

Single-sided deafness and Phonak CROS

Audiological background

Unilateral Hearing Loss (UHL) includes anything from a mild hearing loss in one ear and normal hearing in the other to "Single-Sided Deafness (SSD)," a term coined for the purposes of describing the condition of a single normal or aidable ear and an ear with such a degree of impairment as to be considered unaidable. The unaidable ear may be deemed unaidable because of the severity of the hearing thresholds or poor aided discrimination abilities. The overall prevalence of unilateral hearing loss in the United States adult population aged 20–69 in 2003–2004 was 8.9%. This compares to the 7.3% of the population exhibiting bilateral hearing loss (Agradwal, Platz and Neparko, 2008). According to Lieu (2010) approximately one third of children identified with a hearing loss through newborn hearing screening have a UHL.

Unilateral hearing loss

UHL including SSD can have tremendous perceptual consequences due to the degradation of binaural functionalities that are used for spatial hearing and listening in the presence of competing signals. The brain uses interaural timing differences (ITDs) and interaural level differences (ILDs) to make listening easier in noisy environments. These cues are also some of the main cues for localization and are frequency dependent. One of the major complaints of people with a unilateral hearing loss is related to the loss of the head shadow effect; the attenuation of a signal by as much as 6.4 dB due to the presence of the head between the two ears (Lieu 2010). While low frequency sounds are only weakly influenced as they travel around the head, high frequency sounds do not reach the other ear and decrease in intensity as they hit the head itself. When these sounds do arrive at the contralateral hearing ear, they are soft and if noise is present, can be difficult to understand. Additionally, unilateral hearers suffer from the loss of binaural summation and binaural release from masking. For bilateral hearers, both of these phenomena result in improved perception due to receiving inputs from two ears with the head in the middle.

Pediatric Unilateral Hearing Loss

Children with UHL are known to carry significant risk for difficulties with their speech and language development and educational achievement. Fifty four percent of students in the United States with UHL receive special education services (Bess, Klee &

Culbertson, 1986; Oyler, Oyler, & Matkin, 1988; English & Church, 1999). The Colorado department of education data (2002) revealed that 36% of students with UHL were on an individual education plan (IEP). This is the required document in the United States for children with a disability who also meet the requirements for special education.

UHL may also lead to significant psycho-social consequences. In a general quality-of-life study of children with UHL, conducted by Lieu (2010), he concluded that children with UHL are at risk for speech and language delay, educational difficulties, and a lower quality of life than peers with normal hearing similar to children with bilateral hearing loss.

Management



It is unclear what percentage of individuals with UHL opt for some form of amplification; however, there is a range of specialized solutions on the market for the population with SSD (Figure 1). One solution is a CROS (contra-lateral routing of sound) system. This non-surgical option routes sound from the unaidable ear to the better ear and presents the signal to the better ear via an air conduction hearing aid. A CROS system is appropriate for any client who exhibits unaidable hearing in one ear and normal hearing or any aidable hearing loss in the contralateral ear. While it will not improve

hearing in the unaidable ear, it will help the listener to overcome the disadvantages that result from the loss of binaural hearing such as the head shadow effect. In this case, the aid in the better ear functions without gain, only providing the signal to the better ear without the attenuation that occurs when it crosses over naturally. This eliminates the complaint of someone speaking on one's "bad side." ITDs are not restored with a CROS system, however some clients do report improved spatial hearing. This may be the result of learning how to differentiate between the naturally arriving signals and the crossed signal.

For children in school, an open fitted, ear-level assistive listening system such as a Roger Focus worn on the better ear is often used to enhance the ability to listen across distance and in the presence of competing signals. Other solutions for SSD also include bone conduction devices as well as a conventional hearing aid for the aidable ear only.

