

Performance and Subjective Benefit from a Digital CROS/BiCROS Instrument

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Introduction

Management strategies for patients with single-sided deafness or asymmetrical hearing loss range from non-invasive, low-risk approaches including CROS/BiCROS hearing instruments and FM systems to more invasive surgical procedures including bone anchored hearing aids (BAHA) or cochlear implants. Most of the previous research on CROS/ BiCROS hearing instruments utilized analog technology and showed low satisfaction (e.g. Harford & Dodds, 1966). The largest CROS/BiCROS study of 91 participants focused on return rates and showed high satisfaction with digital instruments; however, limited subjective information was collected from the participants (Hill et al., 2006). In studies that compared the benefits of analog CROS and BAHA instruments, speech recognition performance was equal to the BAHA (Bosman et al., 2003) or better with the BAHA (Hol et al., 2004; Lin et al., 2006; Wazen et al., 2003). In most of these studies, a preference was found for the BAHA, but the BAHA was always the final condition tested in each study. Given the limited subjective reports about the potential benefits of CROS/BiCROS hearing instruments in previous research as well as the advancements in digital signal processing, the goal of the present study was to assess the efficacy and effectiveness of wireless digital CROS and BiCROS hearing instruments.

Methods

Participants:

Participants met the following inclusion criteria:

- CROS Group - Adults or adolescents (>14 years) & severe-to-profound sensorineural hearing loss in one ear with normal hearing in the opposite ear.
- BiCROS Group - Adults or adolescents (>14 years) & severe-to-profound sensorineural hearing loss in one ear with a lesser degree of sensorineural hearing loss in the opposite ear.

Table 1 provides the demographic information for the 12 adults in the CROS group and 14 adults in the BiCROS group; Figure 1 provides average audiograms for each group.

| CROS Participant | Age (yrs) | Previous HA User | Duration of Hearing Loss (yrs) | BiCROS Participant | Age (yrs) | Previous HA User | Duration of Hearing Loss (yrs) |
|------------------|-----------|------------------|--------------------------------|--------------------|-----------|------------------|--------------------------------|
| 1 | 44 | No | 33 | 1 | 53 | No | 34 |
| 2 | 79 | No | 76 | 2 | 68 | No | 3.5 |
| 3 | 43 | No | 2.5 | 3 | 39 | No | 35 |
| 4 | 20 | No | 20 | 4 | 60 | Yes | 12 |
| 5 | 62 | Yes | 2 | 5 | 79 | No | 50 |
| 6 | 69 | No | 0.1 | 6 | 67 | Yes | 8 |
| 7 | 55 | No | 30 | 7 | 58 | No | 25 |
| 8 | 82 | Yes | 22 | 8 | 55 | No | 2 |
| 9 | 28 | No | 3 | 9 | 60 | Yes | 50 |
| 10 | 24 | Yes | 4 | 10 | 70 | Yes | 17 |
| 11 | 47 | No | 37 | 11 | 85 | Yes | 47 |
| 12 | 40 | No | 39 | 12 | 56 | No | 3 |
| | | | | 13 | 67 | Yes | 6 |
| | | | | 14 | 68 | No | 43 |

