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Efficacy in noise of the Starkey Surflink Mobile 2 technology in directional versus omnidirectional microphone mode with experienced adult hearing aid users

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EFFICACY IN NOISE OF THE STARKEY SURFLINK MOBILE 2 TECHNOLOGY IN DIRECTIONAL VERSUS OMNIDIRECTIONAL MICROPHONE MODE WITH EXPERIENCED ADULT HEARING AID USERS

By:

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Abstract: ***The Starkey SurfLink Mobile 2 is a remote microphone accessory. Starkey claims that by placing the SurfLink's internal microphone in the directional microphone setting, the participant will hear better in noise over the omnidirectional setting. This study aims to test ~~the this~~the claim about the device.***

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ABBREVIATIONS

CNC	Consonant-Vowel Nucleus-Consonant
COSI	Client Oriented Scale of Improvement
dB	decibel
FM	Frequency Modulated
Hz	Hertz
HL	Hearing Level
HINT	Hearing In Noise Test
M	Mean
NAL-NL1	National Acoustics Labs, Non-Linear, version 1
QuickSIN	Quick Speech-In-Noise
REMs	Real Ear Measurements
SD	Standard Deviation
SNR	Signal-to-Noise Ratio
SPL	Sound Pressure Level

INTRODUCTION

Hearing aid technology has vastly improved over the recent years, and with those improvements has come the advent of the directional microphone. Directional microphones function as a means to improve the signal-to-noise ratio of the user's environment by providing less amplification to sounds coming from behind or to the sides of the individual, and instead focusing the amplification on signals coming from the front. With today's technology, directional microphones can also be adaptive and programmed to adjust their directional response according to the direction in which speech is detected. This contrasts with the use of an omnidirectional microphone that takes in sound from all directions around the user (Kuk, Kollofski, Brown, Melum, & Rosenthal, 1999; Lewis, Crandell, Valente, & Horn, 2004; Blamey, Fike, & Steele, 2006).

Hearing aid technology of today allows for the directional microphone to be programmed to change automatically according to information the hearing aid gathers about the individual's surroundings or at the push of a button on the hearing aid itself. If the audiologist and patient opt for the push-button option, the hearing aid user has to be able to correctly identify situations in which each microphone style is useful. This requires considerable extra counseling time, but can greatly benefit the patient (Olson, Ioannou, & Trine, 2004).

Research on directional microphones has been ongoing for many decades, starting with one of the first studies comparing directional and omnidirectional microphones by Nielson in 1973. The study consisted of twenty-two individuals from 17-68 years of age with slight to moderate hearing loss. Presentation level for the study was set at 55 dB SPL with varying signal-to-noise ratios (+5, +10, +15, and +20 dB SNR) during a word discrimination task (PB words).

Nielson's study found that performance and perception of performance with directional microphones was significantly better when testing was performed in a sound booth. However, when the testing was performed in situations outside the sound booth, in real-world style situations, the benefits of better word discrimination and perceived benefit were not seen.

Since that time, other studies have shown improvement with directional microphone use, even if the improvement is small (Studebaker, Cox, & Formby, 1980; Hawkins & Yacullo, 1984). Studebaker, Cox, and Formby (1980) utilized a Knowles Electronic Maniken for Acoustic Research (KEMAR) to assess the directional microphone advantage in an anechoic environment, a moderately reverberant environment, and a highly reverberant environment. The data collected revealed the advantage with directional microphones was greatest in an anechoic environment, and the performance decreased as reverberation increased. The researchers noted that in an anechoic environment, the use of a directional microphone reduced the noise by approximately 20 dB, but in a highly reverberant environment, the directional microphone became "functionally omnidirectional" with very little noise reduction measured. Hawkins and Yacullo (1984) found similar results when they tested the signal-to-noise ratio of monaural and binaural hearing aid fittings under three different reverberant conditions. Their data revealed a three to five decibel signal-to-noise ratio improvement in a difficult listening situation. The study concluded that there was a directional advantage when the reverberation was less and hearing aids were fit binaurally, and the directional advantage decreased as the reverberation increased.

In a study by Valente, Fabry, and Potts (1995), the use of a directional microphone improved the signal-to-noise ratio 7.4 to 8.5 dB on average over the use of the omnidirectional microphone setting when testing utilizing Hearing in Noise Test (HINT) Sentences in twenty-five adult hearing aid users.

A study by Valente, Mispagel, Tchorz, and Fabry (2006) utilized twenty-five adult participants with mild to moderately-severe sensorineural hearing loss. The participants performed significantly better in the directional microphone condition than in the omnidirectional condition in different types of background noise (HINT Sentences and R-Space Restaurant Noise) and with different speaker arrangements (diffuse and from 180° behind the participant).

Directional microphones can potentially provide benefit to individuals of any age. However, certain age groups may be able to perceive more benefits than others. In a 2010 study by Wu, twenty-four adults with sensorineural hearing loss were tested both in a laboratory setting and out in the field. The participants were tested utilizing HINT sentences and the audio-visual version of the Connected Speech Test in the laboratory under directional and omnidirectional microphone conditions. Following testing, each participant was given a four-week trial period with the hearing aids. The participants were asked to keep a journal of how the different hearing aid microphone settings (directional and omnidirectional) performed in different situations (i.e. talker directly in front of listener, noise sources directly behind listener, etc.). The study found that older adults tend not to perceive directional microphone benefit in real-world situations, compared to their younger peers.

In a three-year, double-blinded 2009 study by Gnewikow, Ricketts, Bratt, and Mutchler, ninety-four subjects with hearing loss were tested both subjectively and objectively on the performance of directional versus omnidirectional microphone conditions. The participants were split into three different hearing loss magnitude groups: mild, moderate, and severe. Each participant was given a trial with omnidirectional microphones for one month, then directional microphones for one month and were tested following each month trial. The participants had better scores on the HINT Sentences and Connected Speech Test in the directional microphone condition over the omnidirectional microphone condition for the objective speech-in-noise measures. However, subjective data (Satisfaction with Amplification in Daily Life [SADL], Profile of Hearing Aid Benefit [PHAB], and User-Preference Questionnaire) did not show a clear perceivable advantage for directional microphone use.

Directional microphone technology has also been studied with regard to the use of noise reduction algorithms. Desjardins (2016) tested fifteen participants with mild to severe bilateral sensorineural hearing loss between ages 54-78 years. In the study, the participants were tested in a dual-task paradigm. The participants were asked to repeat Harvard/Institute of Electrical and Electronic Engineers (IEEE) sentences while performing a digital visual pursuit rotor tracking (DPRT) task in the presence of background noise in four conditions. The four conditions were: no noise reduction and omnidirectional microphone activated, maximum noise reduction with omnidirectional microphone, no noise reduction and directional microphone activated, and maximum noise reduction with directional microphone. The participants were also tested in one quiet condition utilizing the omnidirectional microphone with no noise reduction. The study found that listening effort decreased when the directional microphone was activated. However, there was no noted decrease in listening effort when noise reduction was activated and the directional microphone was utilized, over directional microphone use alone. In 2015, Park et al. tested twenty-five hearing aid users that were fit unilaterally with two different hearing aid devices. The participants were tested using the Korean-HINT Sentences in three conditions: omnidirectional, omnidirectional plus noise reduction, and a fixed directional microphone setting. The results showed there was no benefit seen in omnidirectional mode versus omnidirectional mode with noise reduction activated, but benefit was noted in the directional microphone setting.