Another option is a Bone Anchored Hearing Aids (BAHA). This has been approved by regulatory agencies for use in SSD cases. In this case, the signal is picked up on the unaidable side and is transmitted through the skull to the cochlea of the better ear cochlea via bone conduction. Clients must either wear the transducer on a headband or undergo surgery for the placement of a post-auricular screw in the cranial bone with a transcutaneous abutment that the speech processor is snapped onto. BAHAs are fairly expensive and require surgical placement. None of these interventions remediate hearing in the unaidable hearing ear but all try to overcome the disadvantages of the unaidable ear by making maximal use of the better ear.

Figure 1
Specialized solutions for unilateral hearing loss

Condition	Solution			
	Wireless CROS	Bone anchored devices	Ear level wireless system	Conventional hearing aid
 one unaidable ear one normal ear	●	●	●**	
 one unaidable ear one aidable ear	●	●*		●***

* limited for mild to moderate hearing losses

** only for the use-case of listening over distance, e.g. in classroom situations

*** aidable side only

Technical description

CROS systems consist of a CROS transmitter worn on the unaidable ear that transmits signals to the better hearing ear. A hearing aid is worn on the better ear to receive the transmitted signal and route the sound into the ear canal. There are two options available depending on the hearing status of the two ears; CROS and BiCROS. The CROS system is targeted at people with SSD and normal hearing in the better ear (Figure 2). The BiCROS system is targeted at people with SSD and some degree of hearing loss in the better ear (Figure 3). The current generation of CROS solutions offers significant advantages over previous generation options. Early CROS transmitters required the user to run a cable between the ears behind the head. This cable was coupled to a hearing aid with an audio shoe resulting in a bulky system with frequent intermittency. Later options included an amplitude modulated (AM) wireless transmission between the ears, eliminating the need for the connecting cable between the devices. The disadvantages of this system included significant roll-off of gain above 1500 Hz and limited ability to shape and fine-tune the frequency response. Additionally, there is a high rate of absorption of the RF signal through the head, resulting in variable sound levels depending on the size of the client's head as well as a worse dynamic range and higher noise floor. Current solutions, such as Phonak CROS II, a wireless CROS system, are made possible by the unique ability to stream in real-time the full audio bandwidth between devices. This proprietary digital induction technology allows for a reliable signal level, stable connection between the ears, resistance to interference, and efficient power usage allowing for even small custom CROS transmitters worn in the ear. The ear-to-ear streaming from Phonak CROS II uses a low carrier frequency and offers an acoustical bandwidth of 8kHz. Many advanced Phonak features available in premium hearing aids remain available in the CROS and BiCROS configuration. For instance, in Phonak CROS II, the multi microphone adaptive binaural beamformer uses real-time audio streaming to produce a highly focused directional beam towards the front. With an active beamformer, individuals take advantage of better understanding of speech in one-to-one conversations in diffuse background noise,

Figure 2

CROS configuration. A CROS transmitter picks up the sound on the unaidable side and wirelessly transmits it to a receiver, housed in a hearing aid on the normal ear.

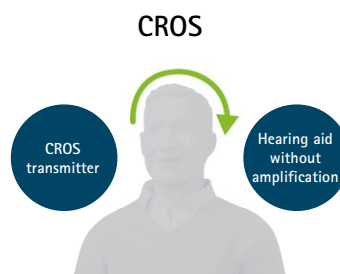
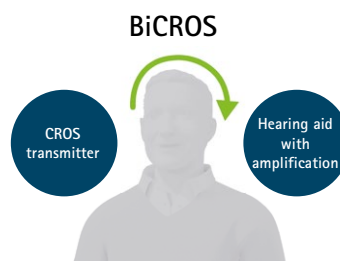


Figure 3

BiCROS configuration. A CROS transmitter picks up the sound on the unaidable side and wirelessly transmits it to a hearing aid on the better ear. Amplification, signal processing and sound cleaning is applied to the signals from both ears to ensure they are maximally audible and usable for the listener.



especially when there is also noise near the front. AutoSense OS, the automatic operating system introduced with the Phonak Venture platform, seamlessly manages audibility across changing environments. The streamed signal from the CROS transmitter undergoes the same signal processing (sound classification, gain adaption, and sound cleaning) as the signal in the hearing aid. This means that the signal heard in the better ear will be optimized for any environment whether the listener is in a noisy restaurant, listening to a concert or having a quiet conversation. Compared to the early CROS solutions, the dynamic range is optimized and the noise floor is significantly lower. This is especially important for CROS users with normal hearing on the better ear.