Table 1. Demographic Information for Participants

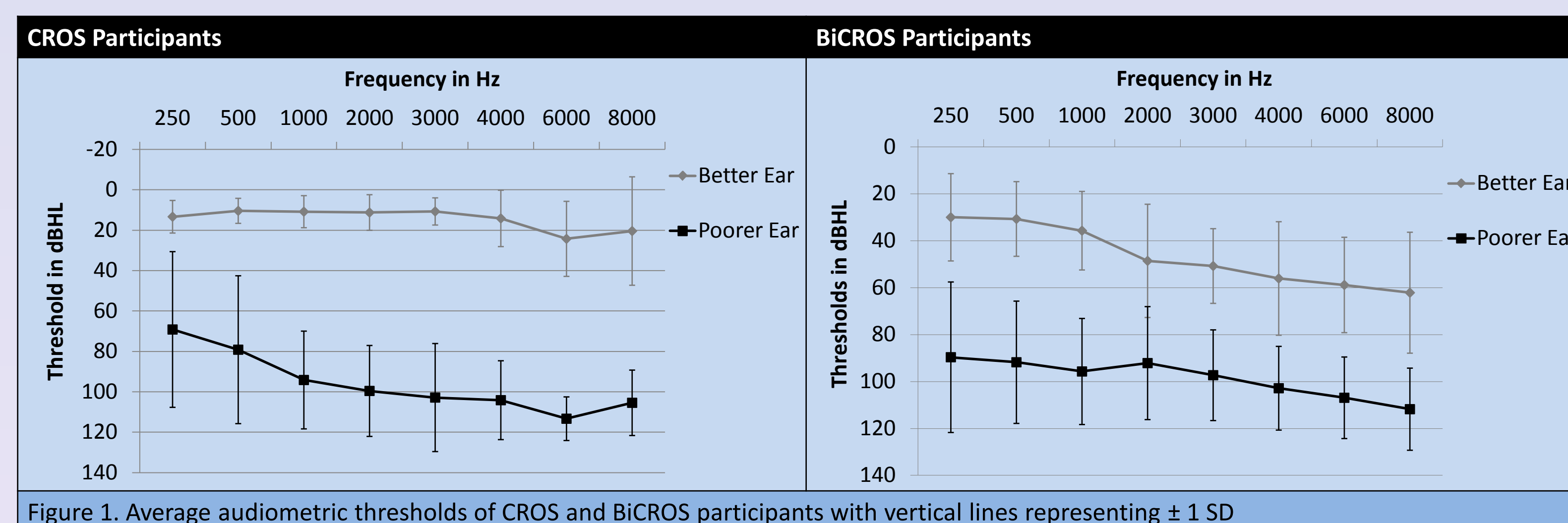


Figure 1. Average audiometric thresholds of CROS and BiCROS participants with vertical lines representing ± 1 SD

Hearing Devices: Participants were fit with a Phonak Audéo S SMART on the better ear and a Phonak CROS on the poorer ear.

Pre- and Post- Study Questionnaires:

Each questionnaire was completed before the study to reflect experiences with unaided hearing and at the end of the study to describe hearing experiences with the CROS/BiCROS devices.

SSQ: Speech Spatial and Qualities of Hearing (Gatehouse & Noble, 2004)

- Measures self-reported auditory disability in everyday domains and situations
- 3 subscales: speech hearing, spatial hearing, and qualities of hearing

APHAB: Abbreviated Profile of Hearing Aid Benefit (Cox & Alexander, 1995)

- 24-item, inventory used to rate participant difficulty with communication in various everyday situations
- 4 subscales: ease of communication, reverberation, background noise, and aversiveness

APS-SSD: Auditory Performance and Satisfaction Scale for Single-Sided Deafness

- Our laboratory-developed questionnaire focused on difficulties hearing on side of poorer-hearing ear
- 3 listening situations: hearing at home, hearing at work or school, and hearing in social situations (sample in Figure 2)

| APS-SSD | No Hearing Instrument | | | | | | CROS Instrument | | | | | | | |
|---|-----------------------|------------------------|-----------------|---------------------|-------------------------|------------------------|------------------------|-------------------|-------------------|-----------------|-----------------|-------------------------|------------------------|------------------------|
| | Can Function Fine | Very Slight Difficulty | Mild Difficulty | Moderate Difficulty | Considerable Difficulty | Significant Difficulty | Cannot Function At All | Can Function Fine | Slight Difficulty | Less Difficulty | Some Difficulty | Considerable Difficulty | Significant Difficulty | Cannot Function At All |
| 1. Hearing someone facing you in a quiet environment | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| 2. Hearing someone speaking on the side of your poorer ear in a quiet environment | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 0 | 1 | 2 | 3 | 4 | 5 | 6 |

Figure 2. Sample questions from the APS-SSD

Post Study Speech Recognition Testing: The Bamford-Kowal-Bench Speech in Noise Test (Etymotic Research, 2005) and AzBio Sentences (Spahr & Dorman, 2004) were used to assess speech recognition in noise. Testing with BKB-SIN was conducted in both aided and unaided conditions at S0/N0, S0/N90, and S0/N180. Testing with AzBio sentences was also conducted in aided and unaided conditions with SGood/NPpoor and SPoor/NGood.

