Going beyond directionality in noisy conversations with Dynamic Spatial Awareness

Spatial awareness, or localization, is important in quiet, but even more critical when it comes to understanding conversations in noise. Traditional directional microphones are supposed to help people hear better in noise, however they also cause harm by removing localization cues. Localization helps the listener to know where a speaker is situated, which is essential to being able to hear and follow the conversation, especially in noise – a situation where even individuals with normal hearing struggle to localize sounds.

Unitron has introduced new technology that addresses localization issues in noise for those who wear hearing instruments. Dynamic Spatial Awareness is a key component of SpeechPro, a combination of three technologies that work together to determine the location of speech and help patients hear their best in noisy conversations. Field trial study results clearly demonstrate how Dynamic Spatial Awareness improves localization abilities in difficult listening situations, and how those improvements increase after acclimatization.

Authors

Betty Rule, Hon. B.Sc. Experimental Physics
Senior Product Manager
Favorite sound: my family's laughter

Jesse Sinclair, MClSc, Aud(C)
Corporate Audiologist
Favorite sound: my children laughing

Carolina Rubiano Galvis
Senior Validation Specialist
Favorite sound: the heartbeat

Leonard Cornelisse, M.Sc.
Hearing Scientist; Manager, Hearing System Engineering
Favorite sound: live jazz music

Localization improves understanding in noise

Localization is key for understanding conversations in noisy environments. With normal hearing and a properly functioning auditory pathway, localization can be performed quite well, until the signal-to-noise ratio (SNR) becomes negative. This is partially due to the fact that the ability to locate a target talker becomes compromised in noise, which makes it more challenging to ignore other sounds and focus on the target speech. This lack of localization makes it difficult to hear and understand the words being spoken[1,2,3,4] – something audiologists refer to as the "cocktail party problem."[5] In addition, while left/right judgements are slightly influenced by noise, front/back confusion is very strongly influenced by increased noise levels.[1]

Hearing loss can make matters worse. When hearing instrument wearers complain that sounds feel "jumbled" inside their heads, or that they have difficulty following who is speaking, you may not immediately realize these are issues associated with localizing sounds. What a patient is really complaining about in this situation is a lack of spatial separation. Our brains are able to gain acoustical advantages provided by spatial separation of speech from competing noises.[6,7] When faced with multiple talkers, spatial differences enable our brains to sort out the acoustic mixture into distinct sources so we can focus our attention on one source.[8,9,10,11] Hearing instruments interfere with this spatial separation in noise, which is what causes the sounds to be "jumbled" and makes it difficult to focus on the speaker and understand what they are saying.

Solving the "cocktail party problem"

Even with normal-hearing individuals, knowing where the target talker is located significantly improves their ability to understand speech in noise.[12] Kidd and colleagues found that being able to focus attention on a specific talker along the spatial dimension "can play a very significant role in solving the 'cocktail party problem.'" [13]

Unitron's SpeechPro was engineered to help patients experience the best conversations in crowds and noise. Three advanced technologies in SpeechPro – Speech Locator, Speech Focus and Dynamic Spatial Awareness – enable it to not only zone in on speech from any direction, but also provide beneficial localization cues to enhance speech and improve a patient's ability to hear in noise, beyond traditional directional microphones.

Speech Locator finds speech

In noisy situations, Speech Locator uses a combination of techniques and sound features to pinpoint where speech is coming from. It relies on multi-microphone detectors and beamforming techniques to locate different sound sources. Acoustic features are extracted from the input sound to determine if it contains speech. Then, level detectors and SNR detectors add the final touch to binaurally determine the location of speech. While Unitron's previous platforms included some of this technology, Speech Locator is a significant upgrade. In fact, it's 50% more accurate and 36% faster at locating speech than the technologies in the North platform. This combination of speed and accuracy is critical because, much like driving a car, getting somewhere fast is meaningless unless you are navigating to the correct destination.

