Journal of
The Association of Hearing Instrument Practitioners of Ontario

Signal

Summer 2011 • Edition 90

AHIP Symposium 2011!

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The Association of Hearing Instrument Practitioners of Ontario

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Distribution
Signal is circulated to all hearing instrument practitioners, contributing hearing aid manufacturers and suppliers, as well as Ontario otolaryngologists, audiologists, and other interested individuals.

The mission of the Association of Hearing Instrument Practitioners of Ontario is to represent and guide its members in their practice which include, the testing, selecting and fitting, and dispensing hearing instruments and associated devices in the best interest of the hard of hearing, and may include the removal of cerumen from the external ear canal. Membership is available to hearing instrument practitioners or to those who have an interest in the hearing instrument profession.

Signal is the official journal of AHIP, the professional association of Hearing Instrument Practitioners of Ontario, incorporated in 1988 for the purpose of ensuring quality care for the hard of hearing. *Signal* presents technical and trade information to assist hearing instrument practitioners to better serve the hard of hearing.

Manuscripts
Researchers, practitioners, and others are invited to submit articles and papers for publication. *Signal* assumes no responsibility for return of unsolicited materials, and is not guaranteeing that every article of paper submitted will be published in *Signal*.

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Dear Members,

I would like to take this opportunity to thank you for your support in electing me as president of this great association. I would also like to thank Shelley Randall for her amazing terms as president, her commitment and dedication to the profession was unwavering on all aspects of association business. Congratulations as well to the newly elected board of directors who I will count on and have generously offered their valuable time and expertise.

I strongly feel all members can in some way assist the association whether or not they have decided to run for election. If you have specific expertise or ideas you feel would help serve your association please contact us at any time.

Over the years AHIP has devoted excessive time and energies to ensure the rights of Ontarians who are hard of hearing and your interests are protected, you have my assurance that this will continue. As president, in addition to regular association business dealt with through various committees, priority will be given to government relations and political efforts with respect to formal regulation. Another priority will be to maintain and develop even stronger professional and education relations.

Once again, thank you for your support. Have a great summer!

Vivienne Saba-Gesa, HIS
President

Reason No. 463

"You don't need to tell someone how good it is, you let them hear how good it is."

Phil K., Australia, professional

Reason No. 336:

"I don't have 1000 reasons for using Naída, I have a million! :)"

Dale S., Spain, Naída user

Reason No. 568:

"Ever since I first got Naída a few months ago, I've been able to hear my professors and peers in University with a life-changing clarity I never thought I'd experience again since I lost my hearing."

Laurel C., United States, user

Reason No. 799:

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Cherie, Canada, parent of Naída user

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"It has helped me to regain my social life."

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PHONAK life is on

Dear Members,

Congratulations to newly elected AHIP President **Vivienne Saba-Gesa**; Vice-President **Maggie Arzani**; Secretary, **Diana Blank**; Treasurer, **Donna Ross**; and to the Board of Directors: **Edmond Ayvazyan, Nancy Chan, Loris Letain, Lisa Simmonds Taylor and Cheryl Smith-Interisano**. I would like to extend a special thank you and sincere appreciation to **Past President Shelley Randall** for her personal commitment to excellence in serving the profession with integrity and vision in the best interest of the hearing of Ontario.

The amazing 2011 AHIP Symposium could not have happened without the leadership, commitment and expertise of **Chris Helik and Maggie Arzani**. Quality educational sessions along with amazing exhibits and events, it is all greatly appreciated. On behalf of the entire membership ...Thank you!

Wow, amazing things happening in public relations, new *Signal*, new AHIP website www.helpmehear.ca both just keep getting better! More strange and sometimes not so amazing things happening in government and professional relations – as always updates on all major issues will be sent to you via membership mailings and website postings.

Have a safe and happy summer!

Joanne Sproule
Executive Director

It was wonderful seeing so many of you at this year's symposium. As always, it was a fantastic time. A spotted child and juggling parental duties kept me from attending the gala dinner this year and from the pictures I have received it looks like I missed one heck of a show. The entertainment just keeps getting more impressive. I wonder who I will be asking for an autograph next year?

You may notice that the *Signal* has a slightly different appearance this month. We are working with a new publisher and hope to create a look that is more in line with other industry journals. This edition is packed full of goodies. Of course we have the customary post-symposium coverage, Adam Perrie has submitted an article on how to paint your sound booth and I conducted a member interview with Lynn Bales. There is a very useful article about the new no-mercury hearing aid batteries and a fascinating study on musical experience and its impact on the aging auditory system. So grab a beverage, find a nice seat in the shade and enjoy your summer reading.

Lisa Simmonds Taylor, BA, HIS
Editor-in-Chief

Spotlight On...

Lynn Bales, HID, Kingston, Ontario

By Lisa Simmonds Taylor, BA, HIS

Have you ever been hired by someone you just had a fight with? Well Lynn Bales has, on the spot. See you tomorrow at 9:00! Necessity and a mother's determination to give her child every opportunity were the force behind Lynn becoming very handy at taking ear-mould impressions and performing basic hearing aid repairs. Lynn's daughter Kendra was born with a hearing loss. At the time, it was difficult to obtain reliable results before a child was able to understand and follow instructions. After many unsuccessful attempts to test her at SickKids, Lynn took Kendra to the EC Drury School for the Deaf in Milton. Lynn enrolled herself in an intensive total immersion ASL class and the experts set to work on testing Kendra's hearing. After two or three visits they were able to obtain a good audiogram that revealed that Kendra had a moderate to severe sensorineural hearing loss in both ears. Kendra has been wearing hearing aids ever since. Communication methods switched from sign to speech and with a little help from a Grover puppet Kendra made the transition.

As Kendra grew she needed new ear moulds on a regular basis. An itinerate teacher would visit their home but when it came to impressions Kendra preferred that her mother take hers. Kids can be hard on their belongings and hearing aids are no exception. Lynn found herself rigging up all sorts of repairs to keep the aids going until it was time to replace them again. Lynn had some experience working with small components through her previous job as an electronics assembler and inspector. She worked for Ferritronics which produced printed circuit boards and Lynn's responsibilities included teaching others how to solder under a microscope. She would find these skills very useful in what would be her new career direction.

Kendra was four when her mom took her in to see an audiologist closer to home rather than make the trip to Milton. The audiologist was one of only five dispensing audiologists working in Ontario at the time. As a result it was difficult to get in for an appointment. After waiting six weeks for her daughter's aids to be fit she finally called the office and insisted that they give her the aids, she would fit them herself. She brought her own scissors and proceeded to fit the aids to the new moulds. The audiologist challenged her, asking her how she would now set the aids. She grabbed a screwdriver and followed the prescription. When he observed that she knew her way around a hearing aid he hired her, on the spot.

