Spatial Hearing Abilities in Toddlers with Bilateral Cochlear Implants

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PURPOSE OF STUDY

The purpose of this study was to examine the emergence of sound localization skills in toddlers with bilateral cochlear implants (BiCI) and compare them with their normal hearing (NH) peers using a novel Reaching for Sound (RFS) method.

PARTICIPANTS

Thirteen 24-34 mo. old toddlers with normal hearing (NH):
- Recruited through birth registry list
- No history of hearing loss, ear infections, or other developmental delays
- Tympanometric screening performed

BiCI Subjects (n=13)	Sex	Age (mos)	Age at 1st Implant (mos)	Age at 2nd Implant (mos)	Bilateral Experience (mos)
CIEP	F	34	13	29	5
CIEQ	F	34	10	11	23
CIER	M	38	19	19	19
CIEY	M	37	12	12	25
CIEZ	M	41	12	32	9
CIFB	F	39	20	20	19
CIFI	M	32	7	7	25
CIFJ	M	30	14	14	16
CIFK	M	30	14	14	16
CIFN	M	34	13	13	21
CIFQ	M	28	7	13	15
CIFT	M	36	8	8	28
CIFU	F	36	12	15	21

Thirteen 34-41 mo. old toddlers who use BiCIs:
- At least 1 year of experience with CI1 at first visit
- Native English Speaker
- Primary mode of communication=oral
- No diagnosed developmental disabilities
- Any device type

PROCEDURE

Experimental Design:
Training consists of a randomized *right-left discrimination test*, with blocks of trials in which only two locations, at equal angle separations from midline, are visible. The following rules apply:
- Testing begins with the widest angular separation (60°).
- The child must pass the criterion of 4/5 correct trials before proceeding to a smaller separation of 30°.
- If the child passes at 30°, then testing is also conducted at 15°.
- If the child does not pass at 30°, then testing is conducted at 45°.
- If the child passes at 45° then 30° is repeated, followed by 15°.