Speech Focus zones in on speech

Once speech is located, Speech Focus comes into play. This third-generation dynamic speech perception and targeting technology helps the listener zone in on a speaker of interest in the midst of other speech and background noise. It does this using a variety of strategies:

When speech comes from the front, Speech Focus uses the maximum setting of its multiband adaptive directional system to focus in on the speech and cancel noise sources at the sides and back.

When speech comes from the side, it uses a binaurally co-ordinated asymmetric response. If a speaker is to the left, Speech Focus zones in on speech sounds on the left, and cancels noise from the back and right.

When speech comes from the back, Speech Focus uses a beam that focuses to the back, but maintains some audibility to the front, ensuring that the listener has an adequate awareness of surroundings. In this situation, sounds from the front are reduced by approximately 10 dB, relative to the target speech at the back.

Since the accuracy and speed of Speech Locator is so robust and reliable, Speech Focus is able to be more aggressive at zoning in on speech – even in the SoundNav automatic program.

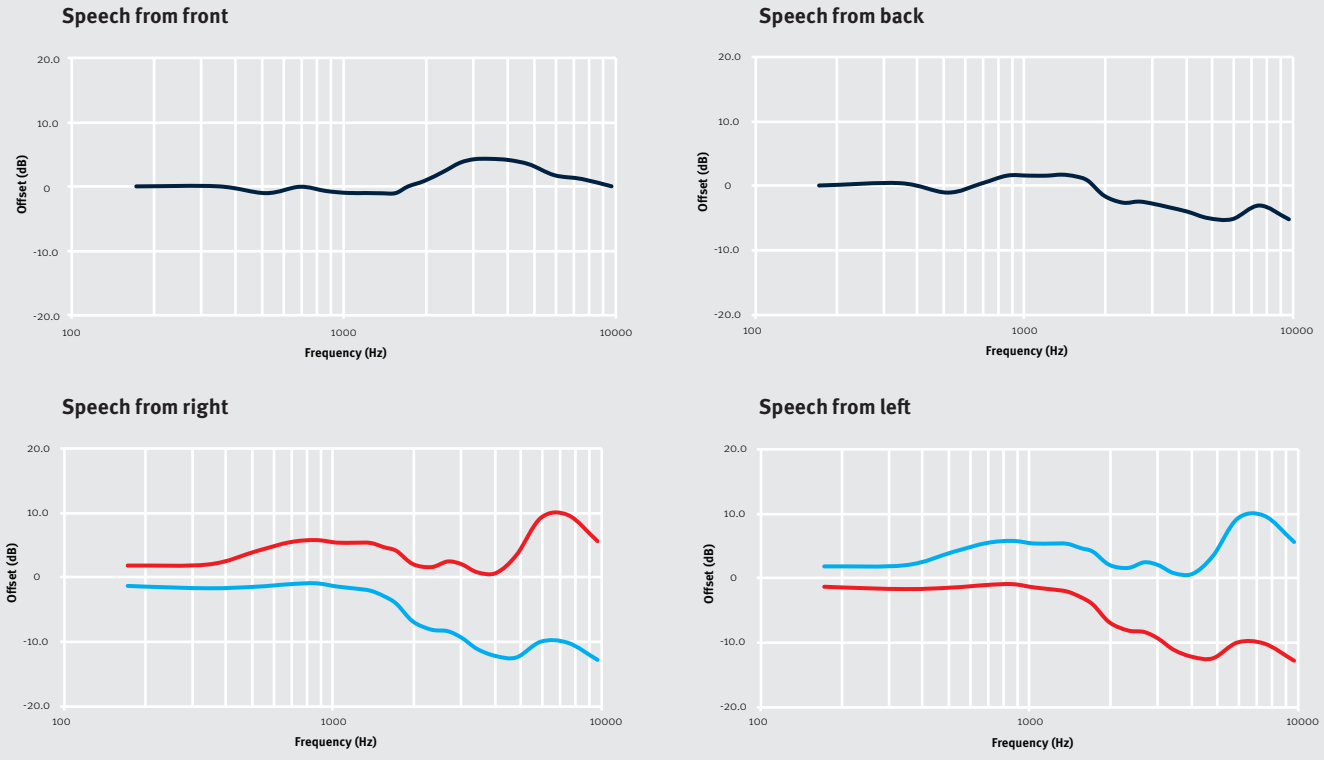
Dynamic Spatial Awareness makes speech stand out