The amount of amplification desired in the better ear will be a factor in the selection of the receiver side device (hearing aid). The Phonak CROS II transmitter is available in four models; two RICs and two custom models, each available with either a 312 or 13 size battery (Figure 4) and can be paired with any RIC or BTE resp. any wireless Custom model using the Venture platform. With this flexibility, it is possible to have a matched set. Transmitter style will often depend on the amplification needs, and therefore, style choice of the better ear. The associated hearing aid will function as merely a receiver or provide amplification as needed. Since the CROS II transmitter can be used in combination with a hearing aid with any level of amplification, the hearing status in the better ear does not determine CROS candidacy. If the better ear has normal hearing, a hearing aid should be selected with an open ear coupling or open venting to prevent the obstruction of sound arriving naturally at the ear.

Figure 4

Phonak CROS II transmitters

Phonak CROS II - 13	Phonak CROS II - 312	Phonak CROS II - 312 Custom	Phonak CROS II - 13 Custom
			

Clinical evidence

In spite of having a normal hearing ear, SSD has been linked to such a degree of impairment or disability that even cochlear implantation has been explored as a remedy (Arndt et al 2010). There is a fairly robust body of evidence showing the benefit of a CROS system over no amplification. Baguley (2006) reviewed four studies comparing the effectiveness of CROS and BAHA with the unaided condition. The results showed that on the three Abbreviated Profile of Hearing Aid Benefit (APHAB) subscales of ease of communication, reverberation and background noise, CROS was beneficial compared to the unaided condition.

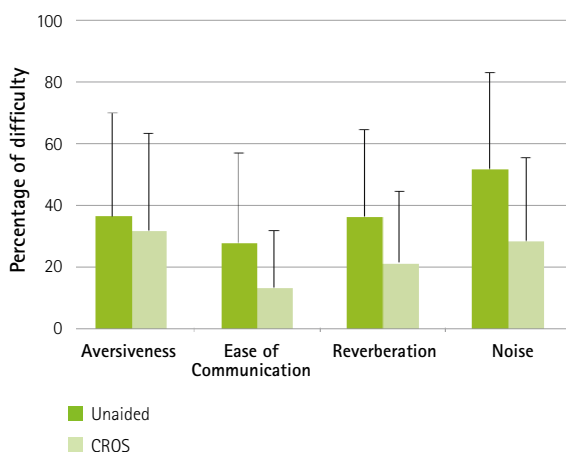
Researchers at the Veterans Administration in the United States (Williams, McArdle & Chisolm, 2012) investigated the subjective and objective benefits of the BiCROS in the veteran population. In their study, experienced BiCROS users were fitted with the Phonak system. Of 39 participants, 37 subjects reported satisfaction of some sort with the CROS system and wished to use the system on a consistent basis. Subjective and objective measures both indicated improved hearing in background noise and also complex spatial listening environments. In 2013 Schafer reported the results

of a study conducted to evaluate the effectiveness and efficacy of contra-lateral routing with 24 subjects. Half of the participants were CROS candidates and half were BiCROS candidates. For both subgroups, results were similar. Difficulty was shown to be significantly reduced across 3 sub-categories of the APHAB (reverberation, ease of communication and noise) with the CROS system (Figure 5). On the Speech Spatial and Qualities of Hearing (SSQ) questionnaire, significant improvement was seen with the CROS across all three subscales. On the Auditory Performance Scale for Single-Sided Deafness (APS-SSD), subjects reported significant reduction of difficulty when the CROS was in use across all three listening domains: home, work and social situations (Figure 6). On AzBio speech in noise testing, the CROS and BiCROS resulted in significant improvement in listening in noise when the noise was directed to the unaidable ear (Figure 7). In total, twenty of the participants reported that they would recommend this solution to others with their condition.