Localization testing:
- Children who pass the training (pass criterion at 15°) proceed to localization testing.
- All 9 holes are revealed (-60°, -45°, -30°, -15°, 0°, 15°, 30°, 45°, 60°).
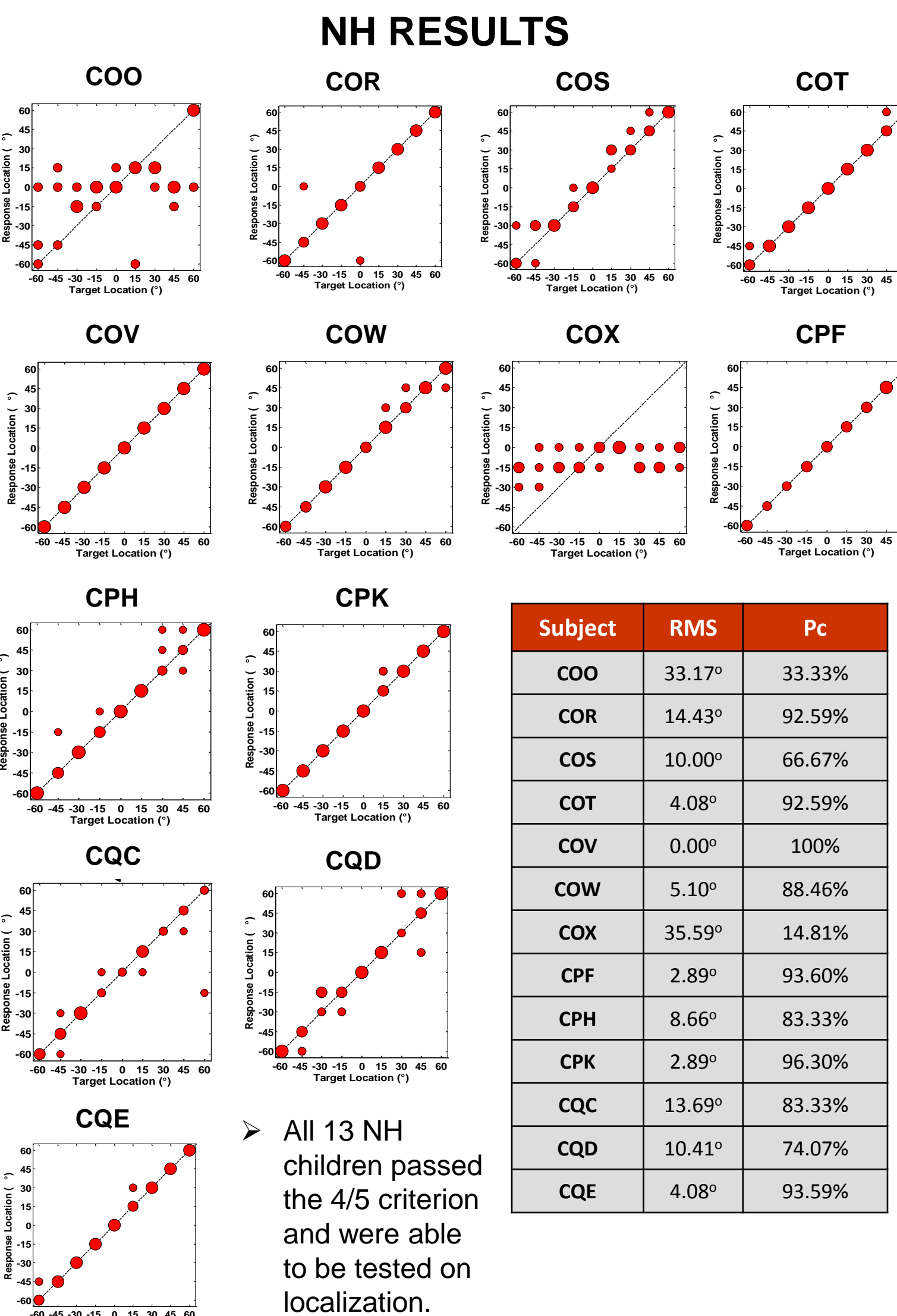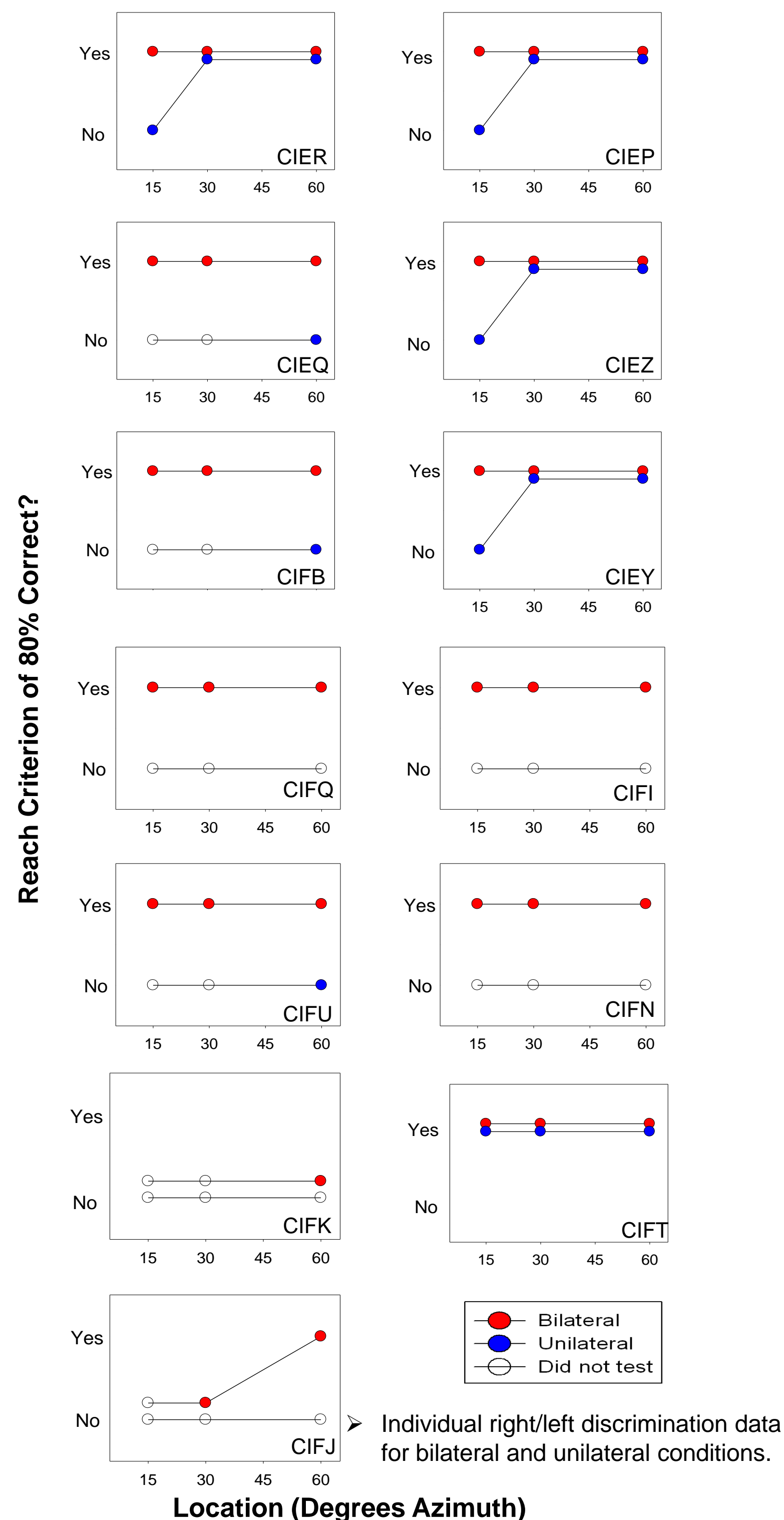- A block of 18 trials with 2 repetitions per location are randomly presented

