different stimulus, and these moments were interpreted using the facial action coding system. The facial action coding system identifies movements by tracking what they call action units. And action units are specific muscles or muscle groups that result in a certain action. So for example.

So for example, action unit six is all the muscles or muscle groups that were involved in raising of the inner eyebrow. So we can see here that multiple muscles are involved. So it's a muscle group that results in a particular action. It can also be just a single muscle that is implicated for a certain action. For example, for action unit twelve, which is the lip corner puller, zygomatic major is the major muscle that helps with this movement, and there are other action units that are present.

Similarly, various action units may co occur during the experiment depending on the emotion being experienced by the participant. The software monitors for the presence of all of these action units and when certain action units are detected together, the software recognizes this as the presence of an emotion. For example, when action unit six and action unit twelve are present together, the software may recognize this as the presence of the facial expression of joy. Similarly, a co occurrence of action unit four, seven and 12 may indicate the detection of the facial expression of confusion, and so on. And again, universality of facial expressions makes this automatic detection possible.

So in the software we get information from all the action units and for all facial expressions, that is joy, sadness, anger, surprise, etcetera, and also confusion and frustration. And we get this information at each instant for the experiment and we focused on emotions of confusion and frustrations, since that was most relevant to our experimental design.

Now, the presence or absence of these emotions is quantified using probability or log odds. Each movement of the face in response to the stimulus is compared to the database of all different facial expressions. For example, these pictures all show individuals smiling. So the amount of the movement of the lip corner puller or the other muscles will be compared to the smiles saved in the smile database, for example. And the algorithm will compute a probability of this moment to represent a smile.

And this probability is represented in terms of an evidence value.

An evidence value of one, for example, for the emotion of joy would mean that it is ten times more likely that the facial expression seen will be classified as joy by an expert human coder compared to not joy. And an evidence value of two would mean that it's hundred times more likely that that facial expression will be classified as joy by an expression human coder. So all of this comparison is based on a human coder versus what is done for the automatic facial expression software. And this evidence value is computed at each instance of the task during the experiment.

So, in this figure, we have time on the x axis and we have that evidence value that I talked about on the y axis. And this evidence value is again the log odds probability of the presence of here the emotion of confusion during the speech and noise task. We can see the time course of presence of this emotion. We can see how it changes during the task. Zero to 4 seconds represents the sentence and noise, the time for which the sentence and noise was presented.

Four to 6 seconds represents the retention period we can see. So after we plotted this graph, we then calculated the area under the curve for just the retention period, and this was used for further statistical evaluation. We use this retention period interval because previous literature shows that maximum listening effort is seen during this interval, and our preliminary results also showed that maximum emotional response was also seen during this interval along with facial expressions. I will also share information that we obtained about subjective listening effort using the listening effort rating scale that we administered. We asked participants to answer this question, how hard did you try?

Did you work to understand what was said? And remember, this is different than how many words you got right. For example, you could get all the words right but have to work very hard to do it. And participants responded to this on a scale of they had to work very hard to not at all hard.

This is a brief procedure that we followed. The results I will be presenting today are part of a larger study, so I will only, due to time constraint constraints, I will only be discussing the results, comparing emotional responses between different signal to noise ratios and in quiet, that is with different difficulty levels, and comparing the emotional responses or facial expressions we acquired comparing normal hearing and hearing loss conditions.

So this is the time course of a sentence in noise. So initially, when the noise starts, initially we would start with just noise. And this is for zero to 1 second interval. This is the region where we get information for the baseline facial expression of the individual. Following this, we have one to 4 seconds of speech and noise, and this is followed by a short period called the retention period.

And like I said, listening effort is generally greatest during the retention period. At the end of this retention period, there is a beep that signals that the participant can now respond.

For statistical analysis, we use linear mixed effect analysis.

I'll first discuss the results from the effect of signal to noise ratio on facial expressions or what happens to facial expressions when the participant is listening to speech in quiet versus speech and noise at different difficulty levels.

So in this figure, we have different signal to noise ratios going from most difficult to the least difficult on the x axis. Both these graphs. And we have percent correct scores on the y axis on this left graph. And we have listening effort rating on the, on this right graph going from greater listening effort to less listening effort.

And we expect speech recognition to get better as we go from more difficult to less difficult situations. And we expect listening effort to also be less as we go from more difficult to less difficult situations. And we see both of these in the results that we found. So, speech recognition scores improve as you go from more difficult to less difficult situations, and listening effort reduces as you go from most difficult to least difficult situations.