Along with directional microphones, hearing assistive technologies (HATs) have been used to provide individuals increased access to language. One type of hearing assistive technology is a frequency modulated (FM) system. An FM system consists of two main parts: an audio transmitter, also known as a remote microphone, and a wireless receiver which routes the signal directly to the hearing aid. The use of a FM System/remote microphone aids the listener in overcoming hearing difficulties caused by distance and noise by maintaining the same loudness level over the distance, therefore improving the signal-to-noise ratio (Lewis, 1994). This is a great advantage for the listener because the noise signal will be reduced, making the speech signal much clearer and easier to hear. Traditionally, it is thought that FM systems and remote microphone accessories are to be used in the classroom; however, the use of a FMs and remote microphones can also benefit individuals outside the classroom in homes and work environments. Wireless hearing aid technology has made the use of a simple remote microphone over its more complicated FM counterpart a more cost effective, more accessible, and easier to use option, while still maintaining the benefit of an enhanced signal-to-noise ratio over long distances.

In a study by Lewis et al. (2004), researchers sought to compare the use of directional microphones and FM Systems. The study consisted of fifty-five participants between 24-81 years of age with mild to severe bilateral sensorineural hearing loss. The participants were tested using HINT Sentences. Results showed that speech perception scores were 1.2-3.4 dB better when the hearing aid utilized the directional microphones over the omnidirectional microphones. The study also found directional microphone use plus the use of one FM receiver improved speech perception scores by 14.2-16.7 dB. The best listening condition was when the directional microphones and two FM receivers were used, further improving speech perception scores by an additional 2.5-2.7 dB.

In 2015, Rodemark and Galster used four different wireless protocols to assess the benefits of remote microphone accessories in sixteen adults. Their research revealed that the use of the FM remote microphone provided significant benefit for the listener in all conditions, including the remote microphone streaming only condition and the remote microphone plus hearing aid microphone setting, when compared to unaided or hearing aid only conditions.

Benefit from the use of a remote microphone has also been shown in cochlear implant users. Thirteen participants with unilateral cochlear implants with a speech recognition ability of greater than fifty percent on HINT sentences were tested. Two testing conditions were evaluated. The first testing condition utilized two remote microphone systems designed for use with the television. Participants were tested with the cochlear implant alone, and with the cochlear implant coupled to each of the different remote microphone devices. Benefit was measured objectively by a speech understanding task during talk-show and a news-show segments and subjectively by asking the participant what he/she perceived as the benefits and limitations of the device. No significant difference in perceived speech understanding or objective speech understanding was found in between the two remote microphone devices. Significant benefit was perceived subjectively and speech perception of the segment improved with the use of a remote microphone and cochlear implant over the cochlear implant alone. The second testing condition utilized AzBio sentences in noise with the cochlear implant alone and with the cochlear implant coupled to a personal FM system. Speech recognition was significantly better in the cochlear implant plus FM system condition. The subjects reported the remote microphone technology/FM system provided them with enhanced comprehension, more confidence, and improved ease of listening (Fitzpatrick, Seguin, Schramm, Armstrong, & Chenier, 2009).

The Starkey SurfLink Mobile 2 is a device that not only works as a remote microphone, but also can be used for TV streaming, music streaming, hands-free cell phone use, and a remote control for the hearing aids. The SurfLink Mobile 2 has the capability to allow the user to switch between its internal directional ("Focus") and omnidirectional ("Surround") microphones at the push of a button. Starkey claims that by placing the SurfLink Mobile 2 in Focus mode, the user should be able to better focus on the speaker and not be as bothered by background noise. The current study focuses on the following research questions:

1. Is performance in noise improved through the use of the directional versus omnidirectional microphone?
2. Are there significant differences in benefit with the directional microphone when words versus sentences are used for speech perception tasks?
3. Did the use of the directional microphone allow the participant to achieve a higher score with respect to number of phonemes correct (even if the word may have been misperceived)?
4. Did the participant subjectively perceive a greater benefit in one setting over another?

METHODS

Participants

Institutional Review Board approval was obtained from Washington University's Human Research Protection Office (WUHRPO) on February 5, 2016 (ID No. 201511027). Potential participants were recruited through the use of the Research Participant Registry and Volunteer for Health Services at Washington University and Barnes Jewish Medical Center. Fliers were also placed in the Washington University School of Medicine Division of Adult Audiology waiting rooms and testing suites to recruit potential participants. In order to participate, the potential participants must be between the ages of 50 and 85 years old, be English-speaking, and currently wear and have worn hearing aids for at least three months. The participants must present with mild to severe bilateral, sensorineural hearing loss. Participants must have thresholds ranging from 0-65 dB HL from 250-1000 Hz and 25-90 dB HL from 2000-6000 Hz. Figure 3 displays the audiograms for the right and left ears of the twelve participants.

A total of twelve participants were recruited for this study. Participants consisted of seven males and five females who ranged from 60 to 84 years of age (Mean: 72.75, SD: 6.22) (Table 1). An audiogram was obtained for all participants via Washington University School of Medicine Division of Adult Audiology's database, a release of information approval from his/her current audiologist, or via mail or e-mail sent to the Principal Investigator from the participant on a secure server. Each method of data retrieval was approved by WUHRPO.

Participants reported a mean length of hearing loss of 15.33 years (SD= 10.52) (Table 1). The participants reported they believed their hearing loss came from age (7), noise exposure (4), or ototoxicity (1). Only one participant reporting having experience with any form of assistive technology used in addition to his/her hearing aids.

Participants did not receive payment for their participation in the study. However, a total of thirty hearing aid batteries were given to each participant in the size necessary for his or her personal hearing aids at the completion of the study appointment.

Materials

Maryland CNCs (consonant-vowel nucleus-consonant) word lists were utilized for this study. Each list consists of fifty words with similar, but not identical, distribution of phonemes. The Maryland CNCs were presented along with four-talker babble coming from 90, 180, and 270 degrees around the participant. Lists five and six were chosen for this study due the results of a 2006 study by Skinner et al. Skinner and colleagues' study assessed the equivalency between CNC lists in a group of individuals with cochlear implants. The study found that lists five and six both had equivalent scores, as achieved by participants.