For the next year Lynn worked with the audiologist,

learning from his text books and preparing for her equivalency exam. Lynn was part of the first sitting to write exams at George Brown College in 1989 and passed. Lynn continued to work with the audiologist for 6 years as his business expanded. Over time Lynn and her family started thinking about moving to a smaller community. Initially they considered moving to Belleville when Lynn was offered a position at the Sir James Whitney School for the Deaf. Unfortunately she found out that the funding for the position was put on hold for six months only after she had already given notice. The industry grapevine worked its magic and she found herself with another job offer but this time in Kingston. She found that the people in Kingston were warm and friendly so she and her family made the move. At Kingston Hearing Centre, Lynn worked closely with the audiology group at Hotel Dieu. When the group discovered that Lynn was the mother of a hearing impaired child they understood that this life experience perfectly suited her to fitting and counselling children and their parents.

The Kingston clinic was originally owned by Eaton's. Eaton's sold the clinic and ownership bounced around for a few years until the clinic was offered to Lynn. She was sorely tempted but her daughter was entering a challenging chapter in her life and Lynn realized that she needed to be able to focus her attention on Kendra for a while, she would not have enough time to run a business … until now.

Lynn took an entrepreneur course in the fall of 2010 and started a new venture in the winter of 2011. She isn't selling hearing aids. That's right, no hearing aids! Lynn has met so many people over the course of her career with noise induced hearing loss (NIHL) that she decided to do something about it. She is on a prevention kick. Her new company EAR-PRO-TECH sells custom made moulds. "NIHL can be prevented we all know this, but the public are not getting it." Lynn did a lot of research and found that quite often those who have purchased ear protection are not wearing it. Either it is too uncomfortable or too hot, or too inconvenient to wear so she is making custom moulds and trying to tell anyone she can about why they should protect themselves from loud noise.

Her research also found a need for other moulds that the general public is not even aware exists, cell phone adapters. swim plugs, snore plugs and iPod/mp3 ear buds for example. "If you wear a hearing aid and go to a clinic you see this sort of thing in the offices,

but if you have normal hearing, you really are not exposed to any of these products. A lot of my interested audience had no idea that you could get custom moulds for your tractor, swim moulds for water or comfortable custom moulds to protect your hearing when riding your motorcycle. I am starting to get involved with some music teachers, and day care centers, who really have a lot of noise to deal with and I have a comfortable solution for their environment as well. There are a lot of occupations that require an ear piece, so I make custom moulds for anyone."

Lynn's business is also unique in that she is mobile. Customers really appreciate not having to book time off work to visit a clinic for an EMI. A house call to order swim plugs for a child can really simplify a busy family's schedule.

In addition to trying to save the world from NIHL, Lynn creates paintings in water colour, oil and acrylic and carves wood. Lynn has made a habit of volunteering her time to causes as well. In 1985 she saw the first pictures of the effect of the famine in Ethiopia. Her response was to organize non-stop, dusk 'til dawn, entertainment night to raise money for African Famine Relief. It was a one of a kind show at that time featuring all Gospel music and Christian entertainment. She helped raise over $3,500.00 for World Vision and they awarded her a special memento, an African Crisis Medallion.

While living in Newmarket, Lynn started a group for parents of hearing impaired children. Lynn could more than relate to how devastated and powerless parents felt when they are first informed of their child's diagnosis. She used her experience and compassion to put together presentations that provided valuable information for care-givers and educators of hearing impaired children. Lynn now volunteers with Crescent Community Centre. The centre offers adults with developmental disabilities the opportunity to engage in meaningful activities of their choice. Activities can be vocational (i.e., employment) or non-vocational (i.e., leisure, arts, volunteering). The emphasis is on community integration. Lynn assists in finding work for the centre, mostly small contracts stuffing envelopes or folding flyers for example.

All the best with your new business Lynn and thanks for sharing your story with the membership.

If you are a member and wish to participate in an interview for the Signal*, please contact the AHIP office and ask to be forwarded the interview questionnaire.*

In Memory of Ruth Anne Lawy

Ruth passed away on May 7, 2011 at the age of 60. Ruth was the beloved wife of Isaac Lawy, mother to Lenny and Aaron and cherished grandmother of Myles. Ruth was a hearing instrument specialist and had her own business for a number of years in the Burlington area. She sold her business but continued to work as a hearing instrument specialist. In 2009 Ruth came to the rescue of the Canadian Hearing Society in Kenora, Ontario when the community had lost all audiology services. Ruth would fly into Kenora on Bearskin Airlines on a monthly basis to provide audiology services to the city until a full-time hearing instrument specialist or audiologist could be hired. Ruth fell in love with Kenora and Kenora fell in love with Ruth. She may have been tiny in stature but she had a huge heart and a great sense of humour. Ruth was instrumental in the selling of the Necklaces of Hope for Cancer at our 2010 symposium. Recovering from her first round of cancer treatment Ruth attended the 2010 Symposium wearing a stylish hat and a huge smile.

Ruth will be greatly missed by all who knew her.

Thank You Sponsors!

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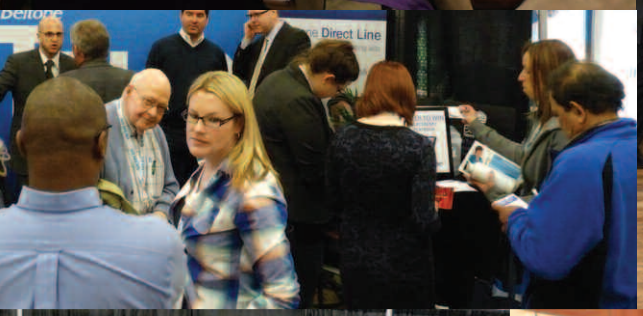
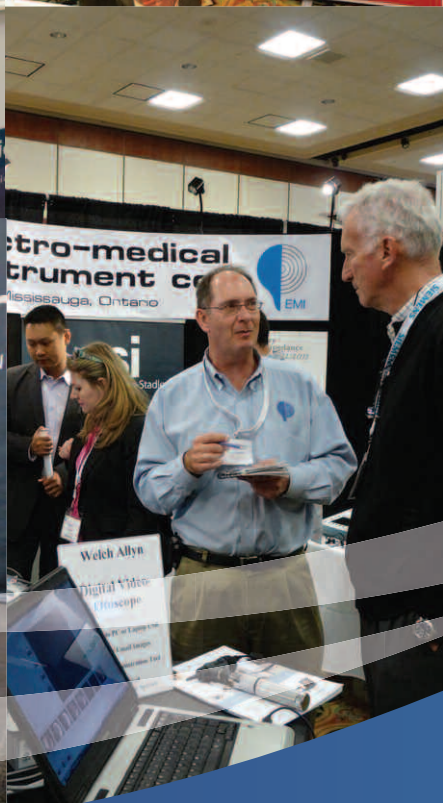
EXHIBITORS!





