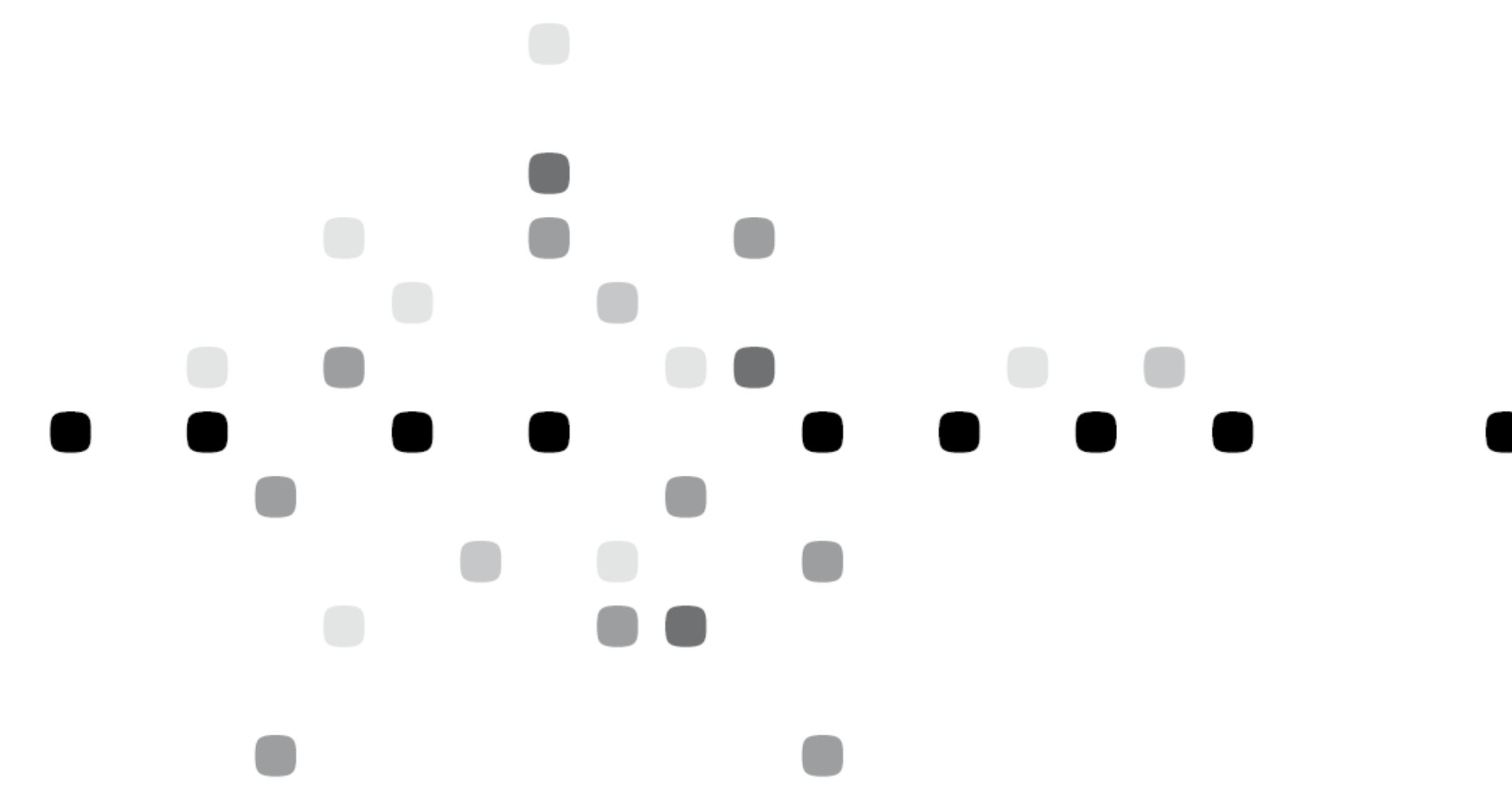


LOCALIZATION CASE STUDY

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INTRODUCTION

It is known that spectral cues that arise from the shape of the pinnae contribute to sound localization, in particular, front/back localization [Musicant and Butler, 1984]¹. When the microphone of a hearing aid is placed behind the pinna, such as in a behind-the-ear [BTE] instrument, the directional properties derived from the shape of the pinna are lost. Today's BTE instruments may contain algorithms which compensate for the loss of these cues and assist with front/back localization. In addition, they may also contain inter ear communication for compression in order to maintain inter aural level differences [ILD]. The preservation of the ILD may assist with left/right localization. Even with these features to help maintain localization cues, some listeners may not be able to utilize this information unless given some guidance or training.

A study was conducted on localization performance of hearing impaired listeners. Their localization skills were evaluated prior to training with a 300ms stimulus [high pass filtered above 2000 Hz] in a 360°, 12-loudspeaker array. The participants wore Clear 440 m-CB instruments for three months and received laboratory based and home based localization training. A particular training method was completed during each month [either laboratory or home based, counterbalanced] and no training was required during the final month. Testing was conducted at intervals of one month, two months, and three months. Performance varied among the participants. Some benefited from home training and laboratory training while others did not seem to benefit as much. This case study poster will examine results from three participants from this study: two of whom benefited from training and one who did not benefit.

Center of Mass Results

The results will be shown using the Center of Mass [CoM] method as described by Edmondson-Jones et al. [2010]². The method of Center of Mass [CoM] allows researchers to consider the proportion of correct responses, direction of resultant performance, and size of errors simultaneously. The CoM approach is visually represented by a circle with a unit radius in a Cartesian plane, with reference to the origin at the coordinate (0,0). When responses are perfectly correct, yCoM will be 1 while xCoM will be 0. Thus, yCoM indicates target accuracy by measuring how close it is from the point of perfect responses (i.e., 1); and xCoM shows the lateral accuracy by measuring how close it is from the origin (0,0).

