Decision Making in Children's Speech-In-Noise Perception, in partnership with the University of Pittsburgh

Presenter: Ashley Parker, PhD

It is my pleasure to introduce Dr. Ashley Parker. Today, Dr. Parker will be presenting for us a course on decision making in children's speech and noise perception. And this course is proudly produced in partnership with the University of Pittsburgh.

Each year we produce two courses with upit. And if you haven't seen any of the other courses, they are located in our course library at this time. I hand the mic over to you, Dr. Parker. Thank you so much.

Christy. Is my volume. Okay, everyone, can, can you guys hear me?

I don't see anyone, so I'm going to assume. Okay. Christy tells me I sound good. Thank you so much. Thank you both.

Hi everyone. Thank you so much for having me here today. My name is Ashley Parker. I am a visiting assistant professor at the University of Pittsburgh and will be transitioning into removing that visiting title this summer. And I'm so happy to be here with all of you today.

Going to go through some, some of the quick disclosures. Here are my disclosures, here are the limitations and the risks of this talk and here are the learning outcomes for my particular talk. So this talk is going to focus on drift diffusion models, which are computational models of decision making. And I'm going to walk you through how we use these in our audiology based tasks and in, you know, in our hearing science field. So I don't have like a little introductory slide and I've introduced myself being assistant professor being it's part of University of Pittsburgh.

But I'll also mention here that I'll put it on my first slide and then I'll walk through this. But I am, I have a PhD, I do not have an AUD, I am not an audiologist. And I say this because I, while I do not, I am not a practicing audiologist, I value so much the partnerships and the really the feedback that I get from audiologists because something that I think us more basic scientists have to remember is that if we aren't working with audiologists and we aren't having some sort of clinical destination or goal of our work, then what are we doing? What are we doing it for? If there's no sort of clinical relevancy, even if it's not, you know, like, even if it's not something that you can pinpoint the exact relevancy there like base a lot of basic science goes into getting to the point of clinical practice, I still think we really need that goal.

So thank you guys for inviting me to audiology online and you are some of the most valuable people to our work. So jumping into the content of My talk. Let's start with a question that seems really simple. But you guys know, audiologists know that this is actually a really complex question. Why do some people struggle more than others when it comes to understanding speech and noise?

This is something that audiologists and speech scientists, hearing scientists, have puzzled over for, honestly, decades. We all know that background noise makes listening harder, of course. Like, even with perfectly normal hearing, even with decent speech and noise, understanding being in a noisy, complex background is going to make listening more challenging. It's going to make it harder. But even among people with normal hearing thresholds, there's a wide range of performance.

Some listeners seem to sort of sail through a noisy environment with ease, while others really struggle, even if their audiogram looks pretty perfectly normal. So today we're going to dig into what's happening behind the scenes, sort of the brain and the cognition that might explain some of this variability that we see. This talk is the point of this talk is really to go beyond the audiogram and ask, what are the cognitive and the neural processes that might be influencing how well someone can categorize speech sounds in challenging inner noisy conditions? What is the brain and cognition behind the behavior?

When we talk about speech, perception and noise, it's important to remember that it's not just about the ears, it's about the entire brain. Accurately perceiving auditory signals, especially in noisy environments, is a complex cognitive process. It involves peripheral hearing, of course, but it also relies heavily on central auditory processing, on memory, attention, cognition, cognitive control, and language. It's really a full brain task. Now, for most adults, the brain has matured enough to handle these challenges pretty efficiently.

We may not love talking in a crowded restaurant, but we can usually manage. But in children, and especially those who are still developing these foundational cognitive and linguistic skills, this kind of listening environment is much more demanding. They're doing all of this complex processing while their systems for processing are really still under construction. So here's a key point that I want you to take away right now is that even within typically developing kids, there's a lot of individual variability. Some children really struggle to pick out speech in noisy settings and think about how ubiquitous noisy environments are to adults.

But even more so kids, they're in classrooms all day. They're in bustling cafeteria. I eat my, my lunch in my quiet office by myself. Kids are eating it with, you know, 200, 100 other kids in a cafeteria every day. They are home and they have the TV on.

The TV is, you know, background noise all of the time.

And some children really Some again sail through this, but some of them really, really struggle with this. We see a lot of variability and that's what we're trying to understand. What makes some children more resilient listeners than others, even when they're hearing, is technically air quotes normal.

So why is speech perception in noise. This talk is going to focus on children. And why is speech perception in noise or spin? I'll sort of probably end up oscillating between the two, the acronym and the full length throughout the talk. But why is this more difficult in children than adults?