AHIP Symposium 2011

Exhibitor photos courtesy Lisa Simmonds Taylor

AHIP Symposium







Symposium 2011 photos courtesy Sharon Canzi and Dmitri Markine Photography.

2011

Paint That Booth!

By Adam Perrie, HIS

I recently checked with Mike and Frank from *American Pickers* about the value of antique sound booths. They both assured me that in cars and motorcycles a certain patina, wear and tear can be desirable or even valuable. Patina or that original frost green colour on a sound booth does nothing to improve the value. With this in mind I'd like to share with you how to paint your sound booth. I've painted three with great results.

The important thing to remember when you go to paint the booth is you do not want to plug the perforated holes on the interior. A sound booth wall is typically a sandwich made up of a layer of steel on the exterior, two sheets of drywall, then dense fibreglass absorption batting (similar to fibreglass insulation). Completing the sandwich is the perforated steel layer that you can see from the inside. If you plug the perforations in the sound booth it will lose the capability to absorb and quiet echo from within and also dampen sounds that managed to get through the sandwich. Plugged holes are also very unsightly.

Start by removing the handles and trim. Remember if you remove the door handle and close the door you may have great difficulty opening it again. Use blue or green painters tape to protect the ID/serial number plate and consider taping off the black rubber trim around windows, jack panels and hinges. The taping step may take as long as the painting steps but please don't rush. A job that was well painted looks great for years.

Check for grubby spots around the door handle and light/fan switches and be certain to clean them off before painting. Using a 1-inch angled foam brush cut in around all edges, corners and the areas you taped. The foam brush should be just wet. To achieve this dip it in the paint and squeeze out the excess paint on a flat disposable surface like an old magazine. Then lightly dab the perforated steel as you would if you were using a rubber stamp. Plan on two coats.

Also, fill only the reservoir of the paint tray, don't let paint pool up on to the rolling surface of the tray. Then dampen the roller by dipping it in the paint reservoir and spread it over the roller and also squeeze out the excess paint on the tray then, with a very gently action roll over the perforated steel.

It is not comparable to painting house walls. In painting the interior booth walls you are just gently rolling a paint dampened roller over the steel. Left, right, up and down. Again, do not try to do this in one coat, your impatience will plug the holes. Certainly don't feel bad if it takes three coats.

If you press too hard it will squeeze excess paint into the perforations. You may want to practice a few times on an old cardboard box. The goal is to have the roller

transfer just the right amount of paint to cover the steel.

Using modern latex paints results in a very easy clean up, quick drying times, and minimal odour. I found that the first coat could be applied in the morning and the second after lunch. Also of note is that I found much better results using the small 3-inch foam roller compared to the large 9-inch foam roller. The large roller tended to load up with paint and plug holes much more rapidly. While the large roller puts the paint on much quicker it just did not deliver nearly as nice a job as the small roller.

If you are right handed paint from the left to the right, this hard learned step will help you keep your shoulder and backside out of the paint, which then helps prevent mysterious paint marks that will appear all over the office.

Keep a pencil handy for the few holes that you may plug, use it to poke into the filled area and wipe it off each time. It was quite effective at clearing excess paint.

Also consider replacing the carpet at this time. Chances are it is very worn and filthy and you may have to cut it out as frequently booth walls are built on the carpet. Once you have it out set it aside to use as a pattern to cut the new carpet to fit. Use double-sided carpet tape to hold down the new one that you will install after painting. Don't be tempted to put in a laminate floor, the carpet is there to help the acoustics.

Supplies

Paint/primer all-in-one. 4 litres	$45.72
Mini foam roller	$3.19
Foam brush	$2.29
Shallow plastic paint tray	$11.59
Painter's tape	$4.97
Harvey's Canadian burger combo	$10.92
Total	$ 78.68 + tax
(Don't forget to add carpet)	

The Home Depot can match almost any colour you can come up with and they also have a really good selection of colours on hand. I like a flat or eggshell finish but a semi-gloss also looks good. Don't buy cheaper paints.

Your new paint job will not be as scratch and scuff resistant as the original, but you will find that it is incredibly easy to touch up with the left over paint that you keep in the back. Also, once you have successfully painted it you won't hesitate to do it again when it needs it.

To keep chairs from scuffing and digging into the walls (or to cover up old dents caused by the same) consider attaching a piece of pine at the level of the chair back. Easiest done using double sided tape, or two screw nails.

The fresh clean look of your newly painted booth is well worth the day it will take to do it.

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Educating Our Patients – And Ourselves about the New No-Mercury-Added Batteries

By Gary Friedman

About the Author

Gary Friedman , MS, F-AAA, is an audiologist with ENT Carolina in Shelby, NC. He is not employed or affiliated with any manufacturer or commercial enterprise. Readers can contact him at gary.friedman@entcarolina.com.

In late 2009, I learned that I belonged to a group of hearing health care professionals who had absolutely no idea that zinc-air batteries had approximately 1% mercury in them. I have been working in our industry since 1980, when battery packages read "mercury batteries." When zinc-air batteries became available, I mistakenly assumed they contained no mercury. But, since discovering my ignorance in this matter, I have begun to see advertisements in our professional journals for "mercury-free batteries."

That inspired me to take an online continuing education course from one of the battery manufacturers. I also made phone calls to hearing aid companies and battery manufacturers.

Now, with the goal of sharing some of my experiences with my colleagues so as to assist them in the transition to these batteries, I have prepared the following summary of what I've been doing with my patients in terms of batter education.

Preparing to Transition

Battery manufacturers have published literature stating that no mercury will be added to batteries after June 2011. That gives us nearly one more year to learn how these "mercury-free batteries" work in hearing aids. Actually, the term "mercury-free batteries' is a misnomer, as there are traces of mercury even in hearing aid batteries to which no mercury is added.

Phone conversations with representatives of both hearing aid and battery manufacturers revealed one serious question or problem: The mercury-free batteries may be causing the low-battery warning in hearing aids to be tripped far earlier than necessary.

Further conversations with representatives of both battery suppliers and hearing aid manufacturers revealed that size 10 batteries in high-end digital hearing instruments were the most likely to cause false low-battery warnings to occur.