A sample of the results was shown in Figure 1. The points of perfect responses for individual loudspeakers are indicated with different symbols on the circle of a unit radius. The performance in localization is visually shown by connecting the coordinates of the CoM in response to the stimuli delivered from the target loudspeaker. The more correct the responses a listener achieves, the closer the response symbols will be towards the symbols in the outer circle, Figure 1A. The coordinates of CoM for the target loudspeaker at 0° azimuth in Figure 1B are (0.04, 0.31) and at 180° are (0.07, -0.22), indicating that there are many front to back errors. The performances at the right quadrant (i.e., 60° - 120°) and the left quadrant (i.e., 240° - 300°) are much better (i.e., closer to the perfect circle).

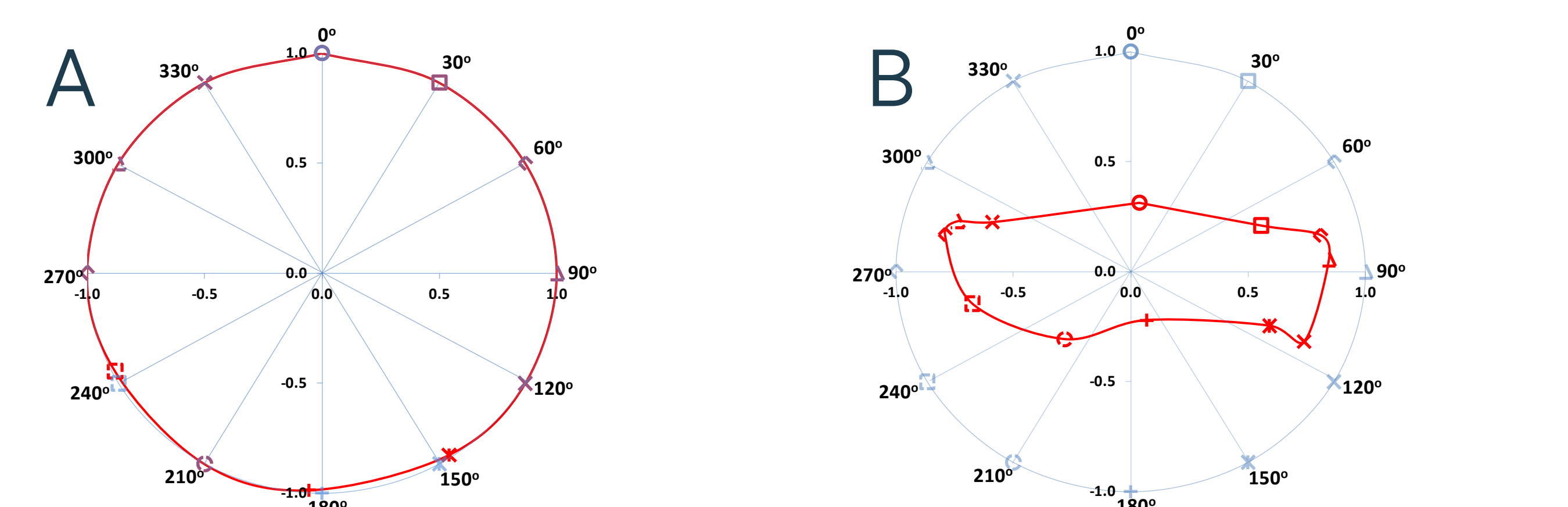
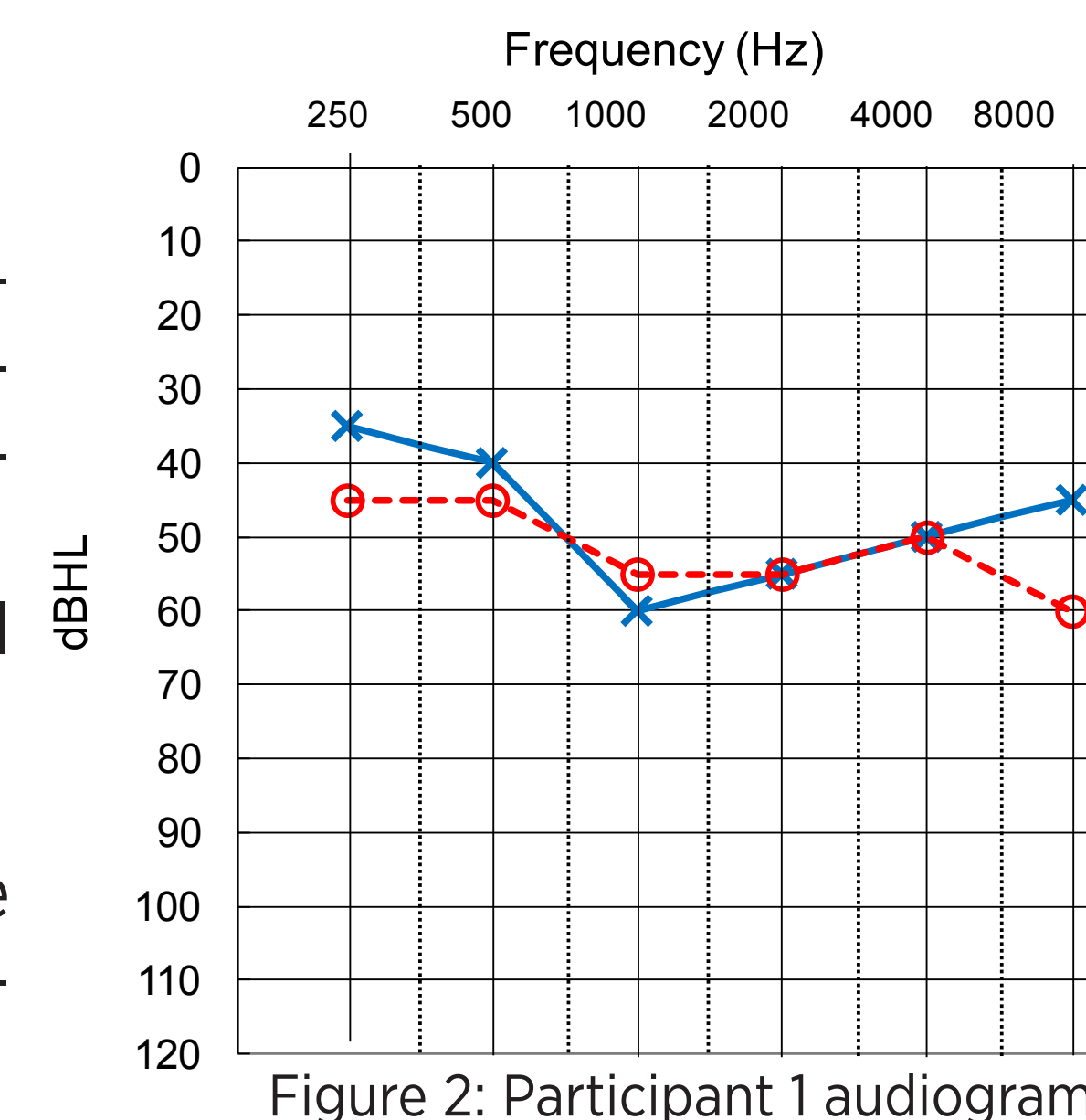