The Quick Speech-In-Noise (QuickSIN) Test consists of twelve lists of six sentences each, with five key words per sentence. The sentences are presented at a steady intensity, while four-talker babble is presented simultaneously at various signal-to-noise ratios increasing from +25 to 0 in steps of five. The QuickSIN manual recommends presenting multiple lists and averaging the scores for more reliable results. When five lists are presented in a condition, there is a 95% confidence interval of +/- 1.2, according to the test manual's published protocols. The QuickSIN is available in the standard format (speech and noise from same speaker), separated format (speech and noise from different speakers), high-frequency lists, and high frequency low-pass filtered lists (Etymotic Research, 2001).

The Client Oriented Scale of Improvement (COSI) is a subjective assessment tool developed by National Acoustic Laboratories. The COSI allows for goal tracking in hearing aid users, assessment of degree of change, and the assessment of final hearing ability. In a 1997 study, Dillon, James, and Ginis concluded that the COSI is statistically valid when compared to longer subjective assessment measures. The research also concluded that it has good test-retest reliability and diagnostic utility.

Instrumentation

All testing was conducted in a sound-treated booth at Washington University Program in Audiology and Communication Sciences' Student Laboratory. Calibration of all equipment was performed before participants were tested each day. All stimuli used were presented via a Grason-Stadler AudioStar Pro two-channel audiometer in the sound field. The participant was facing a speaker at zero degree azimuth approximately five feet away from the front speaker. The Maryland CNC words were routed from a Sony Vaio computer. The CNC words were presented via the sound booth's front speaker. Four-talker babble was presented via three Anchor Model A100/A130 speakers that were placed at 90, 180, and 270 degrees at a distance of five feet from the participant. The QuickSIN sentences were pre-loaded into the audiometer and presented via the front (speech) and back (four-talker babble) speakers of the sound booth. All speakers used were 40.5 inches off the ground. The SurfLink Mobile 2 was placed on a stand at a height of 50 inches and 9 inches away from the front speaker. The set up montages for CNC +5 dB SNR and QuickSIN trials can be seen in Figures 1 and 2, respectively.

Procedure

Prior to testing, the procedure was explained to the participant and any questions were answered. All participants signed a written informed consent document approved by WUHRPO. The participant was interviewed about his or her hearing loss and past hearing aid use. Otoscopy was then performed. If the participant had not had a hearing test within the past twelve months, a hearing test was performed. If a hearing test was necessary, tympanometry and air conduction threshold testing via headphones from 250-8000 Hz were performed bilaterally. None of the participants exhibited a change in air conduction thresholds greater than 10 dB since his or her previous audiogram; therefore, obtaining of bone conduction thresholds and/or word recognition scores were not indicated according to criteria set for this study.

Participants were then fit with Starkey ZSeries i110 MicroRIC 312 hearing aids (SN- R: 15594579, L: 15594575). The hearing aids and SurfLink Mobile 2 were both obtained on loan from the Washington University Division of Adult Audiology in the Department of Otolaryngology at the Center for Advanced Medicine with approval from HRPO. At completion of the study, the hearing aids and SurfLink were returned to the Division of Adult Audiology. Appropriate sized open-fit domes were selected for each participant. Real ear measurements (REMs) were performed with the participant seated at zero degrees azimuth with the participant's head approximately twelve inches from the speaker. The Frye FONIX 8000 Hearing Aid Test System was utilized for REMs with NAL-NL1 targets. A DigiSpeech signal was presented at 65 dB SPL (representing conversational speech), at 50 dB SPL (representing soft speech), and at 80 dB SPL (representing loud speech). REMs were not performed on two participants due to excessive cerumen in the ear canal, preventing insertion of the probe tube. Tympanometry was performed on both participants to ensure the cerumen was not completely occluding the ear canal. In that cerumen was not completely occluding the ear canal in either participant, the testing procedure continued with the hearing aids programmed to First Fit in the Starkey software according to NAL-NL1 targets.

Following performance of real ear measurements, the participant was moved into the sound booth. The participant then was given instructions to repeat the words or sentences heard, while doing his/her best to ignore the noise. Maryland CNC full word lists at 60 dB HL in the presence of 55 dB HL of four-talker babble were then presented with the SurfLink Mobile 2 in Focus and Surround modes. Following the CNC testing, five lists of the QuickSIN Speech-in-Noise test presented at 50 dB HL in varying noise levels (25, 30, 35, 40, 45, and 50 dB HL) were presented in both the Focus and Surround microphone modes. In between each trial, the participants were asked to rate how they thought they performed on the previous task using the Client Oriented Scale of Improvement (COSI) Final Ability rating section. After each trial the participants were asked if they thought they achieved 95%, 75%, 50%, 25%, or 10% of the words or sentences correct. They were asked not to base their answer on anything except the trial in question.

After completion of all testing, the purpose of the study was revealed to the participants. The participants were then interviewed about their opinions on the SurfLink Mobile 2 and asked about any perceived benefit. The participants were asked how well they thought the SurfLink Mobile 2 worked, whether or not they could tell a difference between the Surround and Focus trials, and if they would ever consider purchasing such a device. The participants were then counseled on their results and any questions from the participant were answered.

RESULTS

Maryland CNC Words

As shown in Figure 4, participants performed significantly better in the directional microphone condition (M = 84.34%; SD = 8.18%) than in the omnidirectional microphone condition (M = 75.84%; SD = 8.16%; $t(11) = 4.74$; $p < .05$) on Maryland CNC word lists. Participants also performed significantly better in the directional microphone condition (M = 140.67; SD = 4.25) than in the omnidirectional microphone condition (M = 132.42; SD = 7.05;

$t(11) = 5.7$; $p < .05$) when comparing total number of phonemes correct (Figure 5). This means that even if the participants missed a word overall, they still were able to achieve a higher phoneme score in the directional microphone condition over the omnidirectional condition.

QuickSIN

Participants showed significantly less signal-to-noise ratio loss as measured by the QuickSIN test in the directional microphone condition ($M = -1.25$; $SD = 2.28$) than in the omnidirectional microphone condition ($M = 1.2$; $SD = 3.06$; $t(11) = 4.66$; $p < .05$). Figure 6 displays the median, interquartile ranges, as well as the minimum and maximum scores achieved on the QuickSIN. No outliers were present in the data.

The relationship between word and sentence scores was also analyzed. To compare the effect of condition across scores, the investigators compared standardized effect sizes using Cohen's d. The difference between words and sentences was not statistically different ($t(20) = 0.08$; $p > .05$). This finding indicates that the use of the directional microphone over the omnidirectional microphone did not create an advantage in words more than sentences, or vice versa.

COSI Final Ability Rating

In CNC words, as shown in Figure 7, participants were more confident on the CNC trials when using the directional microphones ($M = 82.08$; $SD = 20.17$) than when using the omnidirectional microphone condition ($M = 75$; $SD = 20.23$; $t(11) = 2.33$; $p < .05$). This represents a statistically significant difference in confidence between microphone conditions.