Dynamic Spatial Awareness is the third component of the trinity of features behind the power of SpeechPro. Speech Locator and Speech Focus do a great job of identifying, locating and zoning in on speech sounds. However, strong directional responses tend to destroy localization cues. Dynamic Spatial Awareness modifies the directional responses of Speech Focus, depending on the direction of the target speech, to restore natural localization cues. Testing was done to ensure that the frequency response change was aggressive enough to enhance the ability to localize the sound source. However, it couldn't be so drastic as to prevent subjects from locating either other sounds in the environment around them or the speech source, if the direction of speech changed quickly.

Figure 1 shows the frequency response modifications applied by Dynamic Spatial Awareness. When speech is located to the front or back, both ears receive the same modification. When speech is located from the right, the right ear signal is boosted in frequency response, while the left ear signal is attenuated to enhance the head shadow effect. Dynamic Spatial Awareness adaptively adjusts the frequency shaping, depending on the location of the speech source. This allows SpeechPro to not only zone in on the speech, but also helps patients identify where the speech source is located, enabling them to follow along with the conversation more naturally.

Figure 1 – Dynamic Spatial Awareness adaptively changes the frequency response of Speech Focus, depending on the direction of speech in noisy situations.

Both ears
Left ear
Right ear



Putting Dynamic Spatial Awareness to the test

To test the localization enhancements of Dynamic Spatial Awareness within SpeechPro, 30 field trial subjects performed a localization task testing traditional directional microphones or SpeechPro with Dynamic Spatial Awareness.[14] Subjects were between the ages of 32 and 87, with a mean age of 68. Subjects were a mix of experienced and inexperienced hearing instrument wearers (20 experienced; 10 new). All subjects had binaural mild-to-moderate sensorineural hearing loss and wore North or Tempus™ hearing instruments.

Testing was performed in a sound room with 8 speakers evenly spaced 45 degrees apart. Target speech was presented in randomized order from a speaker at 0, 90, 180 or 270 degrees azimuth. Cafeteria noise was constantly presented from the 4 remaining speakers at an SNR of -3 dB. After each presentation of target speech, subjects were asked to rate their perception of speech direction, without any help from visual cues. This localization test was performed at the initial fitting and after three weeks of acclimatization.

The results

Subjects wearing the Tempus hearing instruments with Dynamic Spatial Awareness were very good at locating sounds coming from the left or right in noise. At the initial fitting, they successfully located sounds from the left and right 98% and 90% of the time, respectively. After the three-week acclimatization period, their scores improved further, successfully locating speech from the left 100% of the time, and from the right 95% of the time (see Figure 2). These results are consistent with left/right localization abilities in noise for those without hearing loss.[1]

The field study results reinforced the fact that speech coming from the front and back is more difficult to locate in noise for individuals with hearing loss;[14] which is similarly more difficult for those with normal hearing[1]. Subjects correctly identified speech as originating from the front and back 63% and 42% of the time, respectively. After the three-week acclimatization period, these abilities improved, with subjects correctly identifying speech from the front 75% of the time, and speech from the back 61% of the time (see Figure 2). The significant improvement in results from first fitting to post-acclimatization[14] is impressive given that localization is challenging even for normal-hearing individuals without visual cues[1].