Stimulus: The phrase, "When I hide I say…" is followed by three bursts of white noise presented at a fixed level of 60 dB SPL-A.

Task: An experimenter positions a small puppet above the center loudspeaker to draw the child's attention. Once the child's eyes and head are facing forward, the experimenter initiates the trial by playing a sound from one of the loudspeakers. The child's task is to reach into the correct hole and obtain the hidden toy. A trial ends either after the child reaches (either correctly or incorrectly) into a hole, or after it becomes clear that a reach is not forthcoming.
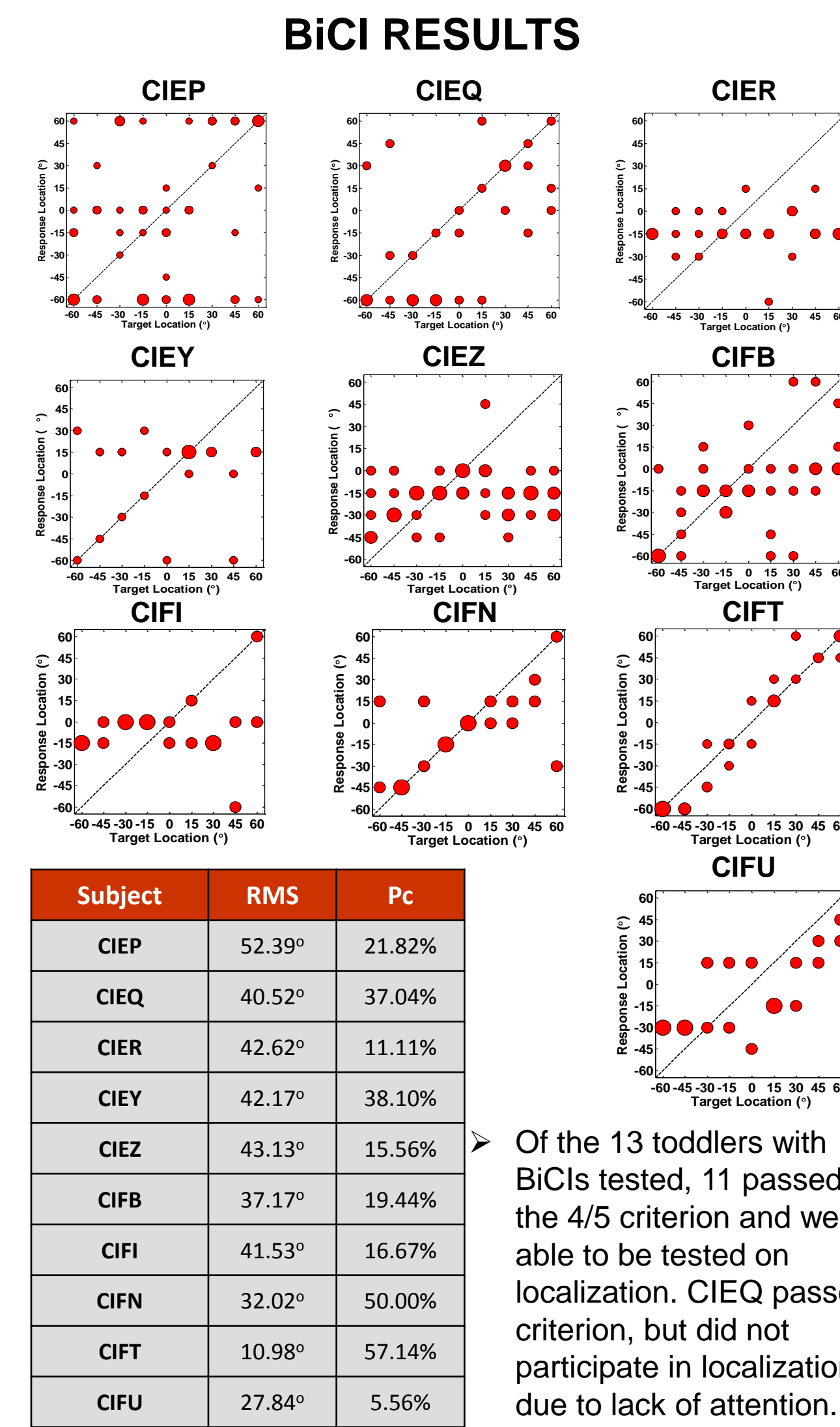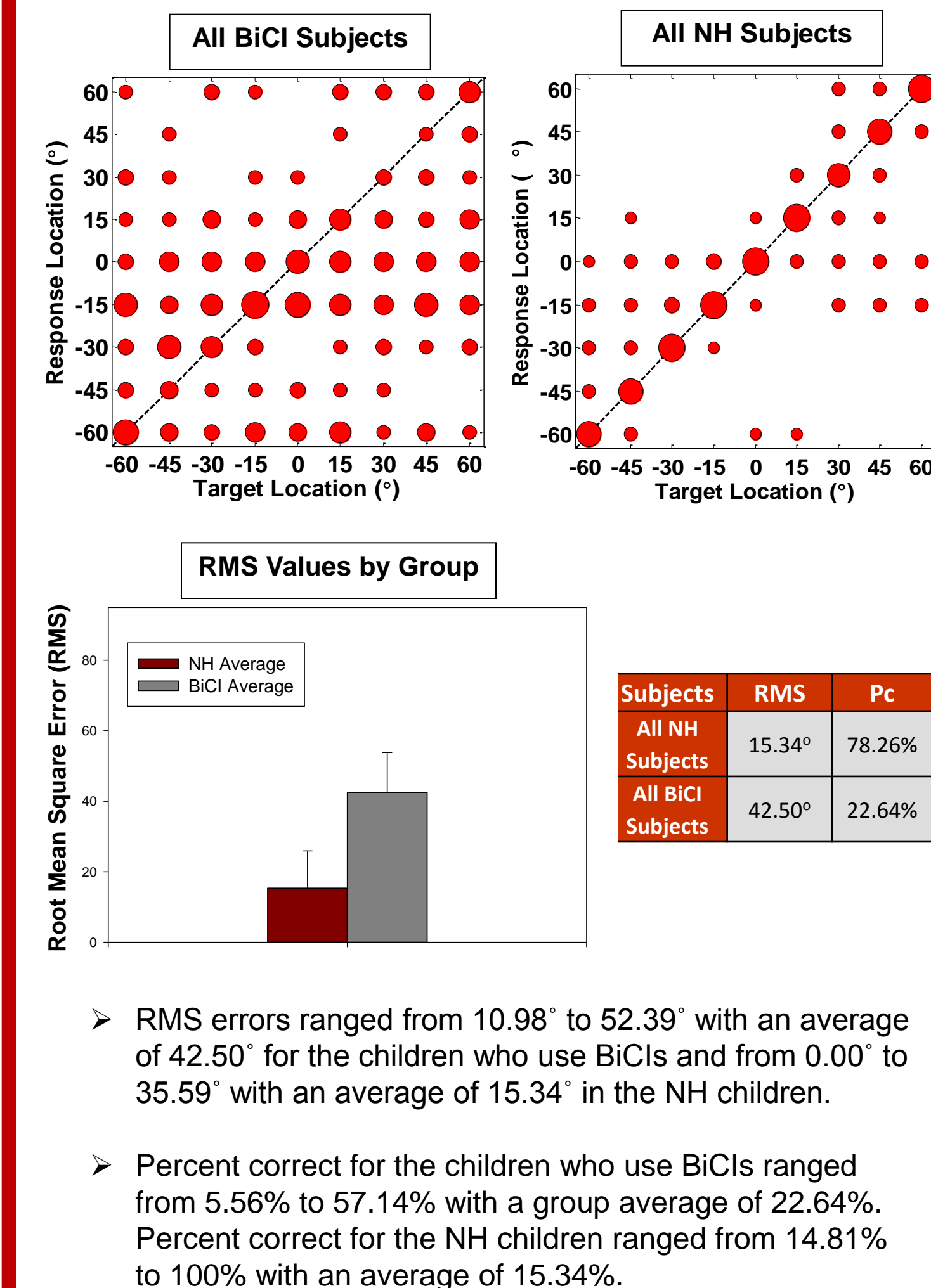
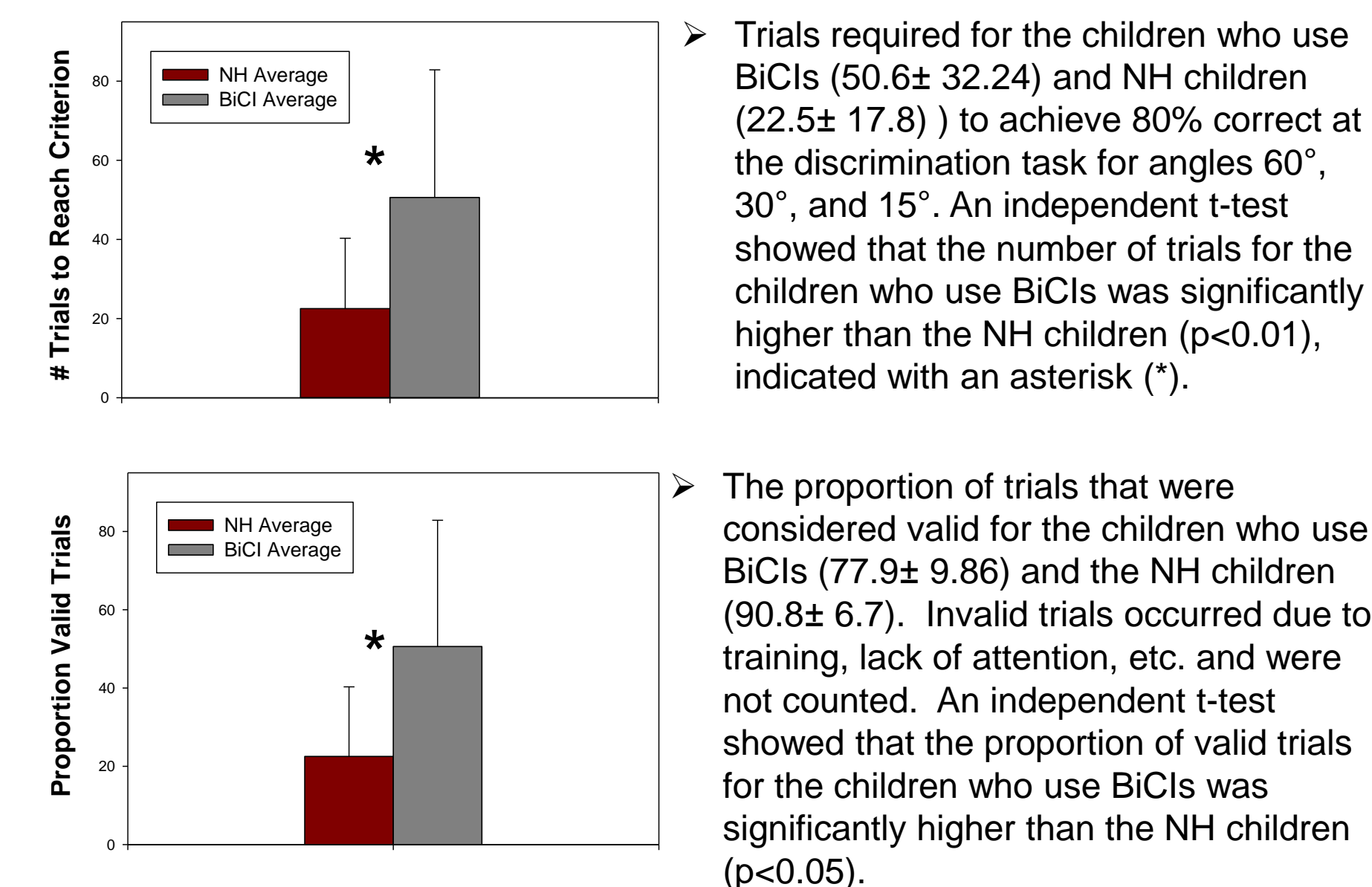## TESTING APPARATUS