Figure 1: Example of near perfect localization performance [A] and poorer localization performance [B]. Each symbol on the outer circle represents a loudspeaker position. The coordinates of CoM are represented by the appropriate symbol for each target.

¹Musicant, AD// Butler, RA. 1984. The Influence of Pinnae-Based Spectral Cues on Sound Localization. *J Acoust. Soc. Am* 75(4):1195-1200.
²Edmondson-Jones, AM// Irving, S// Moore, DR// Hall, DA. 2010. Planar localization analysis: A novel application of a center of mass approach. *Hear Res* 267: 4-11

PARTICIPANT 1

- 28 year old female
- 10 years hearing aid experience; canal aids 14 hours per day [no directional microphones or inter ear functionality]
- Essentially moderate sensorineural hearing loss; word recognition 84% right and 80% left
- Diagnosed with hearing loss at age 18 years; etiology unknown [no family history]



Participant 1 completed home localization training during the first month. Home training was completed 30 minutes/day and five days/week for 4 weeks. At completion of the home training program, the participant's localization ability was assessed in the laboratory. The participant then returned for six laboratory training sessions during the second month. Each laboratory training was approximately two hours in duration. At the end of the second month, localization ability was assessed in the laboratory.

Unaided localization results for Participant 1 shown in Figure 3A and own aid results in Figure 3B:

- Baseline results [red] were all towards the front; between 300° and 60°.
- No training received in unaided condition; however, improvement seen at the 2 month visit.
- Own aid results were almost identical to unaided baseline results. With an ITC instrument, pinna cues should be available due to location of the microphone. However, no sounds were identified to the back.

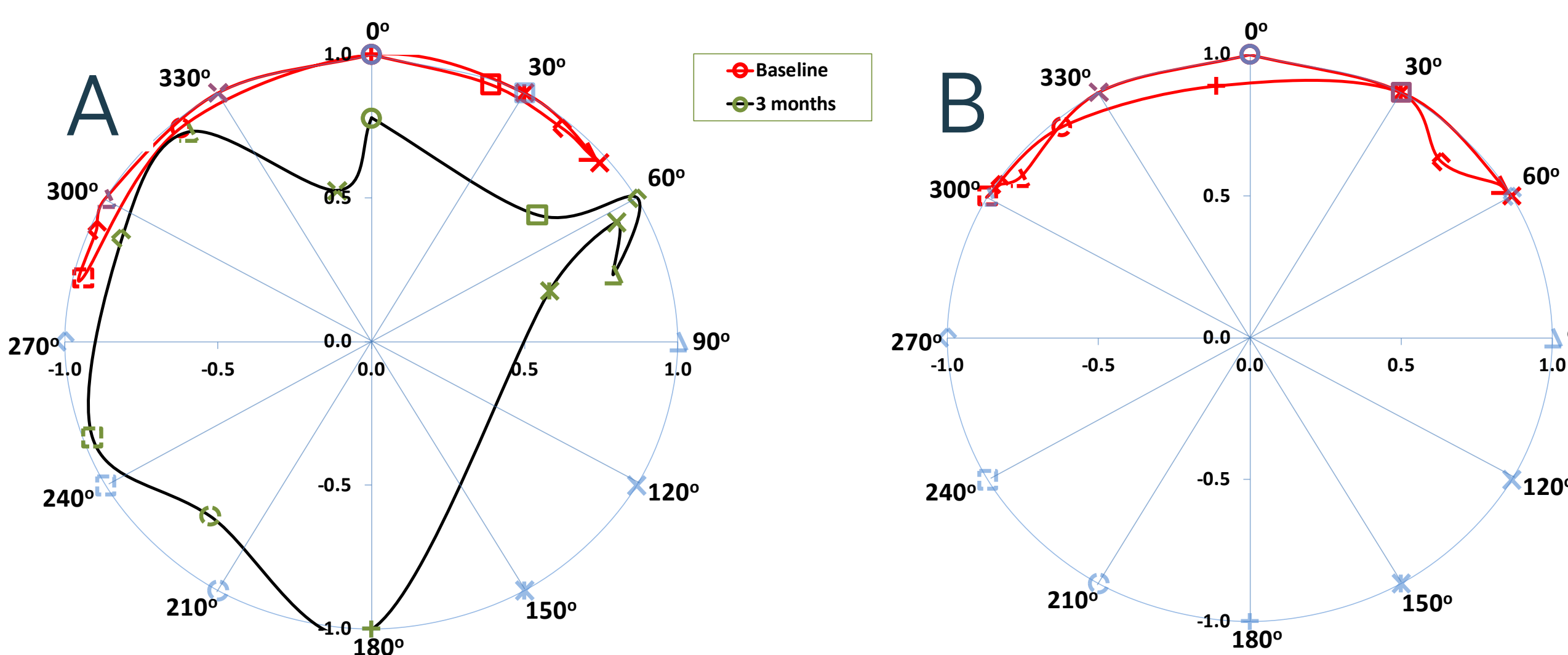


Figure 3: Unaided [A] and own aid [B] localization performance

Results with Clear 440 m-CB for Participant 1 shown in Figure 4:

- Responses for baseline testing [in red] were very limited and similar to unaided baseline results; most were between 330° and 30°.
- Significant improvement after one month of home training; Figure 4A.
- Improvement over baseline also seen after laboratory training complete; Figure 4B.
- No significant difference between results after completion of home training at 1 month and after completion of laboratory training at 2 months.
- This participant reported that prior to using the home training program, she felt like all sounds seemed to originate to the front. She reported that the home localization training program helped her to recognize what sounds were like when they originated from behind her.

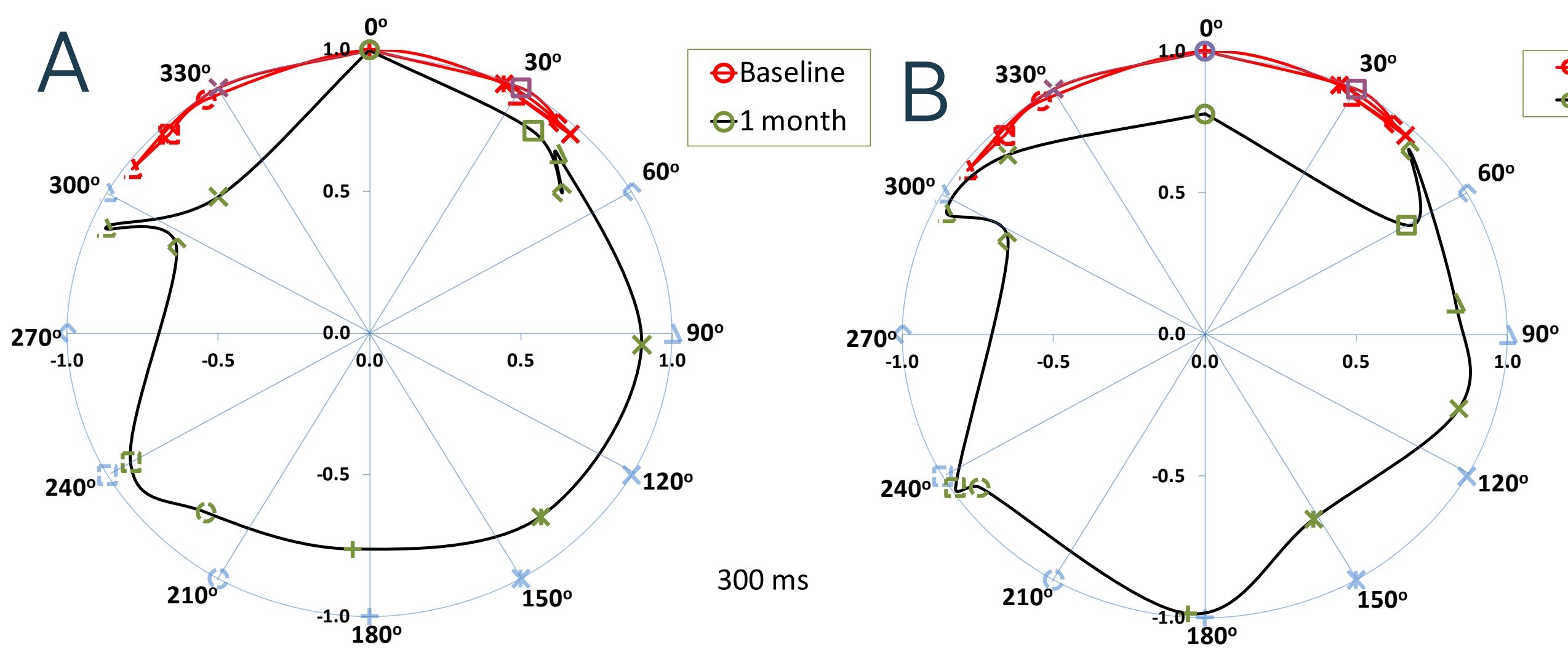
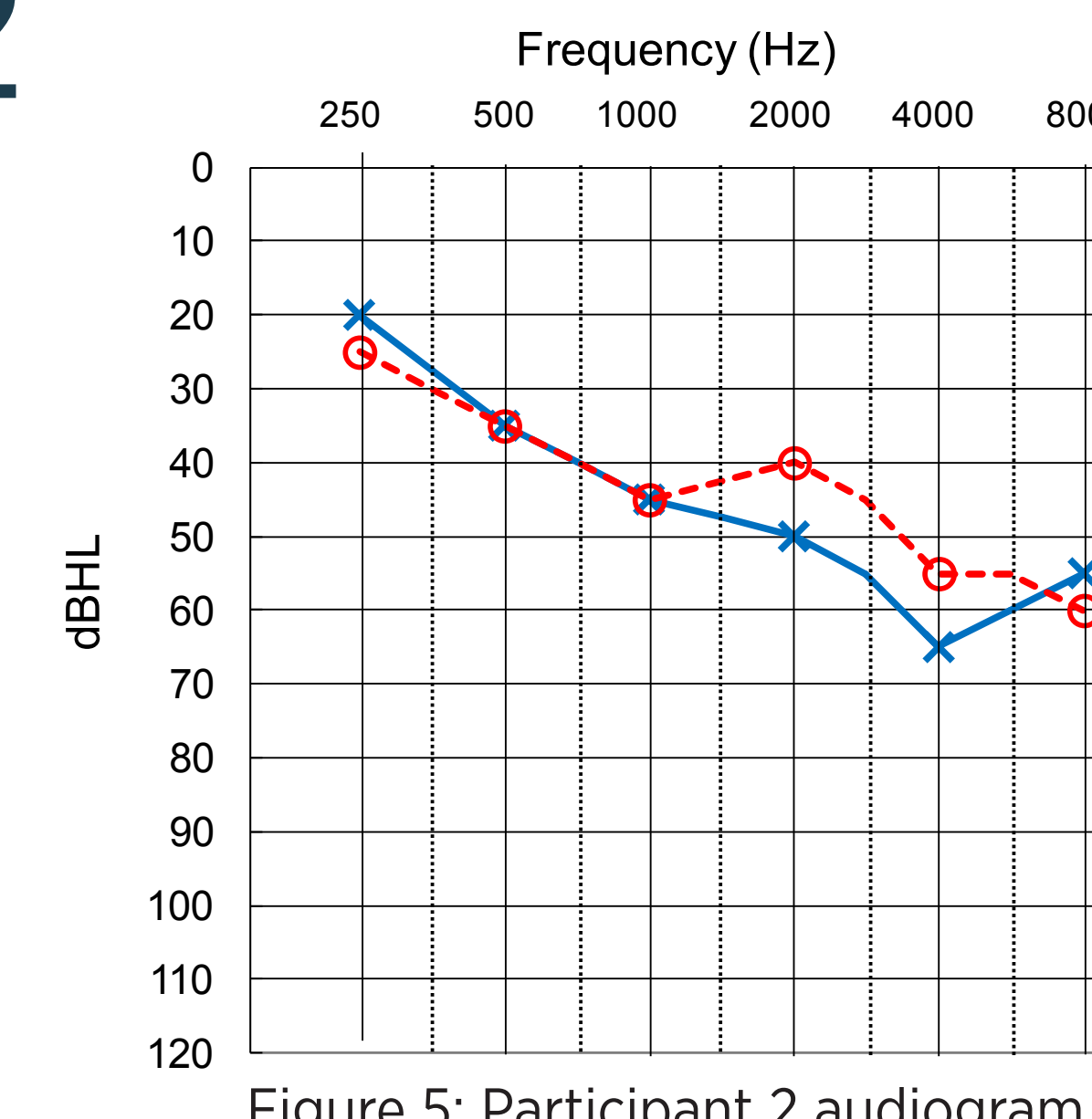