Figure 3 shows the changes in localization performance for each subject out of the 12 trials. A few subjects had the same score before and after acclimatization. The majority of subjects improved their ability to localize sounds post-acclimatization. While subjects exhibited some front/back confusion at the initial fitting, this improved post-acclimatization – and showed better results than those reported in other literature.[15]

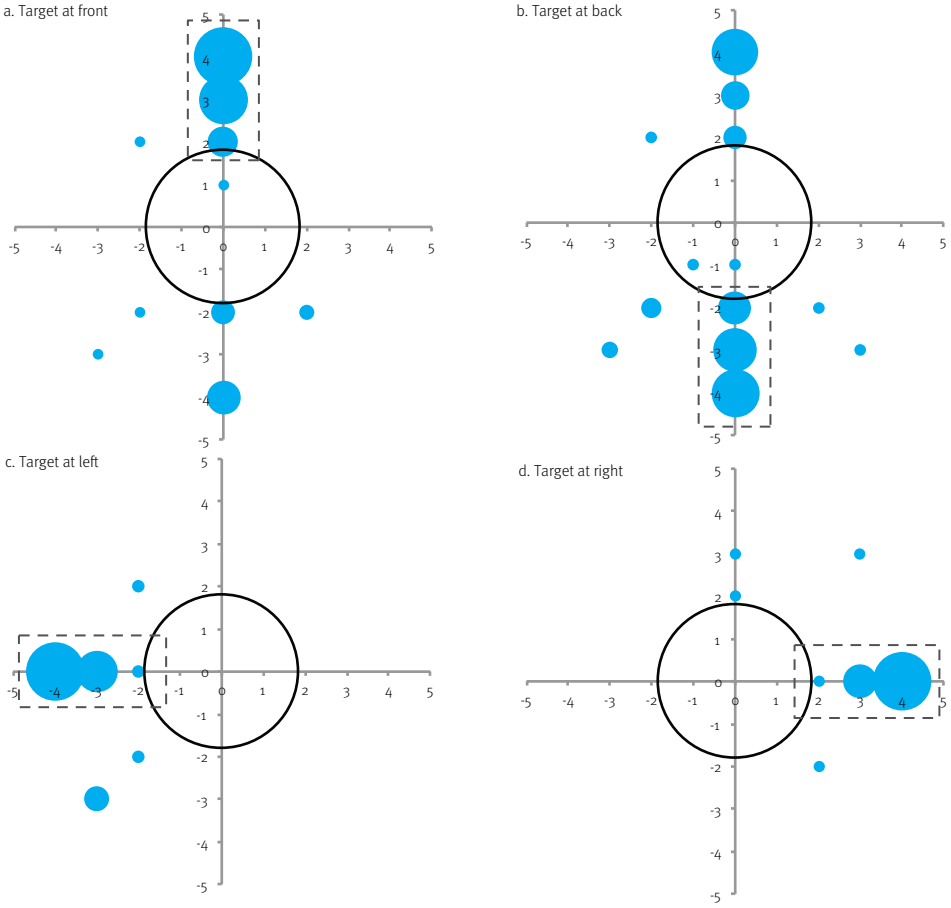
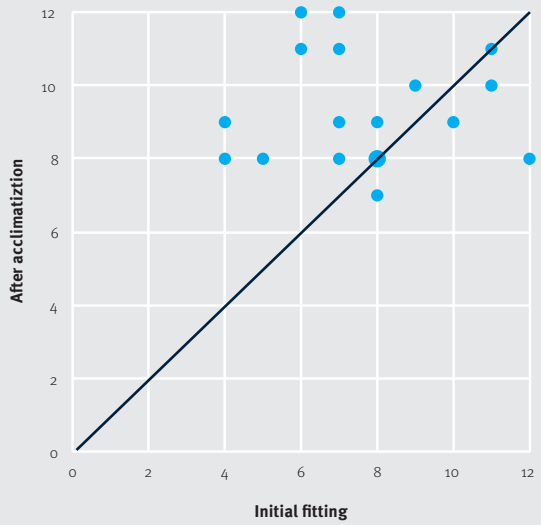


Figure 2 – Field trial subjects performed a localization task for speech from the front, back, left and right in noise post-acclimatization. The top of each graph represents the front of the subject. The larger filled-in circles indicate a larger number of responses for that location. Responses within the black circle in the middle of each graph were heard as being inside the head. Responses within the dotted lines were considered correct– and represent the majority of responses from the test.