We've talked about their sort of developing under construction systems. But breaking that down a little bit, a little bit further, there are a couple of key reasons. So first, in children, the auditory system is still maturing. So even if a child has normal hearing, even if you're seeing a totally normal audiogram, there's central auditory pathways. The brain regions that help make sense of sound are still developing.

Second, cognitive skills like attention, working memory and executive control are also still coming online. These are crucial for filtering out noise and focusing on speech when they improve with age. The children are working with an immature auditory system and developing cognitive control, which makes listening or hear, I'm going to say listening rather than hearing makes listening in noisy environments particularly challenging. So even among typically developing children, as I mentioned, there's a lot of variability in how well they handle speech perception and noise. Some kids breeze through this and others really struggle despite normal hearing and despite normal language abilities.

And that variability matters. Difficulty with spin can impact real world communications. I was just listing off some of the places where kids are just pretty much their entire day in noisy environments. And that is where that real world impact really matters. Following instructions in a classroom, talking with your peers in the cafeteria, understanding caregivers at home, not being able to process speech in noise has real tangible consequences.

Backing up a little bit. I've been talking about how we see this individual variability even in children who have typical development typical hearing. But backing up a little bit, we see clear evidence of speech perception and noise difficulties in several pediatric clinical populations. For example, children with cochlear implants often struggle with speech and noise perception. This makes a lot of sense.

Despite access to the sound, the signal that they receive is degraded and the brain has to work a lot harder to fill in gaps. We see this in kids with auditory neuropathy who show even more pronounced spin difficulties since the timing of the auditory signal is disrupted at the neural level. Neural level. This can make it harder to extract clear speech cues. In children with Dyslexia, even though their hearing is normal.

We've still found, or studies have still found that they have difficulty listening in noise or hearing in noise. And also two children with broader learning difficulties. And I've kind of whittled down learning difficulties as the sort of headliner here, but this can include ADHD or language based learning disorders. SPIN challenges are frequently reported and they're often tied to weaknesses in attention or linguistic processing and bringing all four. This is not an exhaustive list of where we see SPIN difficulties in clinical populations, but in this list in particular, there's a common thread across these groups.

And what there's probably numerous common threads, but one of the most profound common threads between these four groups is poor phonological processing is a consistent risk factor. These children may struggle to build robust phoneme representations, making it harder to identify speech sounds when the signal, particularly when the signal is noisy or degraded. So this we're, I'm going to kind of walk you through the broader study that we're doing and what the sort of battery of tests that we're doing looks like in just a second. But as we were thinking through this and thinking through the data that we have that I'll walk you through, it raised a broader question to us and that was can phonological awareness serve as a protective factor even within typical development for speech perception and noise? And that's part of what we aim to explore in this study.

Sorry, it was a little delayed on. On my fade in text.

Okay, just one second. Making sure. I think my slide is a hair delayed. One second. We're going to try again to get to the next one.

There we go.

Okay, so why look at phonological awareness and speech perception and noise? Phonological awareness is a foundational metalinguistic skill that involves recognizing and manipulating the sound structure of language. So it includes things like rhyming, blending, segmenting words. Phonological awareness is critical for decoding degraded or masked speech. And this can help listeners extract and interpret linguistic features from noisy input.

Also, phonological awareness, which I've you guys can figure out. I have it big in the headline here, but I've abbreviated it as pa. Phonological awareness and speech perception and noise rely on shared representations. They both require accessing sound or accessing acoustic, phonetic and phonological representations of sounds and words. Finally, the big thing here is that numerous studies have shown that phonological awareness has been shown to predict speech perception in quiet.

But we are interested in noise, its role in noise, the role of phonological awareness in speech, reception and noise has really been, to put it just how it is, frankly, very mixed. And that's really what motivated this study is that we are not. This is in some ways, I'll admit, like this is low hanging fruit looking at phonological awareness and vitrioception and noise. But the results have been so mixed. On the next slide, I'll sort of walk you through why we think that they're mixed.

But it's what motivated our study is that we just don't have an answer right now.

So as I mentioned, previous findings have been really mixed. When we look at existing research on phonological awareness in speech perception and noise, the findings have been many different things. Some studies have shown that stronger phonological processing skills are associated with better speech and noise performance. But other studies really haven't found this relationship. They've really gotten to a null result.

And the big question, the question becomes why? And I think that there's a number of possible explanations for why. And some of these really just come down to study design, more so than, you know, like some sort of oddity between phonological awareness and speech perception and noise. And some of those that we've walked through, that my group has chatted through have been, you know, like things like we see differences in recruitment methods. Some studies use community samples, others pull from clinical populations, therapeutic.

And those groups may differ in important ways. I saw a lot of studies that were trying to sort of infer phonological awareness just through like recruiting individuals with dyslexia where they weren't directly actually testing phonological awareness. So like recruitment method issues like that can cause a lot of gray area and cause important differences. There's also variation in participant eligibility criteria. So some studies include a broad range of ages with varying cognitive levels or hearing profiles.

