(4) What rate of 3D sound movement can be reliably detected?

Movement speed - The minimum audible movement angle (MAMA) of a sound source varies as a function of the sound's frequency, bandwidth, angular location, elevation, and velocity [110--112]. However, it is generally agreed that as the velocity of a sound increases, the MAMA also increases. Accordingly, the proposed work will assess **how movement speed affects performance for near-field and far field sounds** in this real-world context.

After searching through several academic databases, we determined that the Han & Chen study is one of the most recent sources of information regarding the minimum audible movement angle. As previously discussed, it is agreed upon that "as the velocity of a sound increases, the MAMA also increases". Our research question will be along the lines of "How significantly does the movement of near and far field sounds affect the listener's ability to accurately perceive that sound?" We will simulate the variations in a VAE, which is admittedly not a replacement for RAEs, but will give us an idea of potential issues that may arise due to the movement/distance of a virtual sound and how it is perceived. It is possible for search and rescue scenarios to have low visibility, putting a greater emphasis on auditory cues.

As for the study design, we want to utilize a mix of Han & Chen (2019) and Perrot & Musicant 's (1977) methodologies. Han & Chen created virtual moving sounds using an HRTF at different speeds and tested if the motion could be perceived. It considered what the MAMA was for different angular speeds but it didn't say how reliably the participants could locate a position. They also didn't consider low angular velocities (they only did 100°/s, 150°/s, 200°/s). In a situation where accuracy is very important, it's critical that we know how lower angular speeds affect perception of virtually created 3-D sound. This insight might allow us can to create sounds movement that's audible and reliable. The Perrot & Musicant study (1977) measured the localization accuracy of moving sounds by playing noise from a speaker on a moving pole. Participants' view was obstructed by a sheet with degrees printed in the azimuth plane. They were told to report where the sound started and ended.

We could conduct a study similar to Han & Chen 2019 with localization in mind. The experiment could be conducted by simulating virtual 3-D sounds moving from different distances (near/medium/far) at different speeds with real world background noise. Since we are testing multiple independent variables, this would require a factorial experimental design, meaning that each level of one independent variable is combined with each level of the others to produce all possible combinations. In the actual testing session, each listener would participate in a total of 18 testing conditions [= 6 angular speeds (i.e., 10°/s, 20°/s, 40°/s, 80°/s, 160°/s, and 320°/s) x 3 distances (close field, medium field, and far field). The sound would be broadband noise. To indicate the angle the sound is coming from we could build a VR environment with degrees in the azimuth plane for the participants to use. Our independent variables would be angular speed and distance. Our dependent variables would be the perceived starting and ending position of the sound. Our constants would be sound source and sound duration.

To create sounds of varying distances we'll leverage spectral cues and the inverse square law of sound. Near field sounds (< 1m) have a low frequency attenuation due to head diffraction. Mid field sounds (1m - 15m) have no obvious cues. Far field sounds (> 15m) have a high pass attenuation due to loss of energy traveling through the air. The inverse square law says that for every doubling of distance, the intensity of a sound is reduced by 6dB.

It has been observed in previous studies that the MAMA in VAE is much larger than RAE, implying that auditory perception is more restricted during simulated motion vs realistic motion. This already introduces a limitation for our experiment, most likely caused by binaural hearing and a lack of realistic audio cues.

Ideas

- Measuring the accuracy of signal detection at various distances and velocities
- What controls do we have over the experiment? Are we creating a study separate from the SAR simulation or does it have to be integrated into the simulation?
- If so
    -
- If not
    - We could conduct a study similar to Han & Chen 2019. The experiment could be conducted by simulating virtual 3-D sounds with sounds moving from different distances (near/far) at different speeds with real world background noise. In the actual testing session, each listener would participate in a total of 18 testing conditions [= 6 angular speeds (i.e., 10°/s, 20°/s, 40°/s, 80°/s, 160°/s, and 320°/s) x 3 distances (close field, medium field, and far field). The sound would be broadband noise.

[Binaural audio rendering with head tracking - MATLAB]()

If you are mimicking the Han 2019 study, what makes yours different?

We're investigating the effect of distance in performance and also measuring the perceived angle of movement if movement is detected at all. We could do a mix between the Han and Perot studies. The perrot study in 1977 measured the effect of motion by using a loud speaker and moving it on a track. In our study we'd be creating all of these sounds virtually. In Perrot's study they had the user wear a head cover that allowed them to see degrees in something like a protractor. They would tell the study if it moved and what angle it moved. We could use VR to create something like that. Take the same measurements as Perrot

TABLE II. Perceived and actual position of onset and offset as a function of source speed and sound pulse duration.