Methods

Procedure: Protocols for the CROS and BiCROS sessions are outlined in Table 2.

| CROS Group | BiCROS Group |
|---|---|
| I. Session 1: (1) Pre-study questionnaires (2) Fitting CROS device (3) CROS Real Ear Verification (Pumford, 2005) (4) Counseling | I. Session 1: (1) Pre-study questionnaires (2) Aid Fitting: NAL-NL2 (3) Aid Real Ear Verification (4) Counseling |
| II. Trial: 4-week trial with CROS device | II. Session 2: (1) 1-week follow-up, aid adjustments (2) CROS microphone fitting (3) CROS Real Ear Verification (Pumford, 2005) |
| III. Session 2: (1) Post-study questionnaires (2) Speech recognition testing | III. Trial: 4-week trial with CROS device |
| | IV. Session 3: (1) Post-study questionnaires (2) Speech recognition testing |

Table 2. Session outline for CROS/ BiCROS groups

CROS Results

CROS results for SSQ

- Average participant ratings for the 3 subscales shown in Figure 3
- Participants provided ratings on a scale from 0 to 10
- 0 = *not at all* able to do or experience what was described
- 10 = *perfectly* able to do or experience what was described
- Wilcoxon Signed Rank Test for Difference in Medians:
 - Significant improvement in audibility for speech hearing ($p < .05$)
 - Significant improvement in audibility for spatial hearing ($p < .05$)
 - Significant improvement in quality of hearing ($p < .05$)

CROS results for APHAB

- Average participant ratings for the 4 subscales shown in Figure 4
- Participants provided ratings on a scale from 1 to 99%
- 99% = high level of difficulty
- 1% = no difficulty in the situation
- Wilcoxon Signed Rank Test for Difference in Medians:
 - No significant improvement in aversiveness ($p > .05$)
 - Significant improvement in ease of communication ($p < .05$)
 - Significant improvement in reverberation ($p < .05$)
 - Significant improvement in noise ($p < .05$)

CROS results for APS-SSD

- Average participant ratings for the 3 listening situations shown in Figure 5
- Participants provided ratings on a scale from 0 to 6
- 0 = *can function fine*
- 6 = *cannot function at all*
- Wilcoxon Signed Rank Test for Difference in Medians:
 - Significant improvement in functioning at home ($p < .05$)
 - Significant improvement in functioning at school/work ($p < .05$)
 - Significant improvement in functioning in social situations ($p < .05$)

CROS results for BKB-SIN and AzBio

- Data (Figure 6) were analyzed with a repeated measures ANOVA; post-hoc Tukey-Kramer Multiple-Comparison Tests
- BKB-SIN: significant effect of condition, no significant effect of CROS, and significant interaction effect
 - *Post-hoc analyses:* best performance in S0/NPpoor unaided condition followed by S0/NPpoor aided condition
- AzBio: significant effect of condition, significant effect of CROS, and significant interaction effect
 - *Post-hoc analyses:* best performance in SGood/NPpoor condition and with CROS; SPoor/NGood unaided worse than all other conditions