And when you introduce noise into those, those recruitment factors that really, or those eligibility factors that can really mess with things, then there's experimental design itself. The type of speech and noise task, the sort of masker that's being used, the difficulty level, these are all going to be in these studies, in these mixed studies, they all vary pretty widely. And that's definitely going to impact or likely to impact how phonological awareness plays a role. And then finally we have differences in analysis approaches. Studies use different statistical methods, different outcome measures, different ways of defining success on speech and noise tasks.

And this really, there are all these factors that I think pretty non controversially can contribute to some of the differences in the studies that have been Found, but it also brings us, if we're coming sort of back to audiology, it brings us to this important possibility that maybe accuracy alone, when we are doing a speech in noise task and we are judging, not judging, but scoring exclusively on accuracy, maybe accuracy doesn't tell us everything. Maybe we need to look at a more detailed or take a more detailed look at how listeners are arriving at their answers, not just whether they got it right or wrong. And that's what led us to incorporate drift diffusion modeling into our study, which I'll introduce shortly.

So how do we usually test speech and noise perception in clinical settings? So, like I say, this is a huge disclaimer. I even not being an audiologist, I completely understand that when you're in a fast paced clinical environment, you have a half an hour at most to see somebody running a computational model is not the way. It's not how clinic works. It's not.

That's not in any way feasible though, with how fast things are getting. It could be in the future. But in clinical settings, we rely on tests like quicksand and hint or words and noise. And this totally makes sense. They're quick, they're easy to administer, and they give us a really good general sense of speech and noise perception abilities.

But these tests really mainly focus on accuracy, whether a child can repeat the correct target word. And at the end of the day, accuracy isn't probably the most important thing, whether they got it or not. Yes. And you can see an example, I think, on the bottom. This is how quicksand is scored.

You have a number of key words and you mark them off if they didn't get that word correct. The score is based on how many keywords were repeated correctly. And the problem with this is it really only gives us part of the picture. It tells us if the child got the word right or wrong, but it doesn't tell us how they processed it. It doesn't tell us how much effort it took.

It doesn't tell us how fast, fast they made the decision or whether they had confidence in their decision. So our study aimed to go beyond accuracy and get a deeper look at the underlying decision processes behind speech categorization in noise.

How can we really test for speech perception and noise difficulties when we don't know the underlying cognitive and neural processes driving individual differences in speech perception skills? How can we really target in our treatments the true deficit when we don't know what the true deficit is? Our goal here was to dig deeper into the decision making processes that underlie decision making or that underlie speech perception and noise. By doing so, we hope to identify more precise mechanisms that we can target for interventions.

I have a, I'm going to call this a schematic of drift diffusion models here, and I'm going to come back to it on another slide in a slide or two to go through more detail with it. So I'll pause. I won't go into detail on it now, but we'll, we'll come back to this exact figure in just a moment.

So we are at our current study now, which is going to examine, or it's going to use computational modeling to examine how children make phoneme categorization decisions under noisy conditions and how phonological awareness plays a role in that.

Let's dive into our methods, including walking through what a drift diffusion model is.

Broadly, we studied children's performance on a phoneme categorization task across several signal to noise ratio conditions using both behavioral and computational modeling outcomes for this study. So I'll back up and say that this is part of a larger scale, R01, that is looking at speech perception in children who stutter. There are no children who stutter in this presentation today. This is our controls only, but just keep that in mind. I know you guys are audiologists, but, you know, we can all appreciate communication disorders across different modalities.

And we have this information on children who stutter as well, though it's not presented today. So just giving you sort of a bigger picture of where what this is a part of, but for what the data set that we're looking at Today, we have 44 typically developing children ages 7 to 12 years old. We put a lot of thought into the age range where the task. And you're, you'll see the task. There's more tasks than the one that I'm going to show you guys, but seven seemed to be the lowest age that they were able to really comply and get through the task and cutting it off at 12 years old, really, because we have a lot of neuroimaging methods in this broader study as well.

It really sort of controls for a lot of the development things that happen in the teenage years. So that is our age range right here. And for the analysis on this study, we've broken them into a younger group and an older group. So 7 to 9 is in our younger group, 10 to 12 is in our older group. And this sort of cutoff is not only just for the equal numbers in, you know, three ages per group, three years per group, but we do start to see some Phonological awareness shifts, really happening from development to getting closer to mastery.

In the older group, their hearing status, they have normal hearing thresholds confirmed by a full audiogram under 20 across frequencies. Their language and their cognitive status is typical. No reported language or cognitive impairments. And you can see in our speech and language battery, everything on here except for the ctop, which is a. We'll go into that in a second.