Results indicated that participants were equally confident on the QuickSIN trials when using the directional microphones ($M = 63.75$; $SD = 23.66$) as they were in the omnidirectional microphone condition ($M = 60$; $SD = 21.74$; $t(11) = 1.47$; $p > .05$).

DISCUSSION

In the present study, the results indicated that the use of the directional microphone setting over the omnidirectional setting on the SurfLink Mobile 2 significantly improved the participants' ability to hear and understand in the presence of background noise. This improvement was seen in words, individual phonemes, and sentences. The ability for a remote microphone accessory to aid with correct detection and understanding of individual words is crucial, in that in many situations context is not given and the listener must rely on hearing only one word to know how to act and respond. In noisy environments like an emergency room or court room, the correct understanding of a single word can alter outcomes, and the use of a directional microphone over an omnidirectional microphone in the SurfLink Mobile 2 would be beneficial in such situations. The study also showed that the detection of individual phonemes was significantly improved with the use of the SurfLink remote microphone in the Focus setting. This shows that even if the participant missed some CNC words overall in the directional microphone condition, he/she was still able to achieve a higher number of phonemes correct in the directional microphone condition, Focus, over the omnidirectional microphone condition, Surround. Finally, the ability to hear sentences in background noise was also tested using the QuickSIN and results indicated that the directional microphone setting on the SurfLink Mobile 2 significantly improved the signal-to-noise ratio loss score (making the score lower or negative) over the use of the omnidirectional microphone setting. This finding indicates that in normal conversational situations with background noise, the Focus directional microphone setting should improve the individual's overall understanding of what is heard.

The results also indicated that participants were significantly more confident in the CNC word trials in the directional microphone setting, but the same did not hold true for the participants' confidence on QuickSIN sentence trials. This finding can be rationalized by considering the two different test situations (words and sentences). In CNC word trials, the participants would repeat whatever word they thought they heard, with no idea if it was correct or incorrect. However, in the QuickSIN sentence trials, the participants were more aware when they did not hear certain words or could not make the sentence "make sense" in their own mind. The researchers noticed that participants seemed more concerned and frustrated during the sentence trials when they knew they were incorrect and did not correctly recite the entire sentence in either condition. Therefore, the participant would tend to be more confident in CNC trials in general over QuickSIN trials.

The results of this study were in agreement with results from similar studies. In a study by Rodemark and Galster (2015), the SurfLink Mobile Remote Microphone was utilized, as were three other remote microphone devices from other manufacturers (Phonak and Resound). In the remote microphone streaming only setting, all devices performed significantly better in noise over trials without utilizing the devices. In a study by Lewis et al. (2004), research showed the best listening condition was when the directional microphones and two FM receivers were used, improving speech perception scores significantly. However, both studies did not assess the directional versus omnidirectional conditions. The findings of Valente, Mispagel, Tchorz, and Fabry (2006) indicated that hearing aid performance was significantly better in the directional microphone condition (compared to omnidirectional condition) in different types of background noise. While no studies were found in which directional versus omnidirectional performance in remote microphone accessories were studied, the results of the previous studies and the rest of the studies discussed in this paper indicate that performance in noise would be improved with the use of a directional microphone via a remote microphone accessory.

This study did have multiple limitations. One limitation was the number of participants. The present study had a total of twelve participants, but results would have been stronger with a larger test population. Another limitation of the study had to do with the SurfLink Mobile 2 itself. During the testing process, a glitch in the device was discovered. During the trials, the SurfLink Mobile 2's microphones were activated and the microphones on the hearing aids were deactivated when the SurfLink was put into Surround or Focus modes. When the Surround or Focus modes were activated, there was a significant static percept that was easily heard by both the participant and research team. A different SurfLink Mobile 2 device was tested and the same static percept occurred. After speaking with the manufacturer, many attempts were made to overcome the issue to no avail. This issue was noted and testing proceeded. The participants were instructed to do their best to ignore the static and focus on the task. All participants noted that they heard the noise but were able to ignore it for the purposes of this study, but would not want the noise present in everyday life. More research is needed to confirm the device's directional microphone function aside from the static percept. A third limitation of the study was that two of the participants were not tested utilizing real ear measurements due to excessive cerumen. If the study were to be conducted again, it would be advantageous for it to take place in an environment equipped for cerumen removal.

The use of the SurfLink Mobile 2 would be an appropriate recommendation for patients who report struggling in background noise, especially in one-on-one situations. This study revealed that the use of the Focus directional microphone setting will significantly improve the patient’s understanding of speech in background noise over the use of the Surround omnidirectional setting. Situations where the SurfLink Mobile 2 in the Focus setting may be especially useful include in a restaurant, lecture hall, classroom situations, medical appointments, and in the car. As previously stated, the greatest benefit will be seen in situations with one conversational partner. The efficacy of the patients’ ability to perform in a situation with multiple talkers with the SurfLink Mobile 2 still needs to be assessed.

Additional future research directions could include assessment of the SurfLink’s Focus and Surround settings with the hearing aid’s microphones activated. Another research avenue could evaluate the Surround and Focus settings on Starkey’s new device, the SurfLink Remote Microphone. This new device is similar to the SurfLink Mobile 2 in remote microphone function, but does not have the other capabilities, has no screen, and is smaller in size. An alternative research opportunity could test the SurfLink device in variable situations and could possibly allow the participants to try the device out in real world situations. Research on how a remote microphone accessory that automatically changes from omnidirectional to directional would perform in a similar testing situation would also be warranted.

CONCLUSION

The Starkey SurfLink Mobile 2’s directional microphone Focus setting significantly helped the study participants hear and understand words, phonemes, and sentences better in background noise. The SurfLink Mobile 2’s remote microphone is a good option for patients looking to hear better in background noise and are comfortable asking his/her conservation partner to wear the device. Overall, the use of the Starkey SurfLink Mobile 2 would be an appropriate recommendation for patients by the audiologist. The results of this study show that the patient can benefit through better speech understanding noise from the use of the Starkey SurfLink Mobile 2 remote microphone accessory.

REFERENCES

Blamey, P.J., Fiket, H.J., Steele, B.R. (2006). Improving speech intelligibility in background noise with an adaptive directional microphone. *J Am Acad Audiol, 17,* 519-30.

Desjardins, J.L. (2016). The effects of hearing aid directional microphone and noise reduction processing on listening effort in older adults with hearing loss. *J Am Acad Audiol. 27(1),* 29-41.

Dillon, H., James, A., and Ginis, J. (1997). The Client Oriented Scale of Improvement (COSI) and its relationship to several other measures of benefit and satisfaction provided by hearing aids. *J Am Acad Audiol, 8,* 27-43.

Etymotic Research. (2001*). QuickSIN: Speech-in-Noise Test* (Version 1.3) Elk Grove Village, IL: Etymotic Research.

Fitzpatrick E. M., Seguin C., Schramm D. R., Armstrong S., Chenier J. (2009). The benefits of remote microphone technology for adults with cochlear implants. *Ear Hearing. 30,* 590–599.