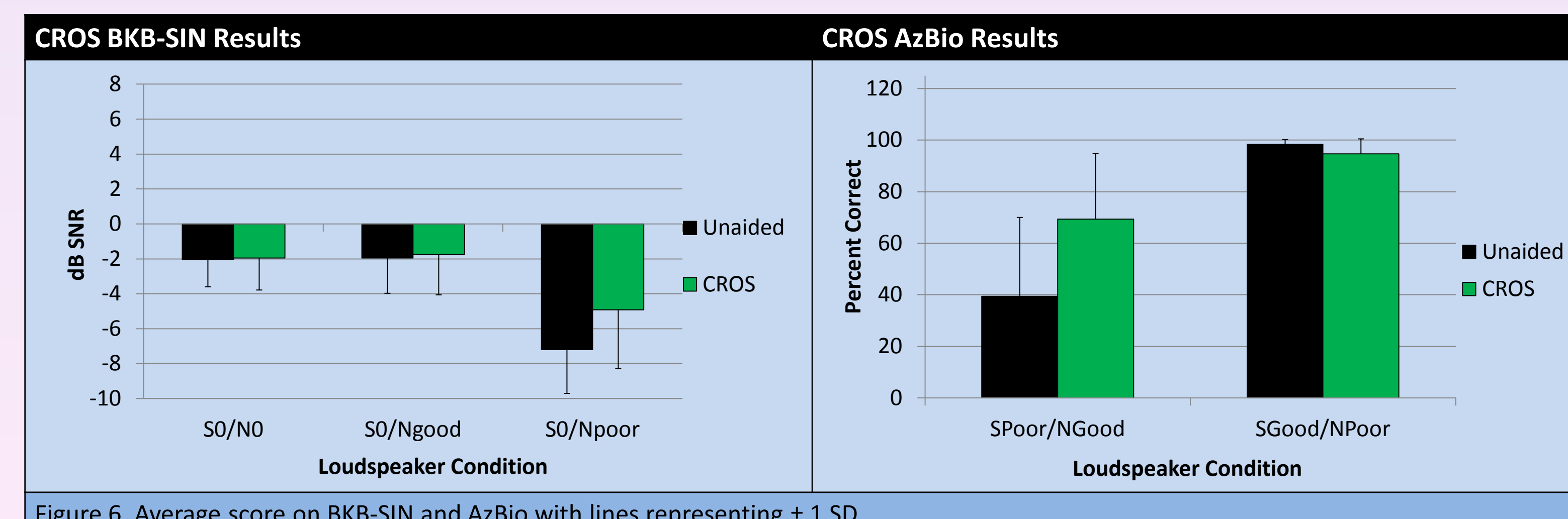


Figure 6. Average score on BKB-SIN and AzBio with lines representing ± 1 SD

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BiCROS Results

BiCROS results for SSQ

- Average participant ratings for the 3 subscales shown in Figure 7
- Participants provided ratings on a scale from 0 to 10
- 0 = *not at all* able to do or experience what was described
- 10 = *perfectly* able to do or experience what was described
- Wilcoxon Signed Rank Test for Difference in Medians:
 - Significant improvement in audibility for speech hearing ($p < .05$)
 - Significant improvement in audibility for spatial hearing ($p < .05$)
 - Significant improvement in quality of hearing ($p < .05$)

BiCROS results for APHAB

- Average participant ratings for the 4 subscales shown in Figure 8
- Participants provided ratings on a scale from 1 to 99%
- 99% = high level of difficulty
- 1% = no difficulty in the situation
- Wilcoxon Signed Rank Test for Difference in Medians:
 - No significant improvement in aversiveness ($p > .05$)
 - Significant improvement in ease of communication ($p < .05$)
 - Significant improvement in reverberation ($p < .05$)
 - Significant improvement in noise ($p < .05$)

BiCROS results for APS-SSD

- Average participant ratings for the 3 listening situations shown in Figure 9
- Participants provided ratings on a scale from 0 to 6
- 0 = *can function fine*
- 6 = *cannot function at all*
- Wilcoxon Signed Rank Test for Difference in Medians:
 - Significant improvement in functioning at home ($p < .05$)
 - Significant improvement in functioning at school/work ($p < .05$)
 - Significant improvement in functioning in social situations ($p < .05$)