This figure shows the evidence of confusion across time. And again, zero to 4 seconds interval is, represents the time period for presentation of speech and noise, and four to 6 seconds was the retention period. So this one. So we can see that the evidence of conf, we can see here the evidence of confusion for different difficulty levels, and we can see that the evidence of confusion increases as the difficulty level increases. And we also see that the evidence of confusion is the most during that retention period.

After this, we, like I said, we determined the area under the curve for each of these difficulty levels.

So in this figure, again, we see on the x axis signal to noise ratios or difficulty levels from most difficult to least difficult. And here on the x axis, we see the area under the curve for confusion.

And we expect that the confusion should be the most for the most difficult condition, and it should decrease as we go to the easier conditions. And we see that, we see that trend here. So the confusion is the most for the most difficult condition, and there's a trend of reducing confusion as you go to the easier situation. And even though I have not included a figure for the area under the curve for the emotion or the facial expression of frustration, we saw similar trends for frustration as well.

Then I'm going to discuss the effect of hearing loss on emotional responses. So, similar to previous figures, we see different signal to noise ratios going from the most to the least difficult on the x axis and the percent correct scores, speech scores on the y axis. Here we need to focus on the darker shade of blue, which represents normal hearing, and the lighter shade of blue, which represents hearing loss. And with with the hearing loss condition, we expect the speech scores to be poor than what we would find for the normal hearing condition. So we see that speech scores are poor for the hearing loss condition across the different difficulty levels.

Then we have the figure that shows again the different difficulty levels from most to least difficult and the area under the curve for confusion. Now we want to again focus on the difference between the normal hearing, which is the darker blue, and the hearing loss condition, which is the lighter blue. And here we expect to see that the facial expression of confusion would be more in the simulated hearing loss condition as compared to the normal hearing condition.

And we do see that at all of those different difficulty levels. So confusion is more in the hearing loss condition as compared to the normal hearing condition. We found that the effect of condition was significant.

Here is a graph showing the area under the curve for frustration, the emotion of frustration. And again we saw similar trends where frustration, the effect of condition again was significant and frustration was

more in the hearing loss condition as compared to the normal hearing condition.

And because we saw similar trends for confusion and frustration, we determined. We decided to determine the correlation between these measures, and we found that they were strongly correlated. They showed a strong positive correlation, which means that possibly both the confusion and frustration response that we obtained was measuring the same underlying emotion in the participants.

So, summary of our results. At this point, we saw that the speech recognition scores were worse and listening effort was greater as the difficulty level increased, which is what we expected. We also saw that facial expression of confusion and frustration were more likely with increasing difficulty level.

So the negative emotional responses that we that we assess, that is, confusion and frustration, increased with more difficult signal to noise ratios or more as the difficulty level increased. And then when we look at the effect of hearing loss on emotional responses, we found that the speech recognition scores were worse in the hearing loss condition. We also found that confusion and frustration emotional responses were greater in the hearing loss condition. We also determined that possibly confusion and frustration were measuring the same underlying construct because they were very significantly positively correlated.

So, like I said, we saw that we saw increased facial expressions of confusion and frustration in the hearing loss condition as compared to the normal hearing condition means that hearing loss increase these negative emotions. And we already discussed how individuals with hearing loss are already at risk of experiencing negative psychosocial effects of hearing loss such as social isolation, anxiety, depression, etcetera. So it's possible that this increased negative affect or feelings of confusion or frustration seen in these difficult listening situations may exacerbate these negative consequences. And we also discussed literature that shows that memory for these emotionally charged situations are greater than for emotionally neutral situations, emotionally neutral stimulus. So it's possible that

individuals with hearing loss may recall these negative emotions they felt at these adverse listening environments and may want to avoid these listening situations.

And we know that emotional existing literature also already showed that emotional responses to non speech sounds aren't affected due to device use. However, this hasn't been explored for speech stimulus as yet. So we need to determine how emotional objective emotional responses or emotional responses to speech are influenced by device use. In the field of education, it has been seen that when a student tries to learn a new concept, initially they face confusion. If this confusion is resolved, it results in new learning.