Boom speed (°/s)	Pulse duration (ms)	Onset Perceived[a] (° left)	Onset Actual (°)	Offset Perceived[a] (° left)	Offset Acutal (°)
600	50	16.0	0	29.2	30.0
600	100	18.0	0	49.2	60.0
360	50	11.7	0	20.7	18.0
360	100	13.4	0	48.5	36.0
360	150	12.3	0	67.2	54.0
180	50	7.0	0	8.0	9.0
180	100	12.1	0	24.3	18.0
180	150	7.7	0	45.9	27.0
90	50	5.1	0	6.4	4.5
90	100	7.3	0	10.7	9.0
90	150	6.2	0	21.7	13.5
90	300	7.3	0	52.2	27.0

[a]Perceived onset and offset values are the mean of 20 estimates.

Where are the gaps in that study?

It considered what the MAMA was for different speeds but didn't say how reliably they could be used to locate a position. Like what's the error when someone thinks it's moved 10 degrees. They also didn't consider low angular velocities (they only did 100,150,200). In a situation where accuracy is very important. It's critical that we know how lower angular speeds affect perception of virtually created 3-D sound. And which speeds allow users to hear the closest accuracy to the angle we're looking for. Eventually we'd have to have a tradeoff and find a middle ground because greater speed = higher MAMA and less accuracy. What's even the benefit?

That work is also 4 years old, what new information is now available?

None tbh lol

I don't know

So how are you mimicking a far/near field?:
http://youngscientistjournal.org/youngscientistjournal/article/implementing-an-audio-processing-system-to-simulate-realistic-distance-with-sound

After plotting our data, we discovered that as the distance between a sound source and a microphone/listener increased, the amplitude of the detected sound decreased nonlinearly. After further researching the physics of sound, we learned that humans' perception of sound decreases logarithmically, explained by the Inverse Square Law, as distance increases.

"[sounds] are judged to be more distant as their high- frequency content decreases relative to the low-frequency content" [https://www.frontiersin.org/articles/10.3389/fpsyg.2017.00969/full]. With the found relationship between sound and distance, we were able to successfully create an audio processing system, making use of low pass filters and a phaser, that can simulate realistic sound characteristics

Spectral content provides a physically measurable cue for ADP only for very short (<1 m) or long (>15 m) distances to the source.

near field (low-pass filtering due to head diffraction) or when the sound travels distances >15 m (high-frequency energy losses due to air absorption).

No measurable ADP cues were studied for sounds located in the range 1–15 m

Near field: < 1m
Mid field: 1m - 15m
Far field: > 15m

Doubling of distance means -6DB in intensity

This is going to be based on the studies you've encountered.
What are your independent and dependent variables for the study?

Independent: Angular speed, duration, and simulated distance
Dependent: Perceived Onset Angle and Perceived Offset Angle

What data do you plan on collecting?
make sure you're not missing any newer data, so comb through a few digital libraries to find information.
Once you're confident in that, rationalize your design choices.

1) Do the power analysis. You can google a calculator online so you know what you need to put into it.
    a)
2) What data collection methods were used in the other studies? That should be considered.
    a)
3) Why those velocities? I'm just curious.
    a) It gives us a good view of how fast and slow angular speeds affect MAMA. The studies we looked at don't take into account both ends of the spectrum and since we're looking for the ideal rate, it's good to know how slow, fast, and medium speed sounds perform.
4) When it comes to far-field some lit can vary on how it's described. Considering the volume you're working with -24dB from max volume you need to keep in mind what that max is to not hurt anyone.
    a)
5) Why 20% noise? And why only one noise condition? When testing different variables (even when it comes to the velocity) you need a control. So you would need to test out no noise and no velocity. Your participants can just be really poor at perceiving different things or they can just not care and be lying. That control condition allows us to account for that and have a sense of a ground truth for each person.
    a) Initially, I was thinking of one noise condition because I didn't want there to be too many variables but if it's not a problem, I'd want more conditions. If we did 0, 20, 40, 60, 80, that would make for (5 * 7 * 2) 70 testing conditions.
    b) Since we're only asking for a starting and stopping angle, our control can be sound with no angular velocity. That just means when we explain the study to the participants, we tell them a sound could move a range of 0 to 180 degrees
6) Why 700Hz? This is an important question that needs to be rationalized. Initially y'all talked about broadband sounds and then y'all mentioned a 3k lowpass filter which is not possible if you have a 700Hz sound. Back this up with literature.
    a) A study performed by Perrot and Tucker on MAMA as a function of stimulus frequency found that dynamic spatial resolution was much larger for signals under 1000hz and over 3000-4000 hz. Han and Chen's study in 2019 also observed this to be true, so we wanted the stimulus to be under 1000hz. Their study also utilized a spectrum of frequencies ranging from 500 to 2900hz, but for our study we want to focus on specifically on angular speed in near/far fields, and keep the frequency constant. 700hz was a bit of an arbitrary choice, but still adheres to the goal of under 1000hz.
7) Is your starting location always at 0 degrees azimuth? Why?
    a) It doesn't need to be. All that matters is that we measure where the sound starts and stops

Minimum audible movement angle during self motion vs sound motion - https://www.frontiersin.org/articles/10.3389/fnins.2014.00273/full

- Using infrared motion tracking, researchers were able to control the movement of virtual signals and measure self-movement in participants. Their performance when presented with self-motion vs. source motion was monitored while ensuring that the actual movement itself was identical in the two conditions. From this, researchers deduced that there was an advantage for spatial processing during self-motion rather than source motion.