Figure 3 – Localization in noise after wearing Tempus hearing instruments for three weeks. The graph shows 12 randomized localization tasks (4 front, 4 back, 2 right, 2 left). Most of the dots (61%) are above the black line, indicating that performance improved post-acclimatization.[14]

- 1 subject
- 2 subjects

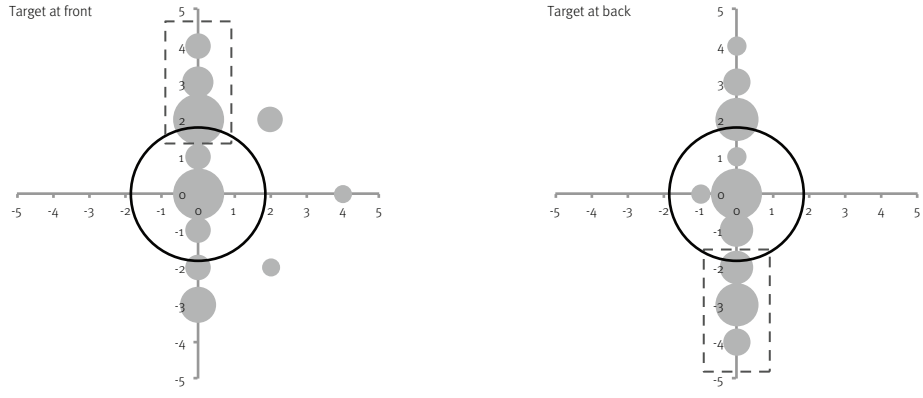
Total subjects = 18



Comparing Dynamic Spatial Awareness to traditional directional microphones

Many hearing instruments rely on traditional directional microphones to focus on speech in noise. Figure 4 presents the results comparing localization tests using traditional directional microphones to those using the Dynamic Spatial Awareness feature within SpeechPro – both at initial fitting and after three weeks of hearing instrument acclimatization.

Traditional directional microphones after 3 weeks



Dynamic Spatial Awareness at initial fitting

Dynamic Spatial Awareness after 3 weeks

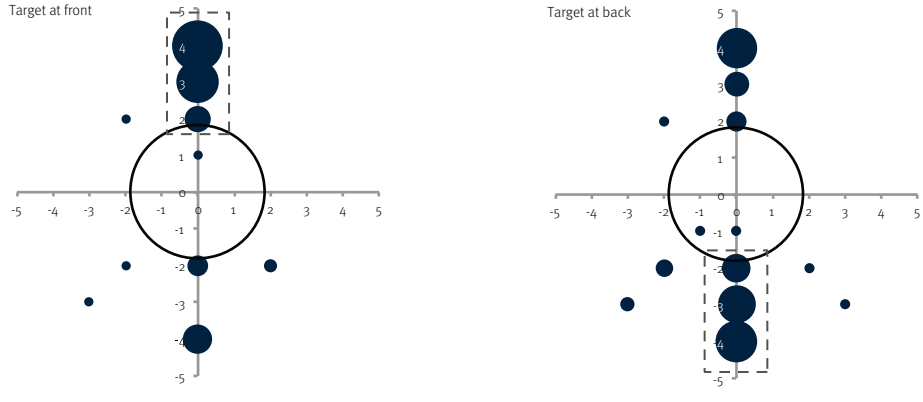


Figure 4 – Results of the localization test for field trial subjects wearing traditional directional microphones post-acclimatization (top two graphs), SpeechPro with Dynamic Spatial Awareness at the initial fitting (middle two graphs), and SpeechPro with Dynamic Spatial Awareness post-acclimatization (bottom two graphs).

The graphs on the left and right are the results for target speech from the front and back, respectively. The top of each graph represents the front of the subject. The larger filled-in circles indicate a larger number of responses for that location. Responses falling within the black circle in the middle of each graph were heard by the subject as coming from inside their head. Responses within the dotted lines were considered correct.