However, if this confusion is unresolved, it may turn into frustration and the persistence of frustration may lead to disengagement in that learning situation, that is, that the student just gives up. Now, this hasn't been assessed in audiology to try to see how affect is affected by these unresolved confusion or frustration. We do know that when listening effort is increased and if the participant is not able to understand speech, then they also tend to give up. So there may be a similar mechanism that is happening in audiology, but we need to determine if improvement in audibility due to hearing devices causes reduction in this confusion and subsequently it may not lead to frustration, and resolving of this confusion could then if that results in increased engagement, because if this happens, then it may result in participants improving their engagement in a communication situation.

We also saw that listening effort is also related to engagement in the communication situation. So, research in CI users has found that they analyze the cost of listening effort to the social connectedness benefit. They are ready to apply listening effort if it results in improved speech perception. However, if they apply listening effort and that still doesn't help them understand speech, then it results in disengaging in the communication situation because the increased effort is not worth the cost. Similarly, it needs to be investigated if increased listening effort will help in reducing the negative

emotions, and then it is possible that it may be worth the cost of the increased effort.

Thus, there are a lot of interrelated, intertwined constructs in this area of effect and listening effort and motivation, and more research is needed to determine if devices will help with this reduction in negative emotions and negative listening and listening effort, improving the overall access of speech sounds and thereby improving engagement in these users. So more research is necessary in this area.

Now I will discuss some potential applications of studying facial expressions and audiology. Many of these users are still under research and not very widely implemented, but I think they hold significant promise for the future.

Before I discuss the applications, I also want to discuss some of the advantages of using facial expressions. Monitoring the automatic facial expressions monitoring that makes it ideal to be used to monitor emotional responses. Compared to other measures of emotional responses, facial expressions are the most unobtrusive method. They do not require any physical wound monitors. They do not affect facial expressions just by being there.

They just require a camera with a software to recognize facial expressions.

They can also be simultaneously monitored with other responses used in audiology, such as pupil responses, because there are software available where these multiple biometrics can be monitored simultaneously.

Facial expressions also allow for continuous monitoring as opposed to evaluation after the task is complete, like subjective ratings. So like we saw in our study, we were able to look at how those facial expressions change at each instant in time. So that's definitely strengthen. There are also some limitations to using this measure. Facial expressions are prone to what is called emotional contagion

and emotional induction.

Emotional contagion is automatically mirroring emotions seen by others. For example, when everyone is laughing, you may laugh even if you don't hear the whole joke or find it particularly funny. And over and above that, emotional contagion is also how we are all very aware and pick up on emotions around us. Hence, the stimulus need to be carefully selected considering the possibility of this emotional contagion.

Facial expressions are also prone to emotional induction, which is when you start to feel an emotion after being exposed to it for a while. For instance, listening to sad speech for an extended period of time can make you feel sad the more you are exposed to it, and that may also be reflected in your facial expressions. Hence, studies need to be designed carefully to avoid emotional induction. Another limitation is that the sensitivity of facial expressions to the different levels of listening difficulty needs to be investigated further. In our study, we found that facial expressions do change with increased difficulty, with changing difficulty levels, but may not be significantly different between each difficulty level that we used.

So these advantages and limitations need to be considered when using facial expressions to measure emotional responses. Now moving on to some of the clinical applications, one of the applications of facial expressions could be to monitor engagement in an individual and this can be especially useful for students here, facial expressions can be used to determine if the student is engaged in the classroom or in an online learning activity and facial expressions can be detected by the camera and deep learning networks can be used to identify the emotions, recognize the emotions behind these facial expressions. So this was used in a classroom of deaf and hard of hearing students where deep neural network provided the teacher with a feedback of whether the students were highly engaged, nominally engaged, or not engaged with the class and this can be beneficial for the teachers, for the teacher in

many ways. However, this is very much still in the research stage and is being studied by various researchers.

Monitoring engagement using facial expression can help a teacher determine the students level of engagement and understanding of the material. It can also help them adjust their teaching methodology based on the level of engagement, and monitoring the engagement of specific students can also help determine if some students need additional supports and this can be used in both in person classrooms and for online learning and for both synchronous and asynchronous classes. In synchronous classes, the teacher may be able to change their listening strategy based on the engagement level seen for the students in asynchronous classes, the software may be able to send reports to the instructor about the engagement of each student. Given this report, the teacher may decide to either send out an announcement with specific techniques if all students, uh, seem to have similar levels of engagement or disengagement, or the student or the teacher may also reach out to set up a meeting with students who appear to be disengaged and gauge their level of understanding further.

So there are a lot of applications for this engagement monitoring.