That's a big. That's the phonological measure that we use. Everything here except ctop, they had to pass. And it was run by one of Our Clinical Research SLPs, the Phonological Awareness measure. I'll go into that more in a second.

That we use is the ctop. It's the phonological awareness composite score from that ctop. And then we have some gender distributions. I believe we are 21 females to 23 males. But yeah, just the screen has been up.

Take a look at the Fuller battery. We're not going to talk about most of the things on here, but this is the full battery of tests that we have.

So going into the CTOP a little bit more. This is the measure that we use to measure phonological awareness. This was not used as exclusionary or inclusionary criteria. CTOP was not. There was no cutoff for this.

And it's what we use to measure phonological awareness, specifically the phonological awareness composite score, which included tasks like elision, blending and phoneme isolation. You can see on the screen here, elision is your ability to remove sounds from a word. Blending is your ability to combine sounds to form a word. Phoneme isolation is your ability to identify individual sounds in a word. And the purpose of the ctop, the purpose of us measuring the CTOP was to provide this robust overall measure of an individual's ability to access and manipulate the sound structure of language.

It's key for reading, language development, speech perception too.

And here is the task that's our phonological awareness measure. And this is the task where we were measuring speech perception and noise. And I actually want to be a little bit more careful to not really call it speech perception and noise because they're not perceiving full words or sentences, they are categorizing phonemes. So I want to be just sort of temper calling it this. The broader goals of this study is to relate this to speech perception and noise.

I mean, how often are you in your daily lives listenings for Boz, Daws and gauze? So the broader picture is to get to speech and noise. But this task specifically Is categorizing phonemes really? It's actually categorizing syllables. But for this task we asked children, they were sitting at a laptop computer with headphones on and they were presented the speech sounds, the syllables ba, da and ga.

So they are only differing between that place of articulation with the buh, duck, guh at 5 different snrs. At 5 different signal to noise ratios. This ranged from at the poor end, the noisier end, negative 6db snr up to positive 8db snr. And then we also had part of that five, those five different, that range. They also heard the syllables in isolation and quiet.

And we, so this, we had 75 trials at each SNR split between the three different BA, DA and GA. And it took about 12 minutes total. And you can imagine this is really why we had to cut it off at 7 years old or start at 7 years old. Because while the task isn't particularly, I'm not going to call it particularly challenging though at negative 6 DBSNR, it's pretty challenging. I mean it's just, there's no other way to put it for me to say it than it's just, it's a boring task.

You're sitting at a computer for 12 minutes with your hand on three different keys categorizing ba, da and ga. So we did find out by age 7, even if they are not having the thrilling time of their lives, they are able to get through it. Especially when you remind them that they're getting paid to do the study. I don't know if I actually I should have gone into this more on the slide, but the masker that we use is a speech shaped noise and you could really compare it to it sounds pretty much like a white noise type of energetic masker. And the outcome measures that we collected from this task, from the behavioral end of this task, we have accuracy and response time.

So pretty straightforward. Did they get it right or wrong? How long did it take them? And then from the drift diffusion models we collected evidence, accumulation and decision thresholds. And I'm going to walk you through what those are, I believe on the next slide.

So what are drift diffusion models? I've been talking for the last 26 minutes about DDMs, drift diffusion models. I'm throwing out terms like evidence accumulation and decision threshold. Now what am I talking about? Drift diffusion models are a way that we can take sort of raw categorization, accuracy and reaction time data and get a little more.

I like to say it's kind of like getting a little bit more bang for a buck. So if I take a minute to introduce DDMs, which we've used to analyze performance on that Ba, Da, Ga categorization task. Drift diffusion models, or DDMs, are a type of sequential sampling model that can uncover what's happening in the decision making process. They're deciding, is this a ba, a DA, or a ga? And it uncovers what is happening in that process beyond just accuracy and response times.

So instead of assuming that listeners instantly arrive at an answer, drift diffusion models propose that listeners accumulate evidence as they hear the stimulus and that a decision is made when enough evidence has built up to cross a certain decision threshold. This is especially useful in perceptual tasks like ours, where we ask listeners to identify a speech sound in noise. And I've thrown out the terms evidence accumulation and decision threshold. So let's disentangle what I mean by that. And I'll use my mouse, assuming that you can see my mouse on the screen, sorry, that my head is turned, I'm different screen, so I can use my mouse.

But our first key metric from a drift diffusion model is what we'll call evidence accumulation. Evidence accumulation. If you see these three sort of noisy looking lines right here, this is what we are measuring with evidence accumulation. Evidence accumulation is how efficient the listener is at extracting information from the stimulus. I want you to think of evidence accumulation as sort of a slope.