Minimum audible movement angle in the horizontal plane as a function of stimulus frequency and bandwidth, source azimuth, and velocity

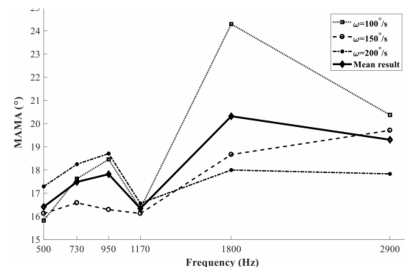
- Minimum audible movement angles (MAMAs) were measured in the horizontal plane for four normal‐hearing adult subjects in a darkened anechoic chamber. Participants were tasked with determining whether a sound stimulus came from a stationary loudspeaker or from a loudspeaker that was moving at a constant angular velocity around them.

Evaluation of the Minimum Audible Angle on Horizontal Plane in 3rd order Ambisonic Spherical Playback System

Minimum audible movement angle as a function of the azimuth and elevation of the source

[Minimum Audible Movement Angle in Virtual Auditory Environment: Effect of Stimulus Frequency (Han & Chen, 2019)]

- According to the fundamental mechanism of VAE generation, it can be hypothesized that listeners cannot discriminate motion in VAE at the same level of sensitivity as in RAE. The lower limit of MAMA (2.8) is less than the resolution for Virtual audio displays (5). VADs are 5 degrees because that's usually the step for HRTF databases
- MAMA is larger in VAE (Virtual Audio Environments) than REA (Real Audio Environments)
- After 1000Hz, MAMA is trash



- Experiment: This experiment was conducted all virtually by simulating the sounds with 3-D audio. In the actual testing session, each listener participated in a total of 18 testing conditions [= 6 frequencies (i.e., 500 Hz, 730 Hz, 950 Hz, 1170 Hz, 1800 Hz and 2900 Hz) x 3 angular speeds (100/s, 150/s and 200/s)

[Minimum audible movement angle as a function of signal frequency and the velocity of the source (Perrot & Tucker, 1987)]

- Spatial resolution is optimal for signals below 1000Hz and above 3000Hz. This affects static and moving sounds in a similar way
- Experiment: They used a similar setup to (Perrot and Musican, 1977). In a sound booth, there was a boom attached to a rotating motor that could spin around the person's head. They used set frequencies and changed the velocities to measure MAMA. They found that both velocity and frequency impact MAMA

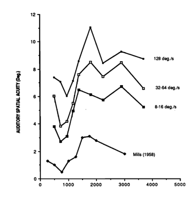
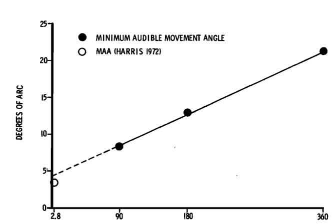


FIG. 1. MAMA thresholds (in degrees) for three velocity ranges (8°–16°, 32°–64°, and 128°/s) as a function of the frequency of the signal localized. The lower function is a replot of the Mills (1958) MAA thresholds obtained under "static" listening conditions across the same frequency range.

[Minimum auditory movement angle: Binaural localization of moving sound sources (Perrot & Musicant, 1977)]

- MAMA increases with the velocity of movement
- The greater the velocity of movement, the more the listener perceives the starting angle of the sound to be in the direction of motion
- Experiment 1: They had stationary speakers and a speaker attached to a moving pole. The idea was to see how speed affected a person's ability to detect the movement of a



sound. They rotated at speeds of 90, 180, and 360 degrees/sec

- Experiment 2: Participants used the same system but this time were blocked from seeing the speakers and were told to identify which angle the sound started and finished

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180	50	7.0	0	8.0	9.0
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[a]Perceived onset and offset values are the mean of 20 estimates.

[Auditory spatial resolution in horizontal, vertical, and diagonal planes]

[Correlational analysis of acoustic cues for the discrimination of auditory motion]

[Minimum audible movement angles as a function of sound source trajectory]

[The Minimum Audible Movement Distance for Localization of Approaching and Receding Broadband Noise with a Reduced Fraction of HighFrequency Spectral Components Typical of Prebyscusis]

Armisha Questions 7/13

Do you have any advice when starting a big build like this?
How do we take the HRTF screening portion from your code?
What were the decisions you made when designing the experimental portion of the study?
How would you recommend splitting up the work?
How much of your code was independently written?
Do you have resource recommendations?