A representative of one battery manufacturer

Reprinted with permission from *The Hearing Journal* 2010;63(7):31–32.

explained that the power levels used are different from those used with batteries containing mercury, and a voltage drop can cause a false warning. I was unable to get solid answers as to how often the warning might be tripped.

Naturally, I became concerned about potential complaints from hearing aid users. When I discovered that some local pharmacies were advertising mercury-free batteries, I knew it was time to provide patient education. Accordingly, I decided to speak with hearing aid wearers about this transition.

Initially, I chose a few patients to serve as sources of feedback on their new mercury-free batteries. But now I'm inviting all my hearing aid patients to contact me about their experience with these batteries.

From December 2009 through February 2010, the first 3 months in which I asked patients to report their experiences with the new batteries, I confessed to them that I had no idea that there was mercury in zinc-air batteries. For some reason, starting out with this admission of ignorance seemed to spur interest in my patients, perhaps because they like it when the "professional" admits to not knowing it all.

Then I laid out the discussion to come by telling them I would explain the changes and offer practical solutions. The first suggestion was for the hearing aid user not to toss dead zinc-air batteries into the garbage in order to keep them out of the landfills. Many of our patients are environmentally conscious.

The average time I spent on my batter counseling was 4 to 5 minutes per patient. I shared the following with them:

1. The manufacturers say the mercury-free batteries will have the same battery life as the older types.
2. The retail cost of mercury-free batteries should be only slightly more than what you have been paying for batteries with mercury.
3. Batteries with mercury will not be manufactured after June 2011.
4. The low-battery warning may falsely go off after only a day or two of use in a hearing aid.
5. We can consider removing the low-battery warning from hearing aids altogether, especially since many patients become aware that a battery is used up and needs replacing when the hearing aid stops working properly. However, patients with milder hearing losses may not always realize when their hearing aid has quit working and so may want to keep the low-battery warning.
6. Some hearing aids may issue a false early warning and others may not with the mercury-free batteries. In other words, we're all going to be on a learning curve for a while.

Dispensers and battery manufacturers alike are extremely interested in how patients perceive the performance of the mercury-free batteries. We all want feedback to improve the transition.

Patient Responses

Many of my patients asked to buy the mercury-free batteries to test them out. As a result, I've received numerous phone calls, but not one patient reported that the low-battery warning had come on mistakenly. That is encouraging. Maybe this is not really a problem.

But if it is a problem, it is one we will all need solved as soon as possible. It's not much of a stretch to anticipate irritated patients walking into our offices and expecting free packs of batteries because they threw out new ones after 2 days.

Almost every patient who replied seemed genuinely interested and appreciative of this educational experience in my office. Change is threatening to some of our patients, but I feel that encouraging them to share their battery experiences helps them feel less threatened and, in a sense, part of the "research team."

I think it is also important for us to share information with battery manufacturers and hearing aid companies as we learn more about this important shift in battery technology.

Musical Experience and the Aging Auditory System: Implications for Cognitive Abilities and Hearing Speech in Noise

By Alexandra Parbery-Clark, Dana L. Strait, Samira Anderson, Emily Hittner, and Nina Kraus

About the Authors

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Abstract

Much of our daily communication occurs in the presence of background noise, compromising our ability to hear. While understanding speech in noise is a challenge for everyone, it becomes increasingly difficult as we age. Although aging is generally accompanied by hearing loss, this perceptual decline cannot fully account for the difficulties experienced by older adults for hearing in noise. Decreased cognitive skills concurrent with reduced perceptual acuity are thought to contribute to the difficulty older adults experience understanding speech in noise. Given that musical experience positively impacts speech perception in noise in young adults (ages 18–30), we asked whether musical experience benefits an older cohort of musicians (ages 45–65), potentially offsetting the age-related decline in speech-in-noise

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perceptual abilities and associated cognitive function (i.e., working memory). Consistent with performance in young adults, older musicians demonstrated enhanced speech-in-noise perception relative to non-musicians along with greater auditory, but not visual, working memory capacity. By demonstrating that speech-in-noise perception and related cognitive function are enhanced in older musicians, our results imply that musical training may reduce the impact of age-related auditory decline.

Aging negatively affects the ability to understand speech in noise (SIN).[1–6] Although hearing loss can explain some of the SIN perception difficulties experienced with aging, SIN perception difficulties cannot be wholly accounted for by hearing thresholds.[7–8] Declines in auditory acuity,[9,10] temporal processing,[11] memory,[12] speed of information processing[13,14] and the ability to filter out irrelevant competing auditory input[15,16] also contribute to difficulties reported by older adults for hearing SIN. Listening to speech in noise requires an active interplay between cognitive (e.g., attention and memory) and perceptual processes that enable the nervous system to distinguish between a target voice and competing noise.[17–19] As listening conditions become harder (i.e., the background noise becomes louder), hearing becomes more effortful and increasingly dependent on the recruitment of attentional and working memory resources.[20–22] Therefore, individuals with heightened memory capabilities may be better able to overcome the deleterious effects of background noise on perception, aiding in the retention, rehearsal and recall of the target speech signal.

Another mechanism subserving SIN perception is the ability of the auditory system to separate rapidly occurring temporal events (i.e., temporal acuity).[23] One means of measuring auditory temporal acuity is with a backward masking paradigm in which perceptual thresholds are determined by how loud a tone needs to be for it to be perceived when directly followed by a competing signal (i.e., a masker). Backward masking not only relates to cognitive performance,[24,25] such as auditory working memory and attention,[26] but it is also negatively affected by aging[27,28] and may contribute to the noted poorer speech perception in older adults.[29,30] These age-related declines in temporal acuity and cognitive processes alongside the growth of the older population as a consequence of increasing life expectancy mean more people will experience communication difficulties, such as problems hearing in noisy environments. Reflective of the well established experience-dependent malleability of auditory function,[31,32] considerable effort has been expended for the development of training programs that aim to improve auditory and working memory functions in older adults as a means to reduce the negative auditory impact of aging (e.g., Listening and Communication Enhancement [LACE, Neurotone Inc., Redwood City, CA, USA) and Brain Fitness (Posit Science Corp., San Fransicso, CA]).

Musicians, who have experienced life-long musical training, demonstrate a perceptual advantage for understanding speech in noise[17,33] that is thought to be driven by auditory-related cognitive enhancements (e.g., verbal memory and auditory attention) and heightened auditory abilities. This musician advantage for speech-in-noise perception joins other work showing that musical training enhances the development of auditory skills[26,34–39] such as language, [40–43] These musician auditory perceptual advantages are supported by functional and structural changes seen both cortically and subcortically for the processing of sound[44–54] and specifically for processing speech in noise.[33]

Musicians are further noted to have enhancements for auditory-specific cognitive abilities, such as auditory working memory[17,26,55–58] and auditory attention,[26] which may reflect the necessary integration of auditory perceptual and cognitive skills for learning a musical instrument.