How steep is the slope of these three different lines? Right here in the red, our participant is accumulating evidence for they believe they heard ba. They're accumulating the blue, the navy. They're accumulating evidence for hearing da. And they're in the yellow, gold, orange here, they're accumulating evidence for ga.

And you can see the red slope is definitely the steepest of the three. And they are correctly in this schematic, they are correctly deciding that the answer, the correct answer, is ba. So evidence accumulation, think of it as the steepness of that slope. It's how efficiently somebody is extracting evidence from the acoustic signal. It refers to how quickly and efficiently the listener is gathering information from the auditory signal to make a decision.

And in our task, it really reflects the quality of acoustic evidence being extracted the steeper that slope, and this isn't even a particularly steep slope, this red one right here, it took them some time, it took them some time to get to their decision threshold, which we'll talk about in a second. But the steeper this slope to get to a correct answer, the stronger, the more robust they are accumulating evidence, they're extracting quality information from that signal. So again, in our task, this reflects the quality of the acoustic evidence being extracted. And for this example, how clearly a child can distinguish BA from DA from ga, looking at that slope. So if these three individual lines, these noisy looking lines, are our evidence accumulation, in order for them to, for that slope to have sort of somewhere to work towards to a threshold to hit.

Now we are looking at these three horizontal lines here for our decision thresholds and our decision threshold. I think decision thresholds are a little bit more straightforward than evidence accumulation. At least when I was learning about DDMs, decision thresholds were a little bit more clear to me off the bat. And decision thresholds are how cautious a responder is in making their decision. So you can see here again, this is a schematic, but you can see these dashed horizontal lines up top, the da, the BA and the ga.

These, this schematic I've sort of mapped out really. So you can see them, the decision threshold level at different points for each speech sound. They can also be on top of each other. But a decision threshold is really, how much evidence does a child or whoever's taking this task require to feel confident making a choice? This is going to be modeled by decision threshold.

It reflects how much evidence a listener needs before committing to a response. If you have a higher decision threshold, that means you require you're being more cautious. You wait for more information before deciding. This can lead to a slower but potentially more accurate response. If you set a higher threshold.

And you could really think of decision threshold as sort of a speed, accuracy, trade off, what level, what is the threshold that you need to hit to make a decision? So to sort of sum all of that up. And this took me, these took me a while to learn. So I always feel like it's a little bit of a large task to do this in a single slide. But evidence accumulation is that noisy slope.

How steep is it? The steeper, the more quality evidence you accumulated, the more efficient you were with that and decision thresholds, these dashed horizontal lines, where on that sort of Y access is that, how high is your threshold? The lower the threshold, the less, the lower the threshold, the risky you are. The higher the threshold, the more cautious you are. Now remember, these are computational models.

This is not observed behavior. We collect our accuracy and our reaction time data and we run it through hours of computational modeling. So theoretically, drift diffusion models assume that when a stimulus is presented, evidence is noisily accumulated from the stimulus towards each decision. Alternative and then a decision is made when a particular I say evidence threshold here because it's a quote from this paper, but really decision threshold has been reached. These types of models are particularly useful in audiology because it connects perceptual performance with cognitive control and listening effort constructs we often talk about but rarely quantify in this sort of precision that we're trying to look for here in this study, DDMs really help us move beyond the how many correct to how listeners are arriving at their perceptual decisions.

The processes we can with this age group, we can look at how that changes across development or within individual differences like phonological awareness or you know, like the level of the acoustic challenge with the different SNRs.

Our goals and hypotheses of the current study are to examine how age, noise level through different SNRs and phonological awareness jointly influence children's phonemes categorization quotes categorization in noise we use drift diffusion modeling to uncover the cognitive and the decision making mechanisms underlying their performance.

Our hypotheses for the study we have a couple and this study we were particularly interested in how phonological awareness might support children's ability to categorize speech sounds and noise, particularly younger children that 7 to 9 group or still developing foundational listening skills and decision making skills. We started with the idea that phonological awareness could act as sort of a compensatory tool that even if a child is still developing more general cognitive or auditory processing abilities, we have strong phono having strong phonological awareness might help bridge that gap. So we expected it to play a particularly protective role in younger children, allowing them to perform like their older peers in these challenging conditions. More broadly, we anticipated that children with stronger phonological awareness would show better categorization performance overall. This means that not only being more accurate but also showing more efficient evidence accumulation, in other words, extracting clearer, more decisive information from the speech signal even when it's degraded by noise.