Gnewikow D., Ricketts T., Bratt G. W., Mutchler L. C. (2009). Real-world benefit from directional microphone hearing aids. *J Rehabil Res Dev. 46,* 603–618.

Hawkins, D. Yacullo, W.S. (1984). Signal-to-noise advantage of binaural hearing aids and directional microphones under different levels of reverberation. *J Speech Hear Disord 4,* 278-286.

Kuk, F.K., Kollofski, C., Brown, S., Melum, A., Rosenthal, A. (1999). Use of digital hearing aid with directional microphones in school-aged children. *J Am Acad Audiol. 10,* 535-548.

Lewis, D.E. (1994). Assistive devices for classroom listening: FM systems. *Am J of Audiol,* 70–83.

Lewis M. S., Crandell C. C., Valente M., Horn J. E. (2004). Speech perception in noise: directional microphones versus frequency modulation (FM) systems. *J Am Acad Audiol. 15*, 426–439.

Nielson, H.B. (1973). A comparison between hearing aids with directional microphones and hearing aids with conventional microphones. *Scand Audiol.* , 45-48.

Olson, L., Ioannou, M., Trine, T.D. (2004). Appraising an automatically switching directional system in the real world. *Hear J. 57*, 32-38.

Park, H.S., Moon, I.J., Jin, S.H., Choi, J.E., Cho, Y.S., Hong, S.H. (2015). Benefit from directional microphone hearing aids: objective and subjective evaluations. *Clin Exp Otorhinolaryngol. 8(3),* 237-242.

Rodemerk K. S., Galster J. A. (2015). The benefits of remote microphones using for wireless protocols. *J Am Acad Audiol. 8*, 724-731.

Skinner, M.W., Holden, L.K., Fourakis, M.S., Hawks, J.W., Holden, T., Arcaroli, J., Hyde, M. (2006). Evaluation of equivalency in two recording of monosyllabic words. *J Am Acad Audiol, 17,* 350-366.

Studebaker, G.A., Cox, R.M., Formby, C. (1980). The effect of environment on the directional performance of head-worn hearing aids. In: Studebaker G.A., Hochberg, I. eds. *Acoustical Factors Affecting Hearing Aid Performances.* Baltimore: University Park Press, 340-341.

Valente M., Fabry D., Potts L. G. (1995). Recognition of Speech in Noise with Hearing Aids using Dual Microphones. *J Am Acad Audiol. 6,* 440–449.

Valente M., Mispagel K. M., Tchorz J., Fabry D. (2006). Effect of type of noise and loudspeaker array on the performance of omnidirectional and directional microphones. *J Am Acad Audiol. 17,* 398–412.

Wu, Y.H. (2010). Effect of age on directional microphone hearing aid benefit and preference. *J Am Acad Audiol. 21(2),*78–89.

TABLES AND FIGURES

Table 1: *Participant Demographics*

Age	Mean: 72.75 Standard Deviation: 6.22 Range: 60-84
Gender	Male: 7
	Female: 5
Reported Length of Hearing Loss	Mean: 15.33 Standard Deviation: 10.52