Thus far, this musician enhancement for speech-in-noise perception has only been evaluated in young adults.[17,33] Although these data imply that musical training has the potential to limit the age-related decline of SIN abilities, this cannot be determined without testing an older cohort of musicians. To define the impact of musical training on the perceptual and cognitive skills of adults in an older cohort, we assessed auditory perceptual and auditory and visual cognitive function in normal hearing musicians and non-musicians between the ages of 45–65. We hypothesized that, like young adults, older musicians demonstrate enhanced SIN perception and that this enhancement relates to greater auditory-specific cognitive and perceptual performance.

Methods

Subjects

Thirty-seven subjects between the ages of 45–65 were recruited from the Chicago area and gave their written informed consent according to principles set forth by Northwestern University's Institutional Review Board. We chose this transitional age group because it allowed control of audiometric hearing thresholds and cognitive factors. All subjects had normal hearing (octave frequencies from 0.125–4 kHz bilaterally #20 dB HL, pure tone average #10 dB HL), were native English speakers, and did not report neurological or learning disorders. All subjects had IQs.100 as measured by the two-subtest Abbreviated Wechsler's Adult Scale of Intelligence[59] To control for the increasing likelihood of cognitive decline with aging, all subjects 60 years or older were screened with the Montreal Cognitive Assessment Battery[60] and demonstrated normal cognitive function (score ≥26). All experimental protocols were reviewed and approved by Northwestern University's Institutional Review Board.

Eighteen subjects were classified as musicians, all of whom had begun musical training at or before age nine and had consistently played a musical instrument throughout their lives (see Table 1). To ensure that our musicians were still musically active, we required musicians to engage in musical activities such as practicing, teaching or performing a minimum of three times a week. Nineteen subjects were classified as non-musicians. Twelve of these non-musician subjects reported no musical experience; the other seven had fewer than three years of musical experience at any point in their lives. All subjects with some degree of musical experience rated their musical proficiency on their primary instrument on a scale from 1–10. Whereas all musicians rated themselves at an 8 or higher, the seven non-musicians with minimal musical experience rated themselves at 1.5 or lower. To ensure that any observed effects could not be accounted for by differences in physical activity levels, all subjects completed a physical activity questionnaire in which participants described the type and quantity of weekly physical activity. To account for varying types of physical activity, walking and biking were given half the reported hourly value, while running, weight training, and more vigorous activities were given a full reported hourly value. The total number of hours of physical activity per week was summed and participants were assigned a final score of 0 (less than 1 hour/week), 1 (1–2 hours/week), 2 (2–3 hours/week), 3 (3– 4 hours/week), or 4 (4+ hours per week). Groups were matched on physical activity levels ($F(1,36) = 1.482$, $p = .517$), age ($F(1,36) = 0.351$, $p = .557$) overall I.Q. ($F(1,36) = 2.79$, $p = .204$; see results below). There were no significant group differences in hearing sensitivity for all frequencies measured (0.125–12.5

kHz, F(1,12)= 0.610, p = .848). See Table 2 for group means.

Speech Perception in Noise

HINT The Hearing in Noise Test (HINT, Bio-logic Systems Corp; Mundelein, IL)[61] is an adaptive test of speech recognition that measures speech perception ability in noise. During this test, participants repeated short and semantically and syntactically simple sentences (e.g., she stood near the window) presented in speech shaped background noise. Speech stimuli consist of Bamford- Kowal-Bench[62] sentences (12 lists of 20 sentences) spoken by a male and presented in free field. Participants sat one meter from the loudspeaker from which the target sentences and the noise originated at a 0 degree azimuth. The noise presentation level was fixed at 65 dB SPL and the program adjusted perceptual difficulty by increasing or decreasing the intensity level of the target sentences until the threshold signal-to-noise ratio (SNR) was determined. Perceptual SIN thresholds were defined as the level difference (in dB) between the speech and the noise presentation levels at which 50% of sentences are correctly repeated. A lower SNR indicates better performance.

QuickSIN. The Quick Speech-in-Noise Test (QuickSIN, Etymotic Research; Elk Grove, IL)[63] is a non-adaptive test of speech perception in which speech is presented binaurally in fourtalker babble noise (three females and one male) through insert earphones (ER-2, Etymotic Research, Elk Grove Village, IL). Four lists of sentences were administered, with each list consisting of six sentences. Sentences were presented at 70 dB SPL, with the first sentence starting at a SNR of 25 dB and each subsequent sentence presented with a 5 dB SNR reduction down to 0 dB SNR. The sentences are syntactically correct yet do not contain many semantic or contextual cues.[64] Participants were asked to repeat each sentence and their SNR loss was based on the number of target words correctly recalled. Sample sentences, with target words underlined, include, "The *square peg* will *settle* in the *round hole*." and "The *sense* of *smell* is *better than* that of *touch*." The total number of key words correctly recalled in the list (30 in

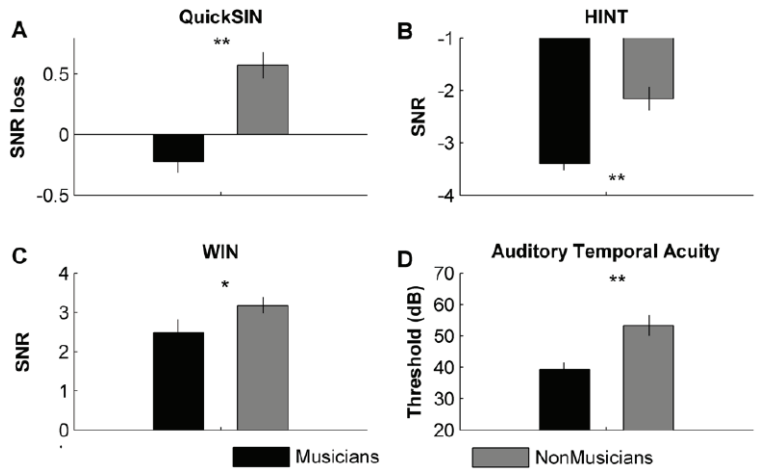

Figure 1. Performance for musicians and non-musicians on speech-in-noise and backward masking tasks. Musicians demonstrated enhanced performance for all three measures of speech-in-noise perception (QuickSIN, HINT and WIN), indicating that they were better able to hear in more challenging signal-to-noise ratios (SNRs). Musicians performed better (i.e.,had lower thresholds) on the auditory temporalacuity test as assessed by backward masking. Error bars represent one standard error.
*p, 0.05**p 0.01. doi:10.1371/journal.pone.0018082.g001