Figure 4: Participant 1; CoM localization results from baseline to one month; home training complete [A] and baseline to two months; laboratory training complete [B]

PARTICIPANT 2

- 77 year old female
- 3 years hearing aid experience, open fit RIC with directional mics but no pinna compensation or inter ear functionality
- Mild to moderate sensorineural hearing loss, bilateral, word recognition 90% right and 78% left
- Family history of hearing loss



Participant 2 completed six laboratory training sessions during the first month of hearing aid use. The laboratory training was approximately 2 hours in length. At the end of the first month, localization ability was assessed in the laboratory. The participant then completed one month of home localization training. After the home training was complete, localization ability was assessed in the laboratory again.

Unaided results for Participant 2 were shown in Figure 6A and own aid result in Figure 6B:

- Unaided baseline results [in red] show very poor front/back localization.
- After training [in black] results to the front improved the most.
- It should be noted that the participant had recently lost her left hearing aid. Results for own aid were obtained with only the right hearing aid. All responses were to the right and back. It is unknown how her performance with her own aids may have improved with two instruments instead of one.

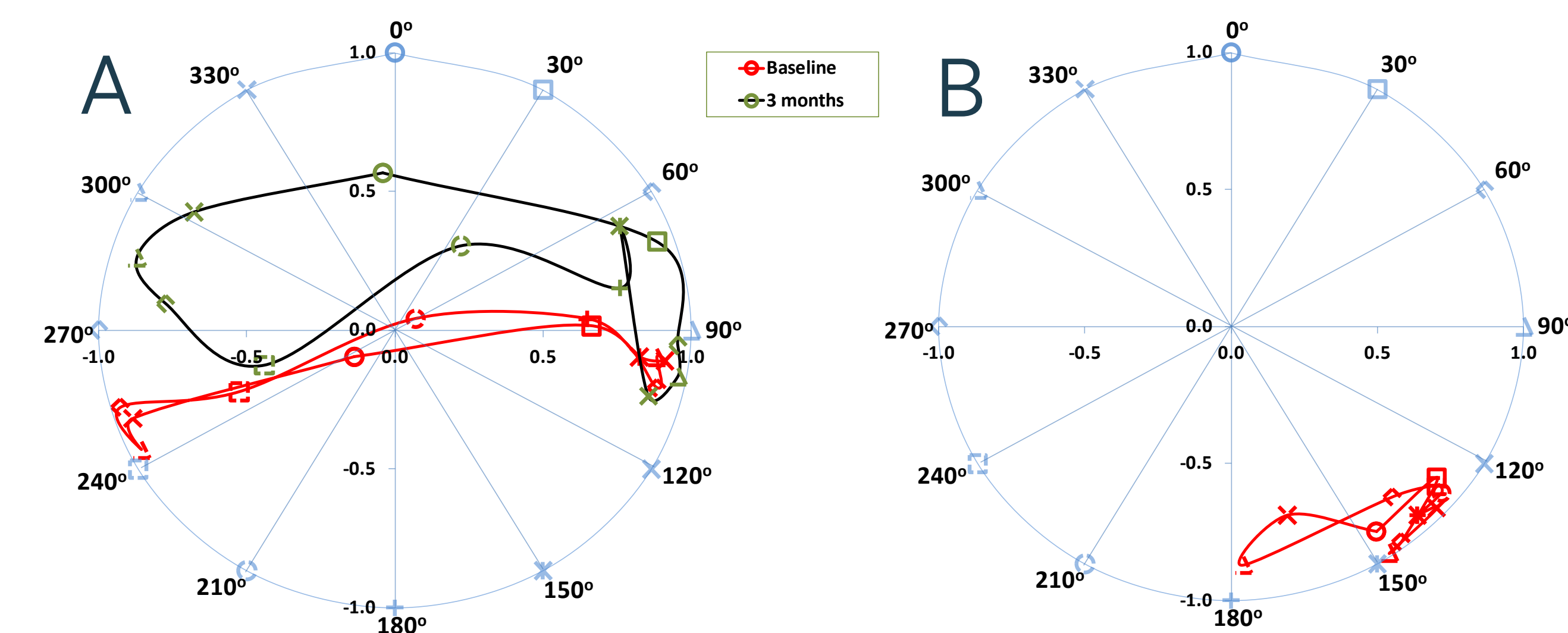


Figure 6: Unaided [A] and own aid [B] localization performance

Results with Clear 440 m-CB for Participant 2 shown in Figure 7:

- Baseline responses [in red] were towards the front horizontal plane and were better than the unaided baseline results shown in Figure 6A.
- After laboratory training complete at 1 month, Figure 7A, improvement seen to the front as well as to the back.
- After home training complete at 2 months, Figure 7B, additional improvement seen towards the back.
- Aided results after training [7A and 7B] were better than unaided results after training.
- This participant reported that she felt she was OK at determining sound sources in her own home. However, living alone, she had no one to tell her otherwise.

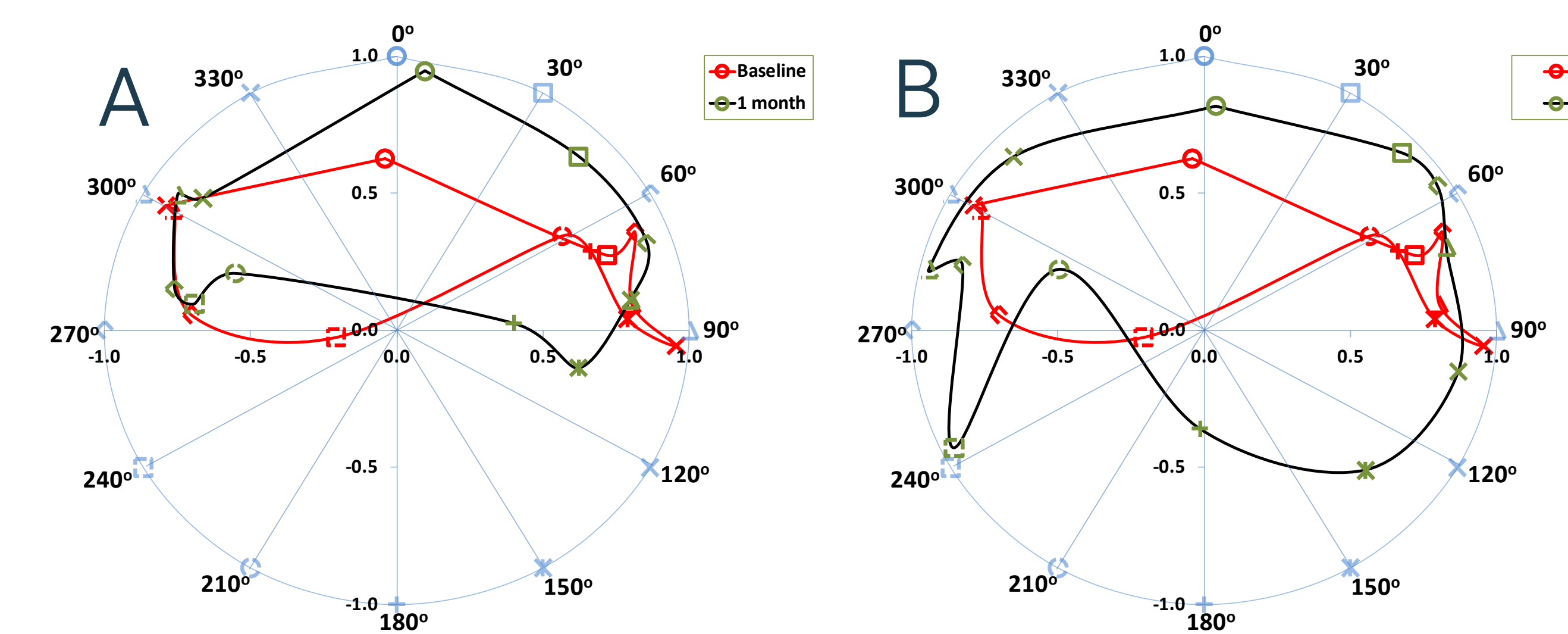
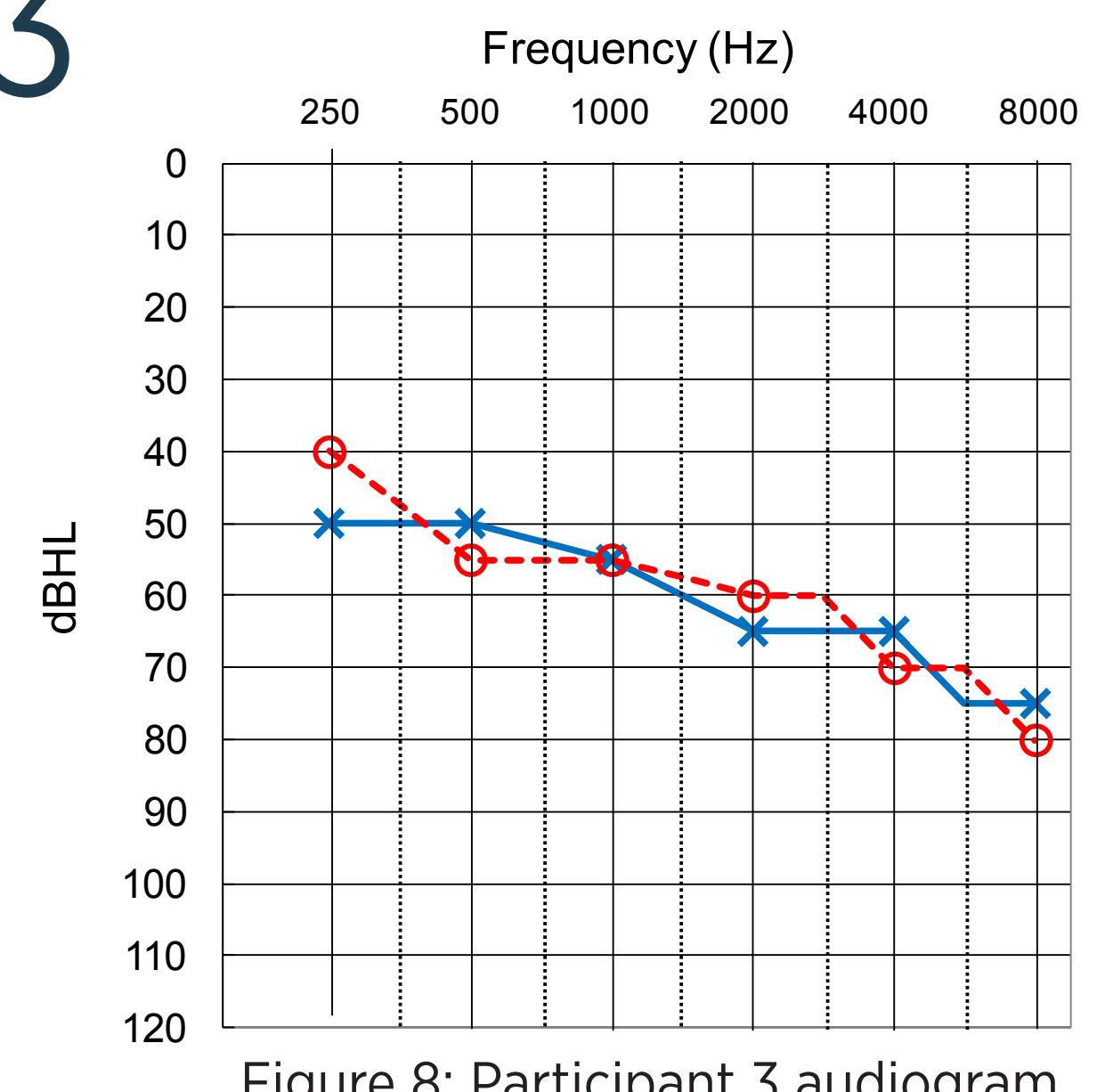