Figure 5

Results of the APHAB with the A. CROS group and B. BiCROS group show significant benefit for the intervention in 3 of the 4 sub-categories compared to the unaided condition,

A. CROS Group



B. BiCROS Group

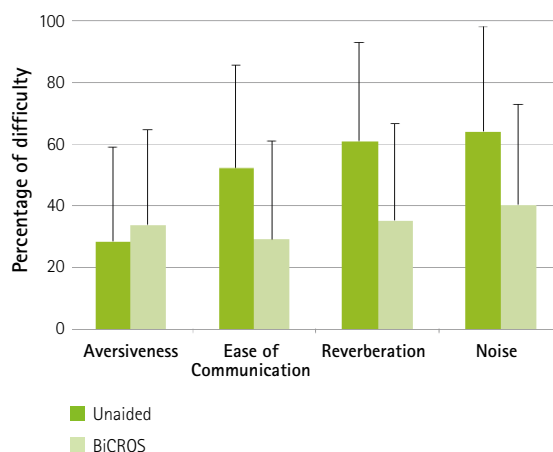
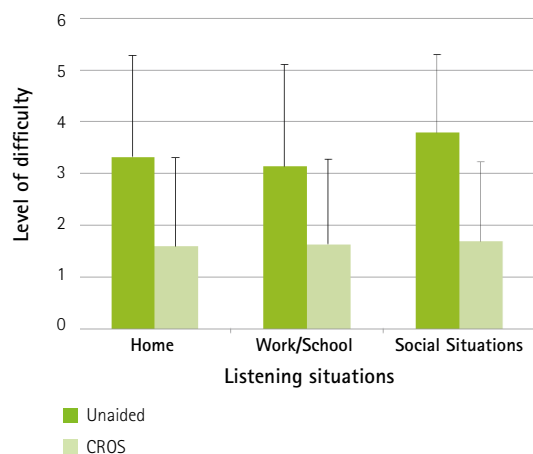


Figure 6

Results of the APHAB with the A. CROS group and B. BiCROS group show significant benefit for the intervention in 3 of the 4 sub-categories compared to the unaided condition.

A. CROS Group



B. BiCROS Group

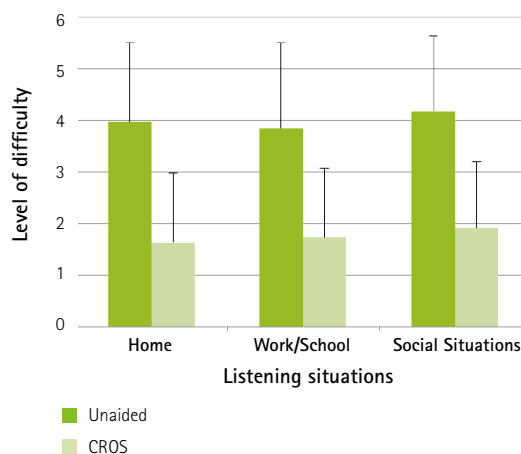
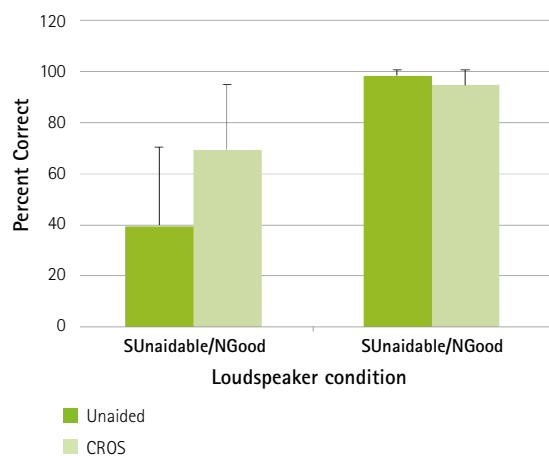