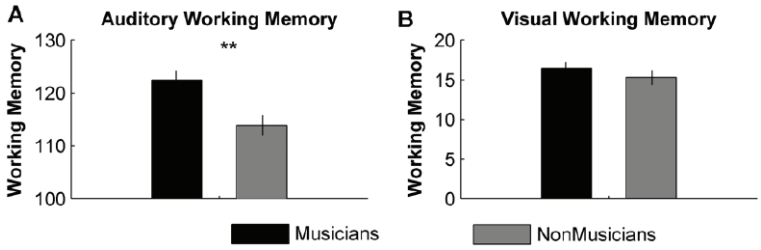

Figure 2. Performance fo rmusicians and non-musicians on working memory tasks. Musicians demonstrated significantly better auditory working memory than non-musicians, but no enhancement for visual working memory. Error bars represent one standard error. **p, 0.01. doi:10.1371/journal.pone.0018082.g002

total) is subtracted from 25.5 to give the final SNR loss [see Killion et al. 2004 and the QuickSIN User's Manual (Etymotic Research 2001) for further details]. The final score is the average SNR loss scores across the four lists. A lower SNR loss value is indicative of better performance.

WIN. The Words in Noise Test (WIN)65 is a non-adaptive test of speech perception in four-talker babble noise (three females and one male), presented binaurally to participants through Etymotic ER-2 insert earphones.65 Participants were asked to repeat the words they heard after the carrier phrase, "Say the word _____". Thirty-five words were presented with a starting dB SNR of 24, decreasing in 4 dB steps until 0 dB; five words are presented at each SNR level. The final SNR score was based on the number of correctly repeated words. A lower score indicates better performance.

Working Memory

Auditory. The Woodcock-Johnson III Test of Cognitive Abilities66 subtests for auditory working memory (AWM) and memory for numbers reversed (NR) were used to assess working memory, both of which required participants to store and reorder aurally-presented information. For AWM, participants reordered a dictated series of digits and nouns by first repeating the nouns in sequential order and then repeating the digits in sequential order (e.g., the correct ordering of the following sequence, "4, salt, fox, 7, stove, 2, 9, boot" is "*salt, fox, stove, boot*" and "*4, 7, 2, 9*"). For NR, participants repeated a sequence of numbers in reverse order. The most difficult item contained eight digits (e.g., "9, 6, 1, 3, 7, 4, 5, 2" which in reverse would be "*2, 5, 4, 7, 3, 1, 6, 9*"). A working memory cluster score was computed based on scores from the AWM and NR subtests. Age-normed standard scores were used for all statistical analyses. A higher score indicates better performance.

Visual. The Colorado Assessment Test's Visual Working Memory subtest (VWM)[67] is an adaptive test for which participants are instructed to monitor a screen containing eight blue boxes that change color one at a time. The first trial begins with two boxes sequentially changing color. Participants were asked to click on the boxes in the order they changed color. The number of boxes changing color increases with successive correct replies. Participants completed both forward and reversed conditions. The final VWM score was an average of the participant's performance on both forward and reversed conditions. A higher score indicates better performance.

Auditory Temporal Acuity: Backward Masking

The backward masking subtest from the IHR Multi-centre Battery for Auditory Processing was employed to assess backward masking acuity (Medical Research Council Institute of Hearing Research, Nottingham, UK).[68] The subtest employed a three-alternative forced choice paradigm in the form of an animated computer game. Three characters opened their mouths to "speak" masking noise sounds (band-pass noise with a center frequency of 100 Hz, a width of 800 Hz and duration of 300 ms). A 90 dB target tone was presented before one of the three noise sounds, with the tone offset coinciding with the noise's onset. The target tone was equally distributed between the three characters. Participants indicated which character was the "odd-one-out" (i.e., which character presented the target tone prior to the masker, rather than the masker alone) by pressing the corresponding button on a response box. The target tone presentation level was then increased or decreased depending on the participant's performance (correct responses —> decrease in dB; incorrect responses —> increase in dB). An adaptive staircase method was employed (3 down, 1 up), yielding a minimum detectable threshold level in dB (see Amitay et al, 2006[69] for further description). A lower threshold indicates better task performance (i.e., the target tone is perceived at quiet levels).

Table 1. Musicians' instrumental histories.

	Years of musical experience	Age onset, yrs	Instrument
Musicians			
1	54	4	Piano/cello
2	50	6	Clarinet
3	49	8	Piano/French horn
4	50	7	Piano/French horn
5	54	6	Piano/Trombone
6	45	5	Piano/Violin
7	49	6	Piano
8	54	6	Piano
9	57	5	Piano
10	59	3	Piano
11	45	6	Piano
12	50	6	Piano
13	49	4	Piano
14	47	6	Piano
15	47	7	Piano
16	43	6	Violin
17	55	6	Violin
18	42	5	Oboe
Mean	50	5.6	

Years of musical experience, age at which musical training began and major instruments played are indicated for all musician participants.
doi:10.1371/journal.pone.0018082.t001

Table 2. Group characteristics.

	WASI (Standard Score)	PTA (.5–4 kHz) dB HL	Age
Musicians Mean (SD)	125 (6.57)	8.26 (2.84)	55 (4.24)
NonMusicians Mean (SD)	122 (6.32)	9.66 (3.32)	54 (6.02)

Group means (standard deviations) for IQ measures (WASI), hearing thresholds (pure tone average (PTA) of the hearing thresholds at 500, 1000, 2000, 4000Hz) and age.
doi:10.1371/journal.pone.0018082.t002

Data Analysis

Data were analyzed using a multivariate analysis of variance (MANOVA). All results reflect two-tailed values. Normality for all data was confirmed by the Komogorov Smirnov test for equality. Relationships between SIN perception, cognitive function and auditory acuity were explored with Pearson's correlation analyses. Statistical analyses were conducted with SPSS (SPSS Inc., Chicago, IL).

Results

Musicians demonstrated greater proficiency on perceptual and auditory-based cognitive measures than non-musicians. Specifically, musicians had enhanced speech-in-noise perception, auditory working memory and auditory temporal acuity (lower backward masking thresholds), compared to non-musicians.