Figure 7: Participant 2; CoM localization results from baseline to one month; laboratory training complete [A] and baseline to two months; home training complete [B]

PARTICIPANT 3

- 66 year old male
- 20 years hearing aid experience; has worn current ITC aids for past 8 years [directional mics but no inter ear communication]
- Moderately severe sensorineural hearing loss, bilateral, word recognition 64% right and 60% left
- Family history of hearing loss



Participant 3 completed eight laboratory training sessions during the first month. At the end of the first month, localization ability was assessed in the laboratory. During the second month, the participant completed the home localization training program. At completion of the second month, he returned for assessment of localization ability in the laboratory.

Unaided results for Participant 3 shown in Figure 9A and own aid results in Figure 9B:

- Baseline results [in red] show a majority of the front/back errors were with 0° and 180°. There were fewer right/left errors than there were front/back errors.
- No training was provided in the unaided condition. After training with the hearing aid, the unaided results for this participant did not improve in the front horizontal plane but did improve in the back horizontal plane.
- There were many front/back localization errors with own hearing aid even with potential pinna cues being available with an ITC instrument.

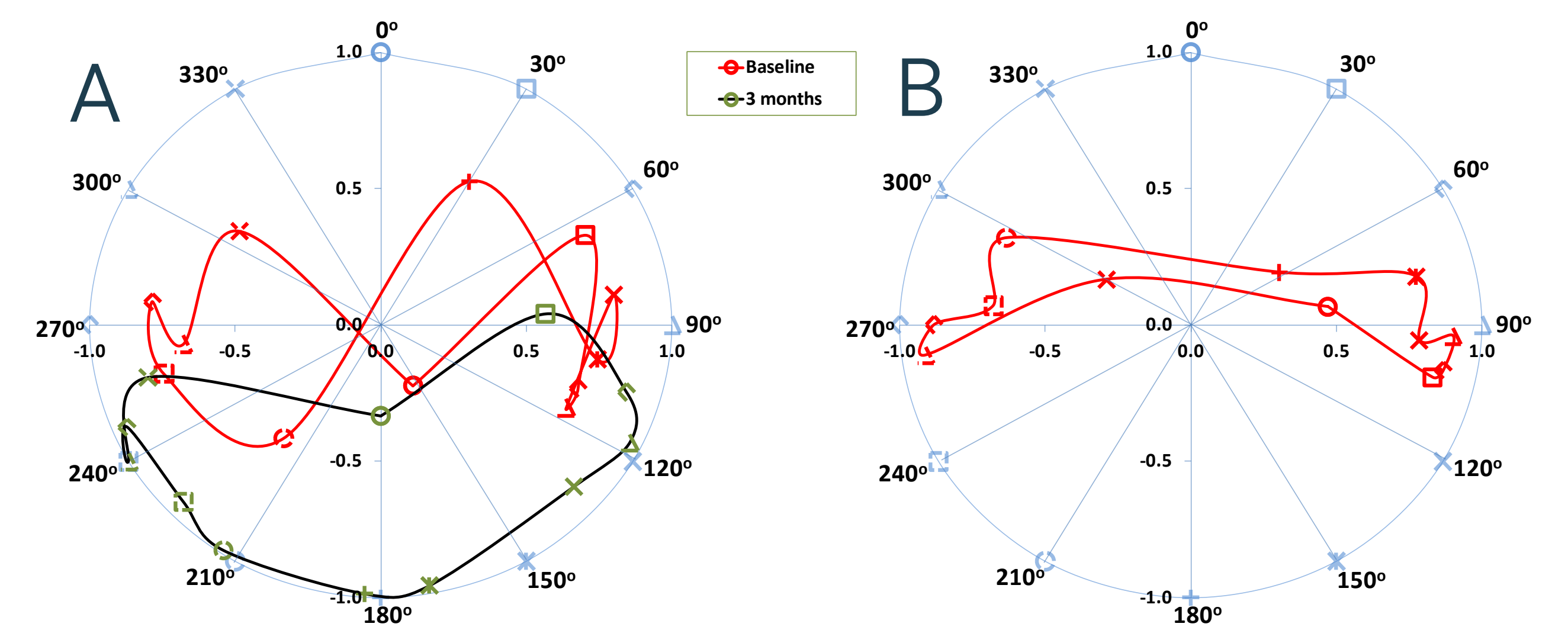


Figure 9: Unaided [A] and own aid [B] localization performance

Results with Clear 440 m-CB for participant 3 shown in Figure 10:

- Aided baseline responses [in red] were somewhat better than the unaided baseline response in that there were fewer front/back errors.
- After laboratory training was complete, Figure 10A, the localization ability for the back loudspeakers improved the most.
- After home training complete, Figure 10B, the improvement that had been seen during the first month for the back loudspeakers seemed to have disappeared. The home training may have introduced confusion.
- This participant reported that he struggled with localizing sounds at home. At the beginning of the study, he was unaware of his localization difficulties. During training, he realized that he was not able to localize sounds at home very well. This problem persisted even after localization training.

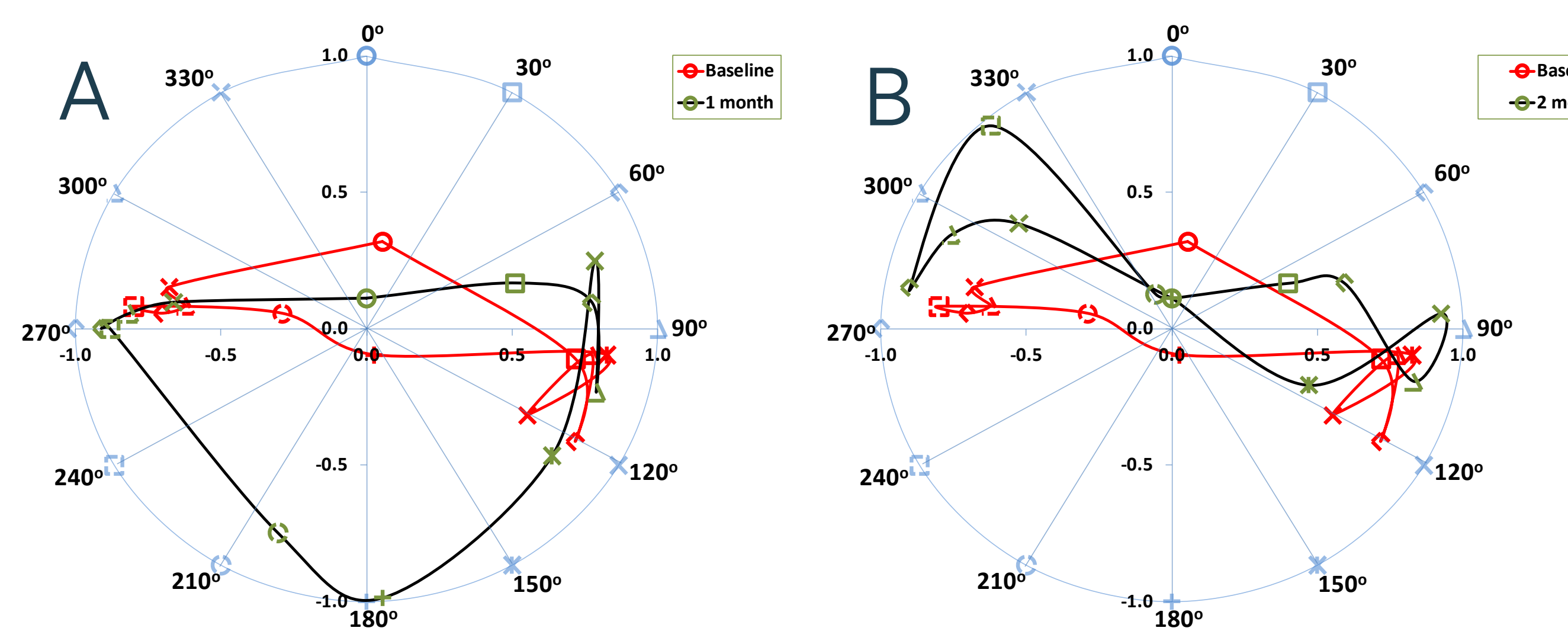


Figure 10: Participant 3; CoM localization results from baseline to one month; laboratory training complete [A] and baseline to two months; home training complete [B]