Figure 1: *CNC +5 dB SNR Set-Up Montage*

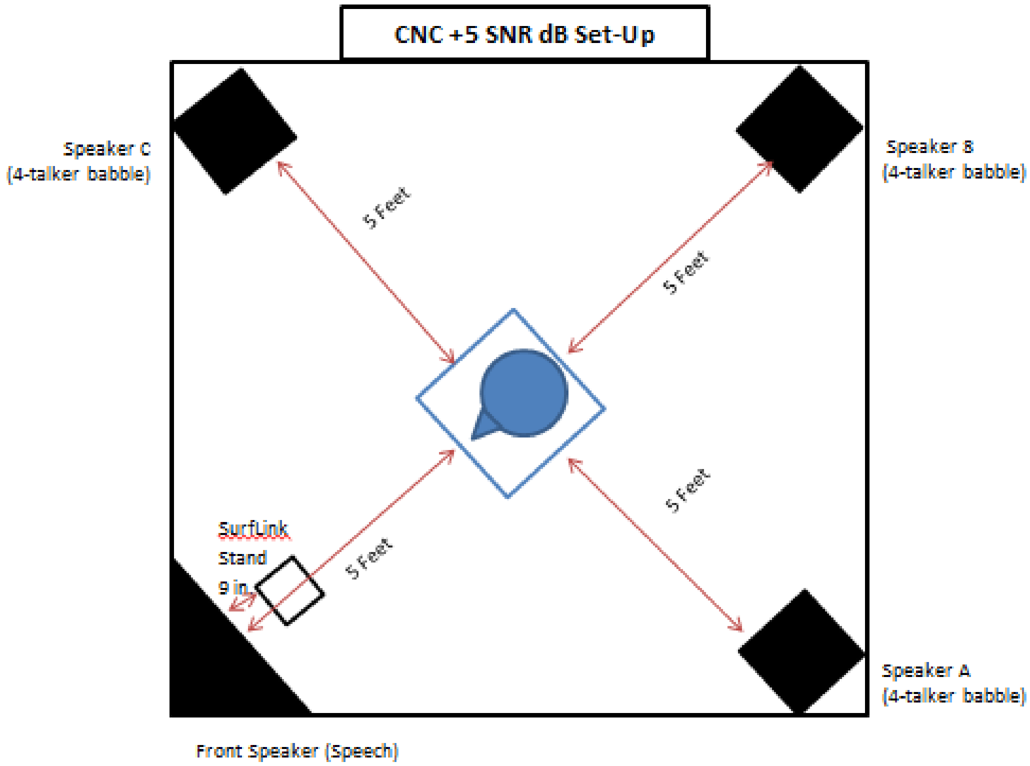


Figure 2: *QuickSIN Set-Up Montage*

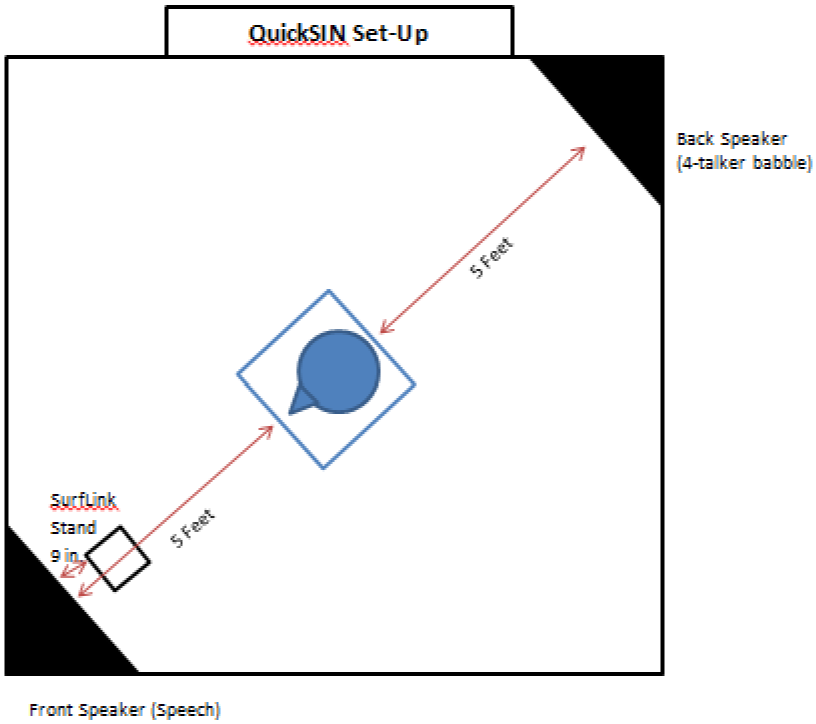