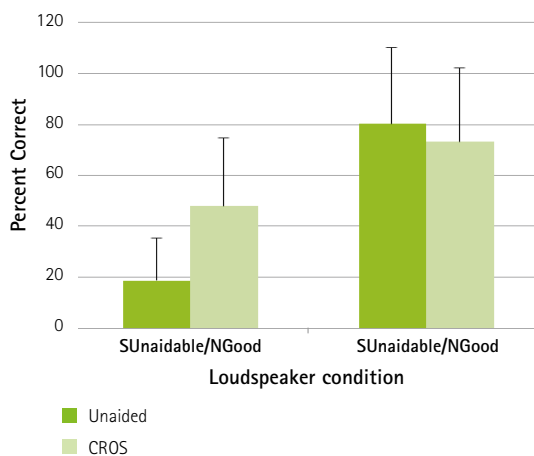
Figure 7

AZ Bio results show benefit in speech perception with the A. CROS group and B. BiCROS group when the speech is presented to the unaidable ear and noise is presented to the good ear. Benefit of the intervention is not seen.

A. CROS Group



B. BiCROS Group



Fitting and fine tuning

When a CROS II transmitter is connected to Phonak Target™, the fitter does not have to select if the fitting is a CROS or BiCROS. This is detected automatically by Phonak Target by using the information entered for the better ear. Any wireless Phonak Venture BTE or RIC hearing aid is compatible with the CROS II RIC models. Likewise, any wireless Phonak Venture Custom hearing aid with Binaural VoiceStream Technology™ is compatible with the CROS II Custom models. The hearing aid selection will depend on the hearing levels and desired features, such as StereoZoom and AutoSense OS for the better ear.

When fitting a CROS, real ear measures can be performed with the stimulus directed to the unaidable ear and the probe microphone measuring the sound level in the better ear. The goal of a CROS fitting should be to match the real ear unaided response (REUR) as closely as possible. This will ensure natural sound quality at the appropriate levels for the sound transferred over. The hearing aid microphone on the better ear in a CROS fitting is now permanently active, eliminating the concern of blocking sound to the better ear. Some electro-acoustic test boxes offer a specialized occlusion measurement tool. Another option is to measure insertion loss. This is done by comparing the REUR of the ear with the hearing aid in place and turned off to the REUR of the ear alone. When fitting a BiCROS system, the insertion gain or real ear aided response (REAR) should roughly match the same respective measurement for equivalent sounds arriving at the onside and offside microphone. This will ensure that the system is providing the appropriate audibility and sound quality.

Additionally there are unique acoustic notifications in the CROS system such as „CROS disconnected“, an acoustical signal tone that is heard in the hearing aid to notify the client that the CROS streaming has been disconnected. Clients should be counseled regarding these indicators.

Software tips

1.

There are times when the signal of interest arrives at a stronger level at the better ear and the signal at the unaidable ear is predominantly unwanted competition. In these circumstances the listener will find listening with the CROS transmitter to be disadvantageous. One common such circumstance is when a person is on the phone. It is important to configure the system so that the CROS transmitter can be swiftly turned off. This is most easily done by incorporating an additional program on the hearing aid. As can be seen in Figure 8, an additional program called "Calm Situation 1" has been created. In fine tuning the CROS transmitter can be turned off in this program.

2.

If a client feels that the CROS transmitter is too loud or unbalanced, this can be addressed either by adjusting the CROS balance in Phonak Target or by adjusting the CROS volume on the CROS II transmitter. The experience level is automatically set to 90% to ensure the fitting is acoustically transparent and natural sounding, however this is adjustable just as with a conventional fitting. The gain and MPO levels can be adjusted in fine tuning to improve the comfort, loudness or balance of the transmitter. Phonak CROS II, if fitted with iCube II, has the CROS transmitter active. This allows for real time adjustments and a faster balancing of the CROS transmitter. Beyond that, gain can be adjusted in the fine tuning screen. If the loudness is asymmetric, the hearing aid or CROS transmitter can be adjusted in the CROS balance tool (Figure 9). When making this adjustment, it is important to be aware that increasing the level on one side will simultaneously decrease the level on the other side. For example, raising the CROS transmitter by 2 steps will increase the CROS input while decreasing the hearing aid microphone input. This does not change the loudness perception in the better ear. For clients who want extra control, CROS II offers a volume control to balance the microphone settings of the hearing aid and CROS transmitter. Based on the CROS balance settings, the microphones can be adjusted using the push button or volume control, depending on the CROS II model chosen.