And then finally, we expected to see developmental differences in the way children make decisions during tasks. Specifically, that younger children would be more cautious, they'd be more slower to respond and hesitant to commit to a choice. And we believe that that pattern would be reflected in their decision threshold parameters which, remember, tell us how much evidence a listener needs before making a categorization decision. Together, these hypotheses let us test not just whether children get the right answer, but how they get there and how factors in this study, how factors like age and phonological awareness shape that process Especially in noisy environments.

All right, so our results, I'll present them here and I'll provide a disclaimer. We are going to. In the top corner you're going to see Q1, 2, 3, 4, 5 for the questions that follow. I was not thinking straight when putting these together. And question one is actually going to come at the end.

So if you see question two immediately, don't worry. Question one is coming just at the end. I think it goes 2, 3, 4, 5 1. There was just no way when putting this talk together I could find a way to feasibly make sense of putting question one anywhere about last. So I apologize, I should have thought through that a little bit more when putting the questions together.

You didn't miss it though. It will come last.

All right, very quick note on our statistical analyses. We use linear mixed effects models here to examine the effects of age group, SNR and phonological awareness, including their interaction terms. Our random intercepts in these models and counted for participant level variability and the outcome measures that we are working through are going to be accuracy, response time, evidence accumulation and decision thresholds.

Here's just the outline of we have our younger group and our older group and this is their phonological awareness, their scores from the ctop. So we have the raw composite. I'm going to go back to the word raw in a second because this is maybe controversial. I would love opinions on this if anybody has anything to jump in with. This is the CTOP scores.

We have our raw phonological awareness composite score on the far left and then we have the three subcategories that you add together to get or you, you use to get the phonological awareness composite score, that being elision blending words and phodium isolation. Now I use the word raw because CTOP is generally scaled a stand. You get a standard score based on age and we did not age correct for phonological awareness. And our reason for that is because in our linear models we have age as a depend, not a dependent variable, but we have it as a fixed factor. So we thought that if we are going to standardize the CTOP scores and include age in our mixed models that we might be over correcting.

But I am up for interpretation or up for debate on this because I understand why that might be something, a process or a way of handling this data that might not be everyone's, you know, choice. I will say that when we use the standard scores in these analysis the results look very similar. But what I am presenting here, the pacs, the Phonological awareness composite score, which you're going to see a bunch on the next slides, is not age corrected.

Okay, so here are our results. I have the results should go pretty quick. We're looking at our accuracy right here. So this is purely just how. What is the percentage of getting it right?

So we have the plot and then we have our linear mix effects model table output on the bottom here we're looking at accuracy. And you can see at first glance when you look at the figure, generally as SNR improves, going from negative six improving all the way to quiet. As SNR increases, accuracy generally improves, which you would expect children do better in quiet conditions. But statistically we found no main effect of age or SNR on accuracy. That means that age alone and noise level alone didn't significantly predict how accurate children were in categorizing these phonemes.

And you can look at this plot and you might wonder. There's clearly an SNR effect here. There's clearly an upward trend, and that's likely. Let me take a step back. There's clearly an upward trend here.

So why isn't there a main effect of snr? You have to remember that in these linear mixed effects models, when we are looking at something like a main effective snr, in the context of this model, it is controlling. Now, if you were to just look at SNR alone, we would see an effective snr. But in these models, we are now controlling for phonological awareness. We're sort of evening it out.

And once we do that, once we control for phonological awareness, that main effect of SNR disappears. So if you're wondering why there's not a main effect of SNR, despite this clear visual trend, it's likely because there's a lot of individual variability and this trend is probably being moderated by other variables like phonological awareness. We're controlling for that PACS measure. So the interaction is really what we're seeing driving that pattern. And we see here a significant interaction between SNR and phonological awareness.

This tells us that as SNR improves, children with stronger phonological awareness skills show a greater benefit and accuracy compared to children with weaker phonological awareness skills. So the two groups are not improving at the same rate across noise conditions. Phonological awareness is acting as kind of an amplifier for performance in better listening conditions. The key takeaway from this slide is that phonological awareness matters most. When the signal becomes more clear, those with stronger skills are better positioned to capitalize on improved listening conditions.

And I kind of hate these plots, because I don't. I probably should change these to have sort of a x axis, like a color map of mapping, like if I did like a scatter plot on top of their phonological awareness scores. This is not captured in these line plots, but it is captured on the table below.

Moving on to response time. So let's look at how quickly children made their categorization decisions. We found a significant main effect of signal to noise ratio, but the pattern was actually unexpected.

Children actually responded more slowly at better SNRS, I.e. they performed slower in clearer listening conditions. This goes against what we typically expect where easier listening conditions usually lead to faster responses. So it raised some interesting questions for us about the strategies and that's what we're trying to tap into here, the strategies for children in making these decisions. Maybe children were taking more time to be accurate when this signal was clearer, or maybe they're more cautious when they can fully perceive all of the different acoustic cues.