There are two main takeaways from Figure 4. First, front/back confusion was most evident for the traditional directional microphones. We can see a significant improvement in front/back confusion over traditional directional microphones with Dynamic Spatial Awareness at the initial fitting, and then further improvement after only three weeks of acclimatization. The ability to locate sounds to the left and right did not change significantly between first fitting and acclimatization (see Figure 5).

The second takeaway from the graphs in Figure 4 is that Dynamic Spatial Awareness improved externalization of sounds, meaning subjects have a better sense of their surroundings. Responses appearing inside the black circle in the middle of each graph represent subjects reporting that the sounds were coming from inside their heads. As you can see from the top two graphs, using traditional directional microphones resulted in many more responses appearing inside the circle than when Dynamic Spatial Awareness was activated. In fact, subjects wearing hearing instruments with Dynamic Spatial Awareness at the initial fitting had a better sense of their surroundings, as evidenced by how many more of their responses fell outside of the middle circle. The bottom two graphs have the least number of responses inside the circle, indicating that the subjects' sense of their surroundings further improved after wearing the hearing instruments with Dynamic Spatial Awareness for only three weeks.

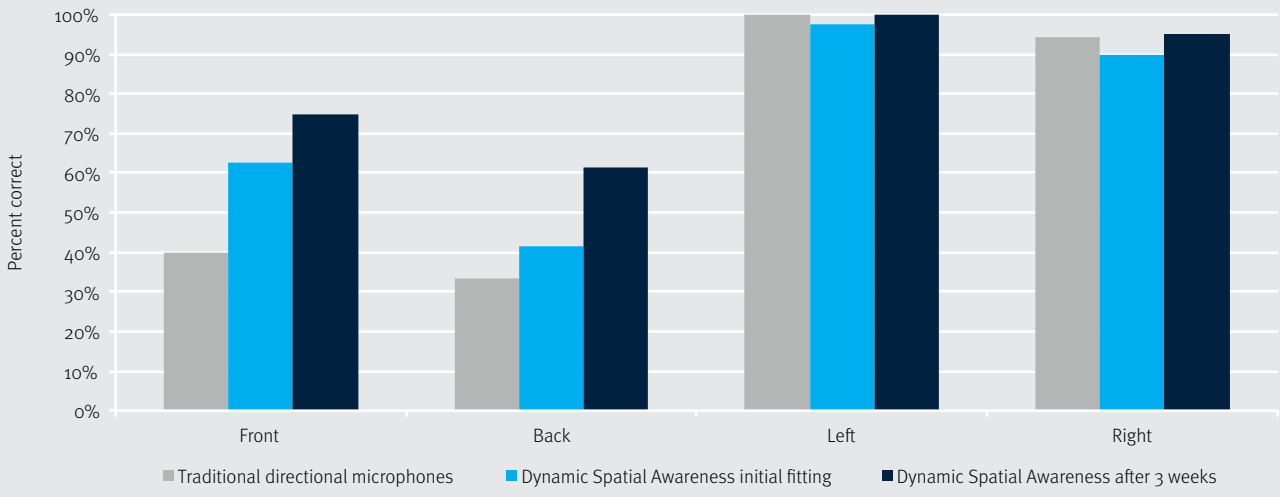


Figure 5 – Comparison of number of correct responses for targets from the front, back, left and right when wearing traditional directional microphones, Dynamic Spatial Awareness at the initial fitting, and Dynamic Spatial Awareness after three weeks.

Conclusion

People who wear hearing instruments spend almost two thirds of each day in conversation.[16] Their ability to localize sound plays a large role in understanding speech in those conversations, especially in noisy environments. In order to address this problem, Unitron created Dynamic Spatial Awareness – a key technology within SpeechPro. Together with Speech Locator and Speech Focus, Dynamic Spatial Awareness helps patients locate and understand speech in noisy conversations quickly and naturally.