Figure 3: *Participant Audiogram Plots*

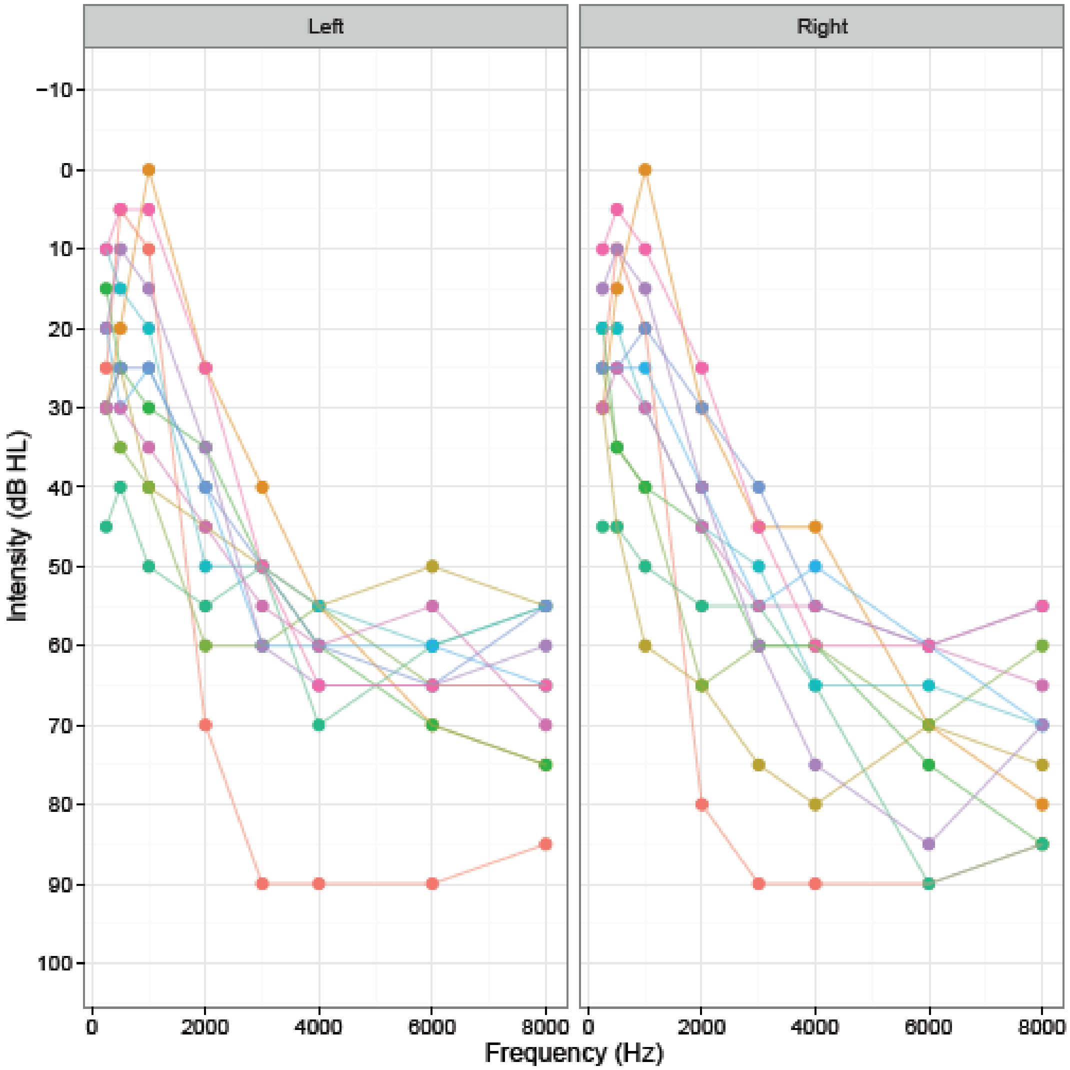
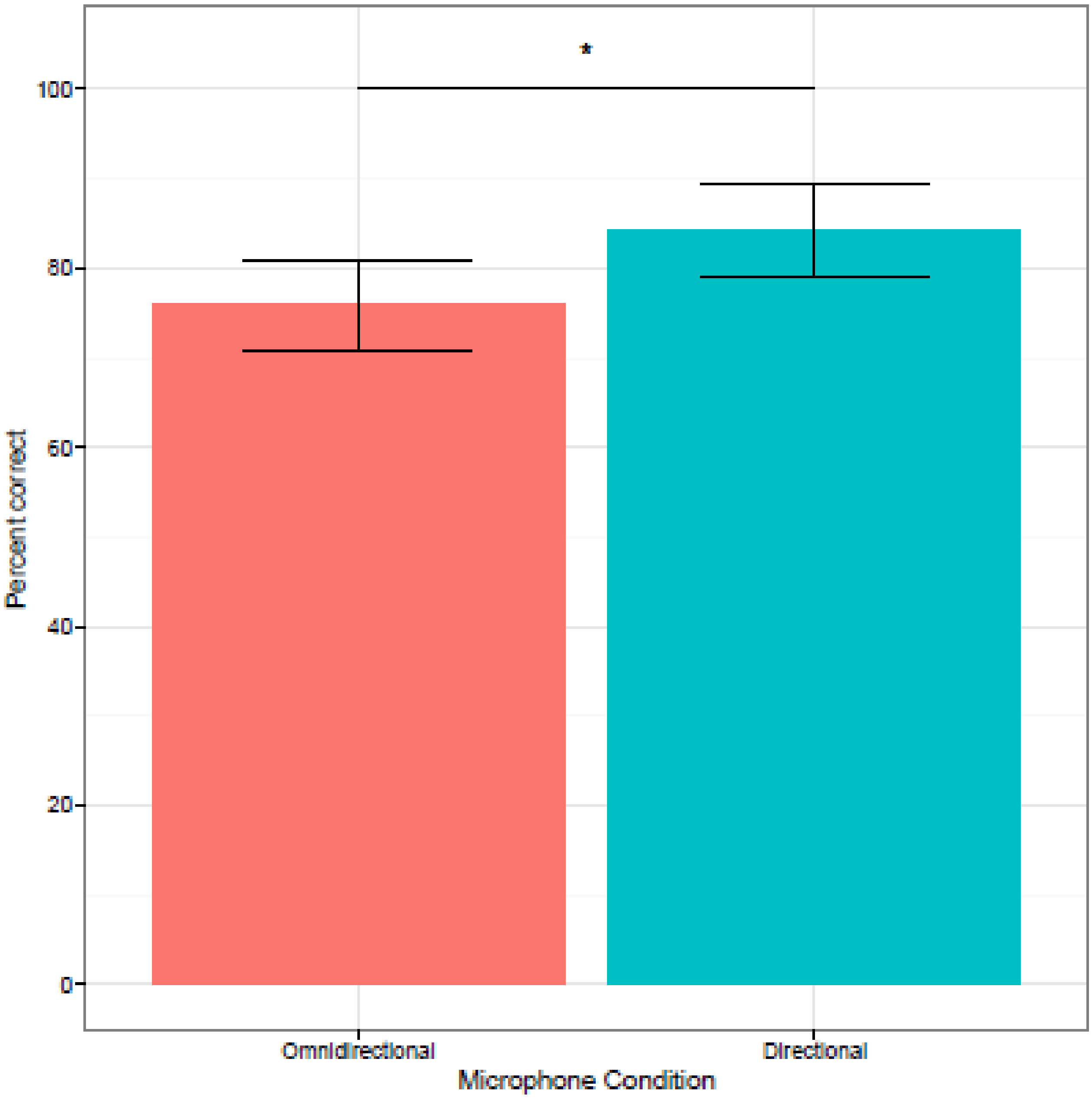
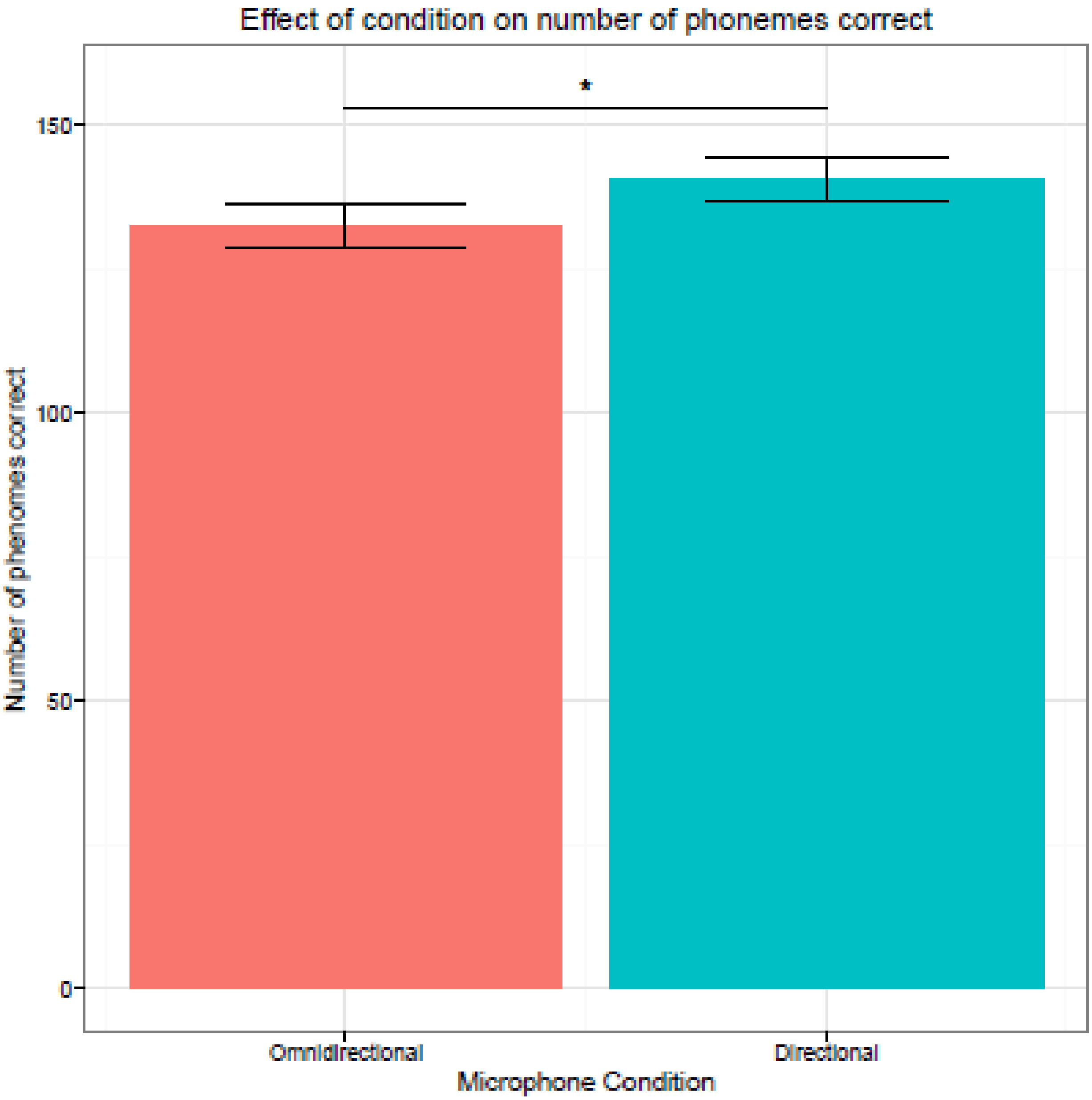