Musicians demonstrated lower thresholds than non-musicians for all three speech-in-noise tests (Fig. 1; HINT: $F(1, 36) = 22.49$, $p<.005$); QuickSIN: $F(1, 36) = 33.11$, $p<.005$); WIN: $F(1,36) = 4.709$, $p = .04$), better performance on auditory working memory composite (AWM: $F(1, 36) = 16.34$, $p<.005$) and higher auditory temporal acuity (i.e., lower backward masking thresholds) (Figure 1; ($F(1,36) = 13.47$, $p = 0.001$). Visual working memory (VWM) scores did not differ between the groups (Figure 2; $F(1,36) = 1.148$, $p = .291$; see Table 3 for group means and standard deviations).

Table 3. Group behavioural performance.

	HINT SNR	QuickSIN SNR loss	WIN SNR	BM (dB)	AWM	VWM
Musicians	- 3.37 (0.52)	- 0.22 (0.39)	2.48 (1.37)	39.35 (9.23)	124 (9.19)	16.38 (3.18)
NonMusicians	- 2.24 (0.87)	0.51 (0.38)	3.3 (0.85)	53 (13.28)	110 (11.18)	15.21 (3.48)
group comparison p - value	< 0.005	< 0 .005	< 0.04	< 0.001	< 0.005	> 0.2

Group means (standard deviations) for the speech-in-noise tests (HINT, Quick SIN and WIN), backward masking (BM), auditory working memory, (AWM) and visual working memory (VWM). For all auditory tests musicians outperformed the non-musicians (backward masking and auditory working memory), however, group performance was equivalent for the visual working memory.
doi:10.1371/journal.pone.0018082.t003

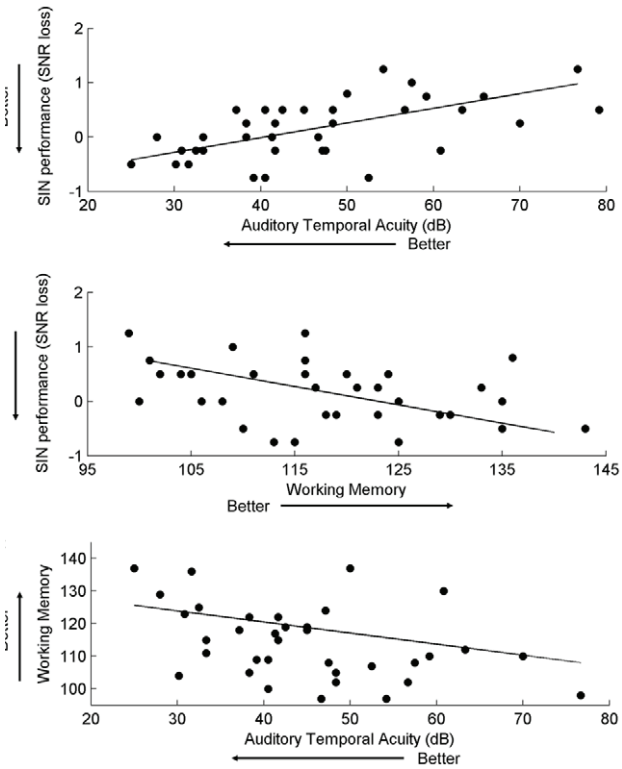

Figure 3. Correlations between measures of speech-in-noise perception, working memory and auditory temporal acuity. Better performance on Quick SIN (more negative) was correlated with lower (better) auditory temporal acuity asassessed by backward masking thresholds (top: *r*=0.573, *p*, 0.005) and higher working memory ability (middle:*r*= 2 0.402, p=0.014). Working memory and backward masking thresholds were also correlated (bottom: *r*=2 0.495, *p*=0.002). doi:10.1371/journal.pone.0018082.g003

Auditory working memory ability correlated with SIN perception, with better AWM performance relating to better performance on QuickSIN (*r* =20.402, *p* = .014) and HINT (r =20.351, *p* = .033) but not WIN (*r* =20.169, p = .316). Backward masking per-formance correlated with all SIN tests, Musical Experience and the Aging with lower (better) backward masking thresholds corresponding to the ability to understand speech in noise at lower SNRs (QuickSIN: *r* = 0.573, *p*<.005; HINT: *r* = 0.411, *p* = .012; WIN: *r* = .372, *p* = .023). A relationship between backward masking thresholds and auditory working memory was also observed (Figure 3; *r* =20.495, *p* = .002). To ensure that the observed correlations between auditory working memory and SIN performance (QuickSIN and HINT) were not an artifact of musicians' enhanced auditory working memory, we defined the relationships between these variables for the musician and nonmusician group through separate analyses. Within-group correlations were absent for these measures, indicating that the relationships between auditory working memory and SIN performance are present only when the two groups are combined. This suggests that these cognitive-perceptual relationships are not driven by the musician group's enhanced auditory working memory.

Speech in noise performance as measured by the QuickSIN related with speech in noise performance as measured by the HINT (*r* = 0.510, *p* = 0.001) and the WIN (*r* = 0.329, *p* = 0.047). No significant relationship, however, was observed between HINT and WIN performance (*r* = 0.199, *p* = 0.236), suggesting that performance on these two tests may rely on different mechanisms. With regards to IQ, no group differences were found for overall IQ (F(1,36) = 2.79, p = 0.204) or for the Matrix Reasoning subtest (WASImr: F(1,36) = 6.979, *p* = 0.271). Musicians did, however, demonstrate higher performance on the Vocabulary subtest (WASIv: F(1,36) = 6.979, *p* = 0.012). Still, the reported musician advantages for SIN perception, auditory working memory and temporal resolution were not driven by WASIv performance (see Results S1 and Table S2 for further details).

Assessing Relationships between Years of Musical Experience, Age of Onset and Perceptual and Cognitive Performance

To investigate the relationships between musical experience and the perceptual (SIN perception, temporal resolution) and cognitive measures (working memory and WASI), correlational analyses were employed. Within the musician group only, age of onset of musical training did not relate to the

perceptual or cognitive measures (see Table 4). However, we only have a limited range of data points (6 years) for this inclusionary measure, as musicians were required to have started musical training before the age of 8. Therefore, the lack of correlation between age of musical training onset and the perceptual and cognitive skills likely speaks to the restricted range of age of onset rather than being a true indicator of a lack of relationship between these variables. Similarly, years of musical experience did not relate to the perceptual or cognitive measures (see Table 5). However, it is important to critically evaluate the nature of these variables before concluding that no relationship exists between them. Perceptual and cognitive skills do not improve monotonically over the lifespan; in fact, these skills are negatively affected by age,1–6,27,28 and the older adults tested here are likely to be affected by age-related decline. Accordingly, we did not predict significant correlations between the linear increase in years of musical experience and these nonlinear perceptual and cognitive measures. In summary, while correlational analysis has proven useful for quantifying the extent of musical practice in children and young adults, its application to this older population is inherently misleading.