Figure 8
Switching the CROS transmitter off

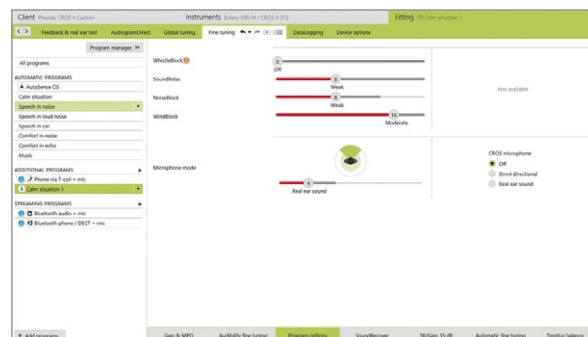
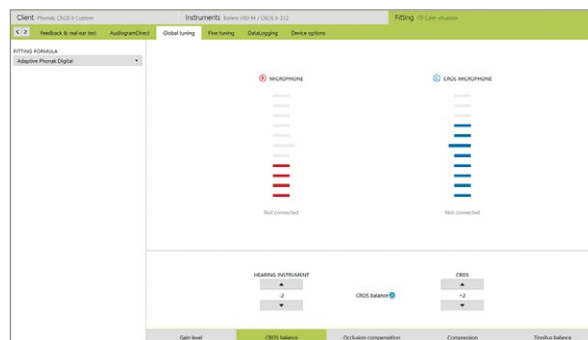


Figure 9
The CROS balance



3.

For children with unilateral hearing in school, a Roger Focus or a Roger/DAI system is recommended to improve listening over distance, in poor classroom acoustics and in the presence of classroom noise. If a Roger/DAI system is selected, a receiver can be coupled to the hearing aid of the CROS system, however, the CROS input and Roger/DAI input will not be heard simultaneously. The hearing aid fitting configuration should include the Junior Roger/DAI + mic program, maintaining input from an active hearing aid microphone.

4.

For the 4-8 year old age range using DSL as the default fitting formula in Junior Mode, there is no automatic program and the push button is disabled, therefore there is no way to access a program with CROS enabled. To ensure that the child has access to the CROS signal when Roger/DAI streaming is paused, in Phonak Target, the Speech in Noise program should be disabled and a Calm situation set as an additional program (Figure 11). In Device options, the push button should be enabled so the child can change to the Calm situation program and activate the CROS signal.

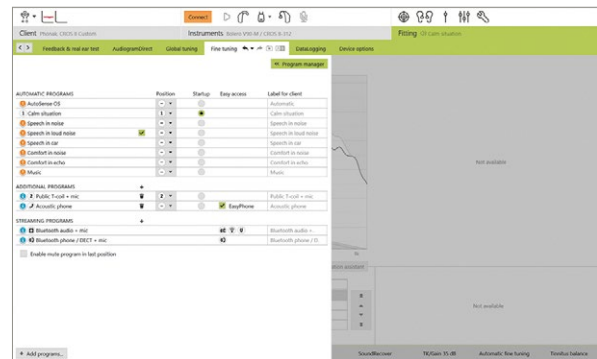
Figure 10

Roger Focus (right) and Roger/DAI system (middle and right)



Figure 11

Setting a CROS fitting in Junior Mode 4-8 years



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Demonstrations and more information

http://www.phonakpro.com/com/b2b/en/products/hearing_instruments/cros_II/overview.html

<http://www.phonakpro.com/com/b2b/en/evidence>