It's something we're still unpacking. Maybe at negative 6, the questions or the signal was just not strong enough against the noise and kids kind of were just like kind of, you know, threw their hands up like, I'm not going to get this anyways, so why don't I just quickly respond where perhaps in these easier listening conditions where they knew they had a chance, they were taking their time more. We're again still unpacking this. We also found a significant interaction of SNR and phonological awareness where children with stronger phonological awareness showed less of an increase in response time as SNR improved. In other words, they maintained relatively fast responses across noise levels, while kids with weaker phonological awareness tended to slow down more as the signal got clearer.

There was no main effect of age group here, which suggests that age alone wasn't a strong predictor of how quickly children made decisions and tasks. And overall, this measure, this response time gives us sort of a different angle on the listening process.

So not just what response was made, but how quickly. And next we'll kind of look at how maybe confidently the decision was reached.

Evidence accumulation then kind of presenting these all. Similarly, if we're looking at our first key drift diffusion model outcome, we have evidence accumulation. We found a main effect of phonological awareness where children with stronger phonological awareness skills showed steeper evidence accumulation rates. Remember that steep slope? This means that they were extracting clearer, more decisive information from the speech signal as they listened.

There was no main effect of age groups, suggesting that phonological skills, not chronological age, were more predictive of how efficiently children accumulated evidence in this task. And then we found a significant interaction between SNR and phonological awareness. We're sort of seeing a pattern here at better signal to noise ratios. So in that plus eight, that quiet range, children with stronger phonological awareness showed enhanced gains in evidence accumulation. So as the task became easier, these children were able to extract even more reliable, efficient information from the signal, while those with weaker phonological skills really didn't improve as much.

This measure is really helping us get at the processing, the quality of processing, not just whether or not they got it right, but how robustly and efficiently they were gathering evidence to make their decision. It also aligns with our earlier accuracy findings where phonological awareness played an important role in the clearer conditions, not the noisier conditions. But it really started to differentiate kids in those quiet or quieter conditions. It also suggests that phonological awareness supports children in making better use of the signal when it's available.

Finally, here, let's look at decision thresholds. So here is this, is that speed accuracy trade off that how. What is your level? Remember the horizontal dashed lines? Let's look at the threshold levels that kids needed to hit at each SNR and by these other the age and the pa, the pacs, the phonological awareness variables.

Remember, decision thresholds reflect how much evidence children needed before committing to a response. So in essence, how cautious or divisive they were during categorization, how risky versus how cautious. Remember, the riskier, the lower decision. The lower the decision threshold, the riskier they were. The higher the decision threshold, the more cautious they were.

And I haven't, what I haven't been doing a good job at here is walking you through before we get into the linear mixed effects models and the interactions is just looking at the plots as is before we sort of start controlling for things. So let's take a second to do that here with decision thresholds. And I apologize that our. This is totally my bad that I don't have a legend here. I apologize.

The older kids are the ones in that pinkish color and the younger kids are in that bright turquoisey color. And you can see here that the younger kids. I'm actually going to flip back just a couple of slides to be 100% positive. Yes. Younger children in turquoise, older children in that pink.

I apologize. Going into our decision thresholds, going back, you can see that before we control for phonological awareness, our younger children have higher decision thresholds. They require a higher level of caution to make their decision at all of these SNRs than did older kids. Looking at decision thresholds and getting into our model, we found two significant main effects here. First, we found a main effect of signal to noise ratio.

As the listening conditions improved, children actually became more cautious. This is going back to what we saw and what I don't know if it puzzled us, but we were working through what we found in response time where children here with decision thresholds, children actually became more cautious than setting higher decision thresholds in easier listening conditions than in noisier listening conditions. So even though the signal was clear, they waited longer or needed more evidence before making a decision. This might reflect more thoughtful processing or greater attention to detail when they could fully access the signal. Second, we found a main effect of phonological awareness.

Children with stronger phonological skills consistently set higher thresholds across all conditions. In other words, they tended to make more deliberate decisions regardless of noise level. This may indicate a more strategic or reflective approach to categorization where they are prioritizing accuracy over speed. We didn't find any significant effects of age nor interactions involving age or age group. So taken together, this tells us that phonological awareness isn't just related to how efficiently children accumulate evidence, but it's also linked to their decision making.

I'm going to call it decision making style. Kids with stronger phonological awareness were both faster and more cautious, suggesting that a more confident that they are using this sort of more confident controlled perceptual process.

So let's summarize the findings. I have two slides left. Sort of the summary and the take home messages.