Discussion

We herein demonstrate enhanced speech-in-noise perception for older adult musicians between the ages of 45–65 which correlates with auditory cognitive and perceptual performance. As with young adult musicians, older adult musicians demonstrate increased auditory working memory capacity and increased auditory temporal acuity (asmeasured by backwardmasking), whichmay undergird the perception of speech in noise. As such, our results indicate that musical training may serve as a means to offset the effects of agerelated communication disorders by improving hearing in noise – an everyday listening skill – through the enhancement of auditoryrelated perceptual and cognitive functions.

Auditory Working Memory Contributes to Speech-In-Noise Perception

Auditory working memory is an important component of language comprehension, even in the absence of background noise.[70–72] The addition of background noise reduces one's auditory working memory capacity,[73,74] resulting in the decreased ability to rehearse and recall a target speaker's utterance,[22] further compromising the perception of a speech signal already degraded by noise. We recently demonstrated improved auditory working memory capacity and SIN perception in young adult musicians as well as a link between performance on both tasks, 17 adding to a growing body of research indicating the importance of auditory-related cognitive abilities for SIN perception.[21] In the present study, older musicians also demonstrate enhanced auditory working memory and SIN perception. This suggests that lifelong musical training may confer advantages for an older population in two everyday human functions that are known to decline with age.

A number of studies have evidenced a musician enhancement for auditory working and verbal memory.[17,55,56,58,75,76] While some research has reported musician enhancements for only auditory and not visual working memory,[55,58] others have found enhancements for both auditory and visual memory.[57] Further complicating matters, it appears that musical training may have distinct effects on working memory abilities at different stages of development, with musically trained children demonstrating superior verbal and non-verbal working memory but musically trained adults demonstrating only superior verbal working memory.[77] While there has been some debate over this work (i.e., musician groups having higher IQ, see Schellenberg and Peretz 2007, Schellenberg, 2006; 2008; 2009 for a review[78–81]), neural evidence suggests that musicians employ different brain

Table 4. Relationship between age of onset and years of practice with perceptual and cognitive measures (musicians only).

Musicians Only		WASI	Auditory Working Memory	Visual Working Memory	QuickSIN	WIN	HINT	Temporal Resolution
Age of Onset	rho	- 0.267	- 0.007	0.271	0.091	- 0.194	0.124	0.090
	p value	0.284	0.979	0.277	0.719	0.440	0.624	0.723

Correlations between age of onset and the cognitive and perceptual measures for the musician group only. No significant relationships were found between age of onset and the secognitive and perceptual measures. In this study, age of onset was an inclusionary measure (musicians were required to have started musical training before the age of 8 years) resulting in a restricted range of data points (6 years). Therefore, the lack of correlation between age of onset and the perceptual and cognitive skills likely speaks to the limited range of age of onset rather than being a true indicator of a lack of relationship between these variables.
doi:10.1371/journal.pone.0018082.t004

Table 5. Relationship between years of practice with perceptual and cognitive measures (musicians only).

Musicians Only		WASI	Auditory Working Memory	Visual Working Memory	QuickSIN	WIN	HINT	Temporal Resolution
Years of experience	rho	- 0.047	- 0.139	- 0.093	0.322	- 0.211	- 0.086	- 0.033
	p value	0.853	0.581	0.715	0.193	0.379	0.735	0.101

Correlations between years of musical experience and the cognitive and perceptual measures for the musician group only. No significant relationships were found between years of musical experience and these cognitive and perceptual measures. However, perceptual and cognitive skills do not improve monotonically over the lifespan, rather they are negatively affected by age. The absence of a significant relationship is not surprising given the linear nature of years of musical experience and these nonlinear perceptual and cognitive measures.
doi:10.1371/journal.pone.0018082.t005

structures for auditory memory tasks, thus providing a neural correlate of improved memory in musicians.[82–84] Here we demonstrate that older musicians have greater auditory working memory capacity, which may contribute to their improved SIN perception. Additionally, our results indicate a musician enhancement for auditory, but not visual, working memory, supporting the notion that life-long musical training refines skills most relevant to musical processing, namely auditory skills, rather than improving memory in a domain-general fashion.

Auditory Temporal Acuity Relates to Speech-In-Noise Perception

Auditory temporal acuity, as measured by backward masking performance, has been linked to speech perception abilities[30] and its decline with age, even in normal hearing older adults,[27,28] is thought to contribute to the commonly reported speech perception difficulties in this population. Consistent with results reported in young adults, the present data indicate that long-term musical experience shapes speechin- noise perception[17] and auditory temporal acuity, as assessed by backward masking perception.[26] Although the brain mechanisms underlying these perceptual enhancements remain undetermined, there is growing evidence that musical training hones auditory perception through the neural tuning of auditory pathway mechanisms (reviewed in Kraus and Chandrasekaran, 2010[43]). Auditory perceptual learning is thought to be driven in a top-down manner, with cortical functions refining neural encoding at earlier stages in the processing stream, leading to increased perceptual performance.[85–88] The refinement of lower level auditory structures via top-down control is thought to lead to the neural encoding of signals at higher internal SNRs, which in turn contribute to heightened auditory perception through a more efficient auditory system.[26,43,89,90] As such, this top-down mechanism provides a possible explanation for the musicians' improved performance on backward masking tasks

and SIN perception. In light of increasing problems with auditory processing experienced by older adults,[91,92] our results indicate that lifelong musical training might limit the degradative effects of aging.

Conclusion and Future Directions

The demographic shift towards an increasingly older population is accompanied by an increase in the prevalence of perceptual and cognitive disorders. One means of offsetting or slowing down age-related declines may be through engaging in mentally stimulating activities,[93] such as musical practice.[94] While research into the impact of musical training on aging processes is a new avenue of investigation, our results indicate a positive role of lifelong musical training on auditory perception and cognitive processes. It is also possible that musical training during developmental years enhances working memory, temporal resolution and SIN and that these effects are carried forward throughout the lifespan. Additional research might tease apart these two possibilities by comparing cognitive and perceptual performance in older adults who ceased musical training at different developmental stages with those who have engaged in musical activities throughout their lives. Regardless of the outcome, the results presented here indicate that older adults with extensive musical backgrounds are better equipped to deal with the auditory perceptual demands of real-world situations. Although more work is needed to determine the efficacy of using music as a management strategy for perceptual and cognitive declines, these results underscore the potential remediatory benefits of musical training for an aging population.

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