DISCRIMINATION RESULTS

(Y-axis: Reach Criterion of 80% Correct? / X-axis: Location (Degrees Azimuth))

Legend: Bilateral, Unilateral, Did not test

> Individual right/left discrimination data for bilateral and unilateral conditions.

LOCALIZATION DATA

NH RESULTS

Plots: COO, COR, COS, COT, COV, COW, COX, CPF, CPH, CPK, CQC, CQD, CQE

Subject	RMS	Pc
COO	33.17°	33.33%
COR	14.43°	92.59%
COS	10.00°	66.67%
COT	4.08°	92.59%
COV	0.00°	100%
COW	5.10°	88.46%
COX	35.59°	14.81%
CPF	2.89°	93.60%
CPH	8.66°	83.33%
CPK	2.89°	96.30%
CQC	13.69°	83.33%
CQD	10.41°	74.07%
CQE	4.08°	93.59%

> All 13 NH children passed the 4/5 criterion and were able to be tested on localization.

BiCI RESULTS

Plots: CIEP, CIEQ, CIER, CIEY, CIEZ, CIFB, CIFI, CIFN, CIFT, CIFU

Subject	RMS	Pc
CIEP	52.39°	21.82%
CIEQ	40.52°	37.04%
CIER	42.62°	11.11%
CIEY	42.17°	38.10%
CIEZ	43.13°	15.56%
CIFB	37.17°	19.44%
CIFI	41.53°	16.67%
CIFN	32.02°	50.00%
CIFT	10.98°	57.14%
CIFU	27.84°	5.56%

> Of the 13 toddlers with BiCIs tested, 11 passed the 4/5 criterion and were able to be tested on localization. CIEQ passed criterion, but did not participate in localization due to lack of attention.

COMBINED RESULTS

All BiCI Subjects / All NH Subjects

RMS Values by Group

Legend: NH Average, BiCI Average

Subjects	RMS	Pc
All NH Subjects	15.34°	78.26%
All BiCI Subjects	42.50°	22.64%

> RMS errors ranged from 10.98° to 52.39° with an average of 42.50° for the children who use BiCIs and from 0.00° to 35.59° with an average of 15.34° in the NH children.

> Percent correct for the children who use BiCIs ranged from 5.56% to 57.14% with a group average of 22.64%. Percent correct for the NH children ranged from 14.81% to 100% with an average of 15.34%.

TASK DIFFICULTY

(Top: # Trials to Reach Criterion; Bottom: Proportion Valid Trials; Legend: NH Average, BiCI Average)

> Trials required for the children who use BiCIs (50.6± 32.24) and NH children (22.5± 17.8) to achieve 80% correct at the discrimination task for angles 60°, 30°, and 15°. An independent t-test showed that the number of trials for the children who use BiCIs was significantly higher than the NH children (p<0.01), indicated with an asterisk (*).

> The proportion of trials that were considered valid for the children who use BiCIs (77.9± 9.86) and the NH children (90.8± 6.7). Invalid trials occurred due to training, lack of attention, etc. and were not counted. An independent t-test showed that the proportion of valid trials for the children who use BiCIs was significantly higher than the NH children (p<0.05).

SUMMARY & CONCLUSIONS

- In **NH children**, RMS error ranged from 0-35 degrees, with 11/13 children showing performance levels similar to that seen in 5-6 year olds. Thus, spatial hearing ability appears to be well developed in the majority of these children, two of whom did not perform well for reasons that are not well understood.
- The **RFS method** appears to be reliable because during training, all children except two were able to understand and complete the task.
- **Right-Left Discrimination with CIs**: 11/13 of the children with BiCI's were able to attain 4/5 correct in training at ± 60°, 30°, and 15° with both CI's activated. However, when the children were only allowed to use one CI (first implanted ear), only one child was able to attain 4/5 correct at ± 60°, 30°, and 15°. This suggests the benefit of bilateral cochlear implants for spatial hearing abilities.
- **Localization with CIs**: RMS errors were notably higher in the BiCI group than in the NH group. Future work on the emergence of spatial hearing in the BiCI group will be conducted to determine whether they can achieve NH levels of performance with additional exposure to bilateral hearing.

REFERENCES

> Litovsky, R., Ehlers, E., Hess, C., Harris, S. (2013). Reaching for sound measures: An ecologically valid estimate of spatial hearing in 2-3 year old children with bilateral cochlear implants. Otology and Neurotology. 34 (3): 429-435.