I know I got to hit 55 minutes and I think the timing is pretty good here. So, summary of findings first, phonological awareness predicted performance across all outcomes. Children with stronger phonological awareness were more accurate, they were more accurate, they accumulated evidence faster and they made more cautious decisions. We found no main effects of age. So age alone didn't predict accuracy, response time or either of the DDM parameters.

But that doesn't mean here that age means nothing because it's actually very interesting that younger children performed similarly to their older peers, especially when they had strong phonological awareness. So it's not just that age means nothing. There is something there to not seeing any age differences that children, younger children, especially younger children with higher, stronger levels of phonological awareness could sort of hang with their older peers when they had that stronger phonological awareness. So phonological awareness may sort of help compensate for developmental Immaturity in these difficult listening conditions. We also saw a significant interaction between signal to noise ratio and phonological awareness for accuracy.

As noise decreased, kids with stronger phonological awareness showed greater gains in performance. Oh, sorry, I forgot to hit my button over here.

Lastly, children became more cautious at better snrs, which really, I don't think we would have really predicted that, that they were showing not only the slowest response times, but also the highest dis decision thresholds, the highest levels of caution at better snrs. And those with. But. But those with stronger phonological awareness set higher decision thresholds overall, suggesting more deliberate processing. So overall, how I want to sum this up is that phonological awareness emerges as a key factor supporting speech perception in noise, more so than we saw with age.

All right, wrapping up here, some take home messages, not just a summary, but like, what can we take from this? Phonological awareness seems to be a key driver in children's speech perception and noise, more so than age alone. I know. In my introduction I talked a lot about how the results of these studies that have looked at spin, speech reduction in noise and phonological awareness have been mixed. And I talked about how maybe accuracy isn't telling us everything.

No one's arguing that accuracy is everything. But we're seeing this when we are able to sort of dig deeper into the cognitive processes, the sort of behind the scenes work that is going on in decision making, which is a part of speech perception and noise. Not consciously thinking about every single phoneme, but it does go into how we accurately perceive speech and noise. Phonological awareness does seem to be a key driver of that, more so than age. We also saw that kids with stronger phonological awareness benefited more from clearer signals, suggesting that these skills help take advantage of better listening conditions.

And this points to phonological awareness as a potential intervention target, especially in noisy educational settings, which we know for most kids is just something that they are dealing with all day, every day. And finally, using drift diffusion models gives us insight into how children make decisions. Not just whether they're right, but how fast, how cautious, how efficient they are processing speech in noise. Here again, this is phonemes in noise. It's not full sentences, it's not even full words, but this is giving us some insight into how efficiently they're processing these phonemes or these syllables in noise.

Are we ready to bring diffusion models to the clinic? No, but we know that basic science can inform not just the tests that we're using, but the interventions that we're building and developing and the last couple years modeling and AI have come to the forefront like just big time. So I think down the road there there's some ability to make some of this type of work have its place with some work in a clinical setting. So I'll wrap up with just some acknowledgments to the wonderful people that I work with at Pitt. As I said, I value the work that I do with clinicians so much.

Audiologists and speech pathologists, there's a couple of them on here. If you ever have the opportunity to visit Pitt or to do, to do anything here, work here, study here. It has been the happiest, healthiest place that I have worked and I'm so grateful to get to represent Pitt at Audiology Online this year. So with that I'll wrap up my talk and if there's any questions I happy to take them and thank you guys so much.

Thank you so much. Dr. Parker, welcome. Go ahead and open up the floor for any comments or questions. And Dr.

Parker, in the meantime, could you advance that very last slide? Absolutely. I'm just going to remind the participants should they wish to earn CE credit for today's presentation, just wait for the exam to populate usually 10 to 15 minutes after and complete that multiple choice exam within a week and they'll be able to earn an hour of ceu. So for today's presentation, still nothing in the queue. We'll go ahead and just go ahead and close.

Dr. Parker, I'd like to take this time to thank you and also the coordinators over the University of Pittsburgh. For those of you who don't know, we have this ongoing partnership with University of

Pittsburgh and in exchange for the presenters time that they dedicate to bringing on their content and presenting the info, we actually donate Audiology Online memberships to the graduating class for, for AUD students each year. So it's been a great partnership and they're so grateful. Yes, yes, I bet.

Especially to start out their career and just have that continuing education burden lifted from their shoulders. I know that's been much appreciated on their end and I heard this year it's like 20 students. Yeah, it was graduation and everything. This partnership. Katherine Palmer, Dr.

Palmer, our chair is so grateful and really hypes it up to the students and it's funny because I have audiology friends who are like not students but they're like, if I come, can I get. They are very. It's a. The students and beyond that are grateful for it. So thank you guys so much.

Wonderful. Thank you so Much, Dr. Parker, for your. We'll go ahead and close out. Everyone have a great day.

Thank you all. I appreciate it.