Figure 4: *Comparison of CNC Words in +5 dB SNR Scores*



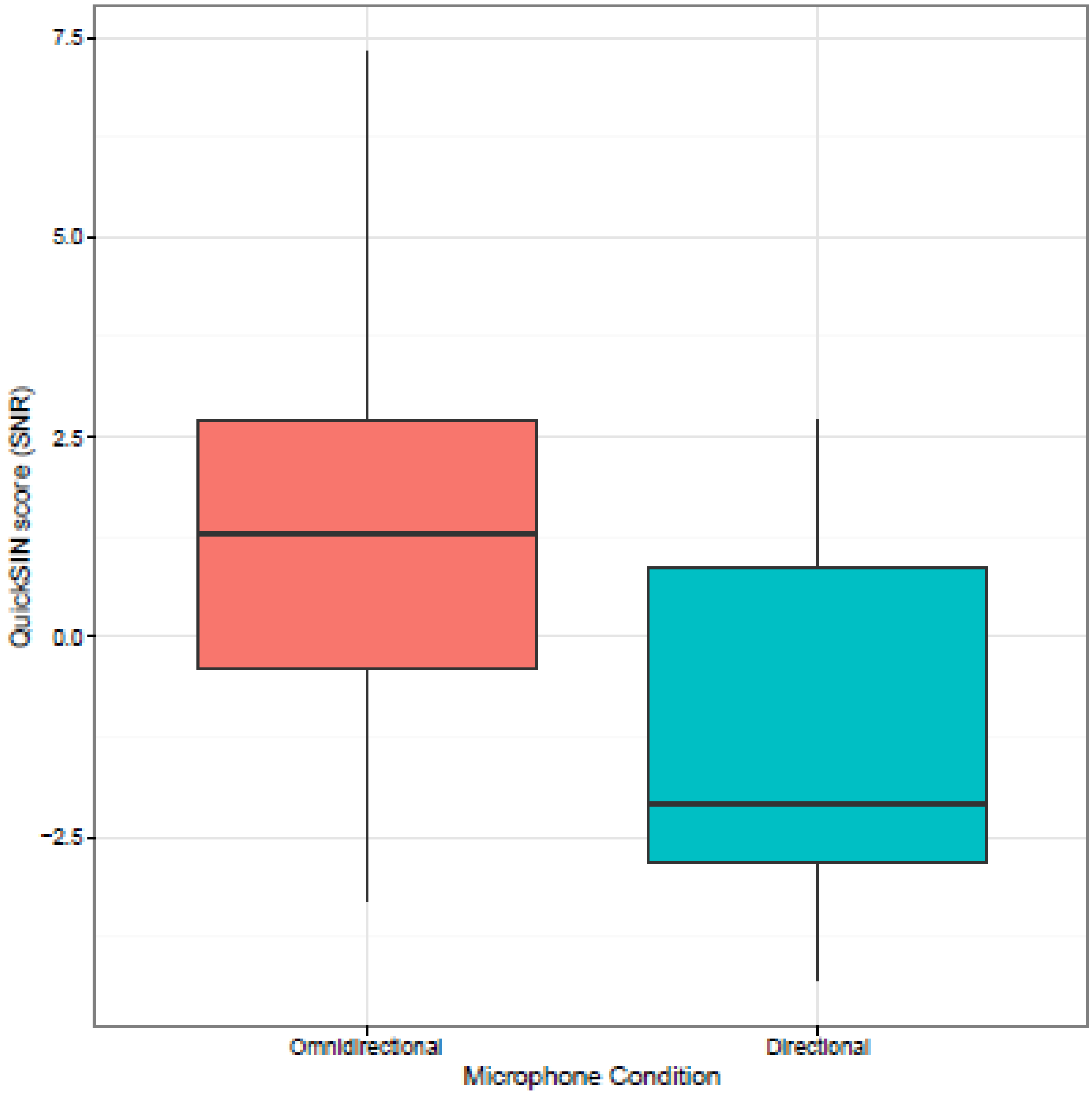
* = $p < 0.05$

Figure 5: *Comparison of CNC Phonemes in +5 dB SNR Scores*



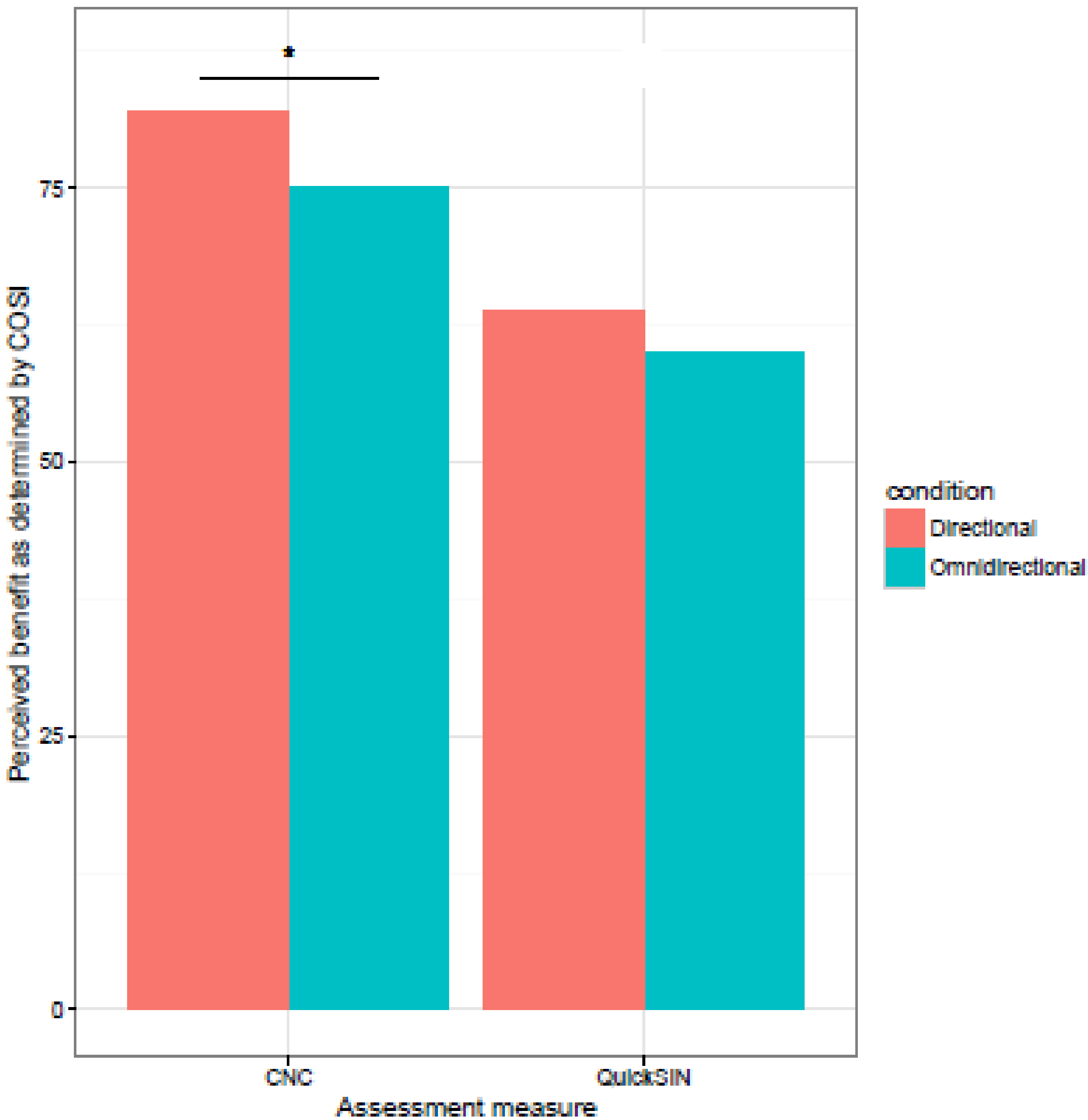
* = p < 0.05

Figure 6: *Comparison of QuickSIN Sentence Scores*



$p < 0.05$

Figure 7: *COSI Result Comparisons on CNC and QuickSIN Trials*



$* = p < 0.05$