BiCROS results for BKB-SIN and AzBio

- Data (Figure 10) were analyzed with a repeated measures ANOVA; post-hoc Tukey-Kramer Multiple-Comparison Tests
- BKB-SIN: significant effect of condition, no significant effect of BiCROS, and no significant interaction effect
 - *Post-hoc analyses:* best performance in S0/NPpoor BiCROS and unaided conditions
- AzBio: significant effect of condition, significant effect of BiCROS, and significant interaction effect
 - *Post-hoc analyses:* best performance in SGood/NPpoor condition and with BiCROS; SPoor/NGood unaided worse than all other conditions

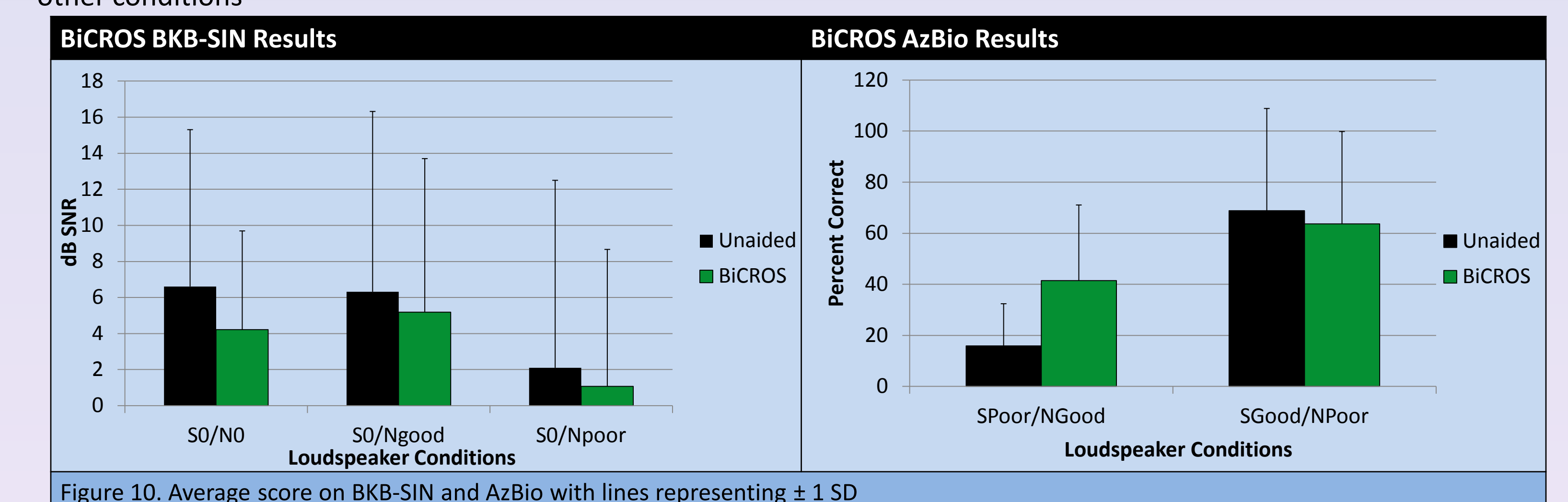


Figure 10. Average score on BKB-SIN and AzBio with lines representing ± 1 SD

Summary & Discussion

Following a trial period, the digital CROS/BiCROS hearing instruments provided significant improvements in fixed-intensity speech recognition in noise performance and subjective ratings of participants relative to an unaided condition. Participants reported significantly improved hearing with the instruments, which provided a louder, clearer, and more salient signal in various environments. Given the lower cost and risk associated with the CROS/BiCROS device as compared to surgical options, the CROS/BiCROS should be considered as a first step in the management of individuals with single-sided deafness or asymmetrical hearing losses. When evaluating the benefit of CROS/BiCROS instruments, subjective questionnaires may be more sensitive for determining patient benefit than speech recognition measures in noise.

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