Results of a field trial study found that subjects wearing hearing instruments were very good at localizing speech from the sides with both traditional directional microphones and Dynamic Spatial Awareness. However, in the more challenging situation where speech is coming from the front or back, Dynamic Spatial Awareness outperformed directional microphones when it came to localizing speech. These effects were present in the initial fitting and improved after a short, three-week acclimatization period. Dynamic Spatial Awareness also provided subjects with a better sense of their surroundings at the initial fitting, which improved over time. These results provide proof that Unitron's unique Dynamic Spatial Awareness is a highly effective technology for helping hearing instrument wearers locate speech in noise. Improving spatial awareness in difficult listening situations plays a significant role in solving the cocktail party problem and contributes to the ease of understanding speech in conversations.

For many years, these solutions have been beyond our reach. Until now.

Unitron is making leaps in localization technology with our Spatial Awareness feature, driven by the Tempus platform. Contact your representative to learn how Tempus is a game-changer in localization.

1. Good, M.D. & Gilkey, R.H. (1996). Sound localization in noise: the effect of signal-to-noise ratio. Journal of Acoustical Society of America, *99*, 1108–1117.
2. Good, M. D., Gilkey, R. H. & Ball, J. M. (1997). "The relation between detection in noise and localization in noise in the free field," in Binaural and Spatial Hearing in Real and Virtual Environments, edited by Gilkey R. H. and Anderson T. R. (Erlbaum, Hillsdale, NJ:), pp. 349–376.
3. Abouchacra, K. S., Emanuel, D. C., Blood, I. M. & Letowski, T. R. (1998). Spatial perception of speech in various signal to noise ratios. Ear and Hearing, *19*, 298–309.
4. Lorenzi, C., Gatehouse, S. & Lever, C. (1999). Sound localization in noise in normal-hearing listeners. Journal of Acoustical Society of America, *105*, 1810–1820.
5. Cherry, E. C. (1953). Some experiments on the recognition of speech, with one and with two ears. Journal of the Acoustical Society of America, *25*, 975–979
6. Zurek, P. M. (1993). "Binaural advantages and directional effects in speech intelligibility," in Acoustical Factors Affecting Hearing Aid Performance (pp. 255-276). Studebaker, G.A. & Hochberg, I. (Eds.) Boston, MA: Allyn and Bacon.
7. Bronkhorst, A. W. (2000). The cocktail party phenomenon: A review of research on speech intelligibility in multiple-talker conditions. Acta Acustica united with Acustica 86 (1), 117–128.
8. Yost, W. A., Dye, R. H. & Sheft S. (1996). A simulated "cocktail party" with up to three sound sources. Percept Psychophys, *58*, 1026–1036.
9. Freyman, R. L., Helfer, K. S., McCall, D. D. & Clifton, R. K. (1999). The role of perceived spatial separation in the unmasking of speech. Journal of Acoustical Society of America, *106*, 3578–3588.
10. Brungart, D. S. (2001). Informational and energetic masking effects in the perception of two simultaneous talkers. Journal of Acoustical Society of America, *109*, 1101–1109.
11. Shinn-Cunningham, B. G. (2008). Object-based auditory and visual attention. Trends in Cognitive Sciences, *12*, 182–186.
12. Kopco, N, Best, V, Carlile, S. Speech localization in a multitalker mixture. J Acoust Soc Am. 2010;127:1450–1457.
13. Kidd, G., Arbogast, T. L., Mason, C. R. & Gallun, F. J. (2005). "The advantage of knowing where to listen," J. Acoust. Soc. Am. 118, 3804–3815.10.1121/1.2109187
14. Rubiano, C. & Hayes, D. (February, 2017). Tempus Field Trial Report 16 KFT-003, Internal communication.
15. Best, V. et al. (2010). "Sound Localization with BTE and CIC Hearing Aids." Presented at International Hearing Aid Research Conference, Tahoe City, CA.
16. Hayes, D. (2016). Global Listening Environment Study, Unitron.

At Unitron, we care deeply about people with hearing loss. We work closely with hearing healthcare professionals to provide hearing solutions that improve lives in meaningful ways. Because hearing matters.

16-048 027-6073-02

unitron.com

sonova
HEAR THE WORLD