The other application is using facial expressions for hearing loss detection and facial expressions denoting discomfort or fatigue can signal that individuals are having difficulties during conversation. One study explored studying these facial expressions using machine learning techniques to try to determine if the person has hearing loss. They studied facial expressions in various signal to noise conditions and created a model to detect hearing loss through these facial expressions through these facial expressions. This promising new application still needs a lot of further exploration but holds exciting potential for audiology.

The other application is listening effort and facial expression and trying to disentangle the presence of effort, motivation and effect systems in challenging listening situations. In our study, we saw that as the

difficulty level increases evidence of confusion and frustration increased these adverse emotional responses and the associated increased listening effort can impact social engagement. And more research is needed to try to study these interlinked concepts. They are complex effects on quality of life and to determine if devices and or hearing rehabilitation can effectively reduce these negative effects.

Great.

That was all I had about the different applications of facial expressions. Thank you so much, Somia. This was fascinating research. We do have a question from a participant, but I'm just wondering how you got involved in this research to start. Oh, that's interesting.

I think we were using facial expressions for a different study to determine the effectiveness of assistive listening devices. And I thought of how these concepts were interlinked listening effort and facial expressions. And then we started wondering if these negative facial expressions can be recorded and they would be present in these adverse listening environments. And so, yeah, that's how this study resulted. I love what you said at the end about the, um, potential for hearing loss detection.

Like, I would have never thought of that. Um, I'm also. I always hear about bias with AI systems, so, especially when it comes to terms like facial recognition. And I heard a study last year that said pedestrian detection systems and cars were biased where they weren't picking up children and they weren't picking up people with different skin tones or whatever. But I heard you say that this whatever system you're using had been trained on diverse subjects.

Are you confident, then, that it doesn't have the kind of bias we hear about with AI systems? Yeah, that's a very good question. So, the software that we used has been trained in different ethnicities and individuals with different ethnicities and cultural backgrounds. However, the study that I used was not, or the study population that I used was very homogeneous, and that's just because of convenience

sampling. So, at least from my study, I'm not sure if these systems work well enough to try to eliminate that bias, but that's definitely something to consider.

The other application that we had thought of was trying to identify these negative effect, this negative effect, and increased listening effort in individuals with cognitive difficulties, like older adults with cognitive difficulties. So, again, even though that's, like, an exciting application, we need to evaluate that specifically in that population, because in individuals with these cognitive problems, affect may already be affected. But. So, yeah, all of those applications need to be evaluated, but there's very less research done so far, and it has so many applications that I hope that this causes individuals to be more interested and carry out that research. Yeah, for sure.

So let's get to a question from one of our participants, said is there any research into understanding if emotional responses are impacted by individuals with CAPD? Oh, that's very interesting. And I haven't come across that research, but honestly, when I was making this presentation, I thought of that because we think of these emotional responses to be worse in individuals with hearing loss. But individuals with CAPD also face a lot of trouble in difficult listening situations like the ones that we just mentioned. So it is possible that they are affected.

Emotional responses are affected in individuals with COPD. It's very interesting. Thanks for that. Great question. We have another participant said, wow, this was so amazing.

We have another question here. Is there any research on facial expressions with individuals with facial anomalies? Great question. We work with a lot of people with craniofacial anomalies or whatever. Yeah.

So I haven't come across any research, at least in audiology, but in our study, we definitely did exclude those individuals who have had any facial surgery or any who have facial nerve paralysis or paralysis or

something, because definitely the facial expressions will be different in those individuals. And that's why this is also a little like, there's a lot of research that needs to go into this before it can be deployed in clinical population, because we see all of these varieties in clinical population. Oh, sure. And that's one thing I love about working with seminars and hearing each year on audiology online, because we have plenty, plenty of courses on clinical. I mean, we have hundreds of courses in our library if you want to know about otoacoustic emissions or tympanometry or masking or whatever.

But with seminars, we always hear about this really cool emerging research, which is just fascinating. I mean, I might not be able to use it with my patients tomorrow, but just to hear about it and to know that these things are underway and to think about the potential down the road, it's just so fascinating. So thank you so much. Thanks to everybody who attended today. If you're earning ceus, make sure you log into your account on audiology online and take the exam that goes along with today's course.

It does expire, so make sure you take that. And Soumya, it's been great having you, and I hope we have you back in the future to talk about either the continuation of this research or other research that you're doing. Thank you. Thanks, everybody. That wraps today's course.

Have a great afternoon.