Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Deniz Başkent

Affiliation   University of Groningen, University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Session Description Music is found in every human culture. Performing involves fine-grained motor, cognitive, multimodal-integration, and aesthetic skills; listening critically involves almost as many. Perhaps most importantly, music is fun. The enjoyable and social aspects of music could make it a powerful and motivating vehicle for auditory training, particularly in a clinical setting among those with hearing loss and cochlear implants. But does musical training improve skills beyond music, such as speech perception in noise and more general cognitive abilities? Can musical training protect against some aging effects in these domains? Many studies have addressed these questions in recent years without reaching a common consensus. The purpose of this symposium is to bring together researchers who have been actively contributing to this debate, to assess current evidence and opinions, to seek common ground, and to chart a way forward to answer these important questions. The session will bring researchers bridging basic and clinical sciences from the fields of auditory and speech perception and neuroscience, musical training, hearing aids and cochlear implants, to explore together the potentials and limitations of effects of musical training throughout the lifespan. To our knowledge, ARO has not hosted such a session in recent years.

Presenter Diversity The proposed list of speakers is highly diverse in terms of gender, geographical location, ethnic/racial background, and academic career stage.

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Signature DB

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Musical Training and Hearing-In-Noise Perception

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Emily Coffey

Affiliation   Concordia University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract   Musical training is a powerful and well-studied model of human neuroplasticity, which harnesses emotional and reward networks and auditory-motor feedback loops to sharpen and reinforce practised skills. It is thought to improve the quality of basic auditory encoding and higher-level functions such as selective attention and working memory. Both sound encoding quality and higher-level functions are important for perceptual skills outside of a musical context, such as speech-in-noise perception, which strongly influences health and well-being. Musical training is an attractive avenue for potentially enhancing poor or degraded perceptual skills; however, the specific nature of musical training benefits, particularly for speech-in-noise perception, is not yet clear. I will present our lab's recent work using electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) to explore the relationship between musicianship, perceptual skills, and neurophysiology. I will also discuss the design of musical tasks for encouraging neuroplasticity, and present some of the Open Science tools we have developed to facilitate and encourage research progress in these areas.

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* Presenting Author

First Name	Last Name	Affiliation
Emily *	Coffey *	Concordia University

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Signature Emily Coffey

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Neural Correlates of Auditory Processing in Individuals Engaged in Music Training – a Perspective across the Lifespan

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Assal Habibi

Affiliation   Univeristy of Southern California

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Playing a musical instrument is a complex multisensory experience requiring several skills including reading and translating abstract musical notation to fine and coordinated motor movements in order to produce a sound. The mastering of this rich and demanding process requires regular and intense practice, often from a young age. While there is a growing body of evidence suggesting that music training benefits cognitive development, the associations between music training and health outcomes specifically in relation to improvement of auditory and language skills is not clear. This presentation will highlight a series of research studies on the role of music training and associated health outcomes across the lifespan. The results from the first two studies provide evidence that music training in children and adolescents leads to improvement of pitch and rhythm perception, speech in noise perception and neuroplastic functional changes in the associated auditory regions that may have long-term positive effects on language development and competency. Results from the third study provide evidence that participating in short-term musical activities leads to better speech in noise perception in older adults without prior music training – and adding to the accumulating evidence that engaging in enrichment activities, such as choir singing provide a cost-effective and sustainable community-based intervention to improve auditory and communication abilities in aging adults. These findings together demonstrate that brain-to-behavior changes induced by music training can positive health and well-being outcomes specifically in relation to auditory abilities, language, and communication skills in individuals across the lifespan.

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First Name	Last Name	Affiliation
Assal *	Habibi *	Univeristy of Southern California

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Signature Assal Habibi

* Presenting Author

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

What Benefits Can We Derive from Music Training for Cochlear-Implanted individuals?

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Eleanor Harding

Affiliation   University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Cochlear implant users report difficulties perceiving music and certain aspects of speech, such as vocal cues and emotions, and 'cocktail-party' speech in multi-talker noise. While evidence exists supporting music as a training tool to improve music and speech perception, results are not unanimous across studies and the precise mechanisms that may contribute to both near- (music domain) and far- (speech domain) transfer training effects are not well understood. Previous research, including from our group, has indicated that musically trained individuals show advantages in perceptual tasks that involve music and pitch. We have also observed beneficial effects for perception of speech in the presence of a speech masker, but not for other maskers (such as steady noise), and also not in all populations (adults vs. adolescents). In some situations, such as perception of voice gender, we have observed musician and non-musician groups weighting voice cues differently than each other, but with no clear benefit from being a musician. Taken together, this evidence suggests that musical training may be a beneficial tool for improving these areas of auditory perception in cochlear implant users. However, perhaps the overall picture is more complex than we can easily characterize: the influence of musical training on psychoacoustic tasks varies across the literature, moreover, musical training is reported to variably affect cognitive processes such as auditory working memory and neural tracking of the acoustic envelope of music and speech. These cognitive processes may influence performance on certain tasks, such as speech-on-speech perception, via top-down processes. In this talk, we will cover our previous and current work with musicians, on potential musician and music training effects and their mechanistic origins, and how we try to utilize this knowledge in developing new ways of using music as an auditory training tool.

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First Name	Last Name	Affiliation
Eleanor *	Harding *	University Medical Center Groningen
Deniz	Başkent	University of Groningen, University Medical Center Groningen

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Signature Eleanor Harding

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Music Training and Nonmusical abilities: The Role of Natural Musical Ability

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   E. Glenn Schellenberg

Affiliation   University of Toronto Mississauga

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Music training is associated with many nonmusical abilities, including those involving listening to speech or other auditory stimuli, as well as general cognitive ability. Individuals with training often show an advantage on tasks that measure these skills, and such advantages are assumed to be a consequence of music training. In fact, music training is often claimed to be a good (even ideal) model for the study of changes in brain and behavior that occur as the result of experience (i.e., plasticity). In recent years, however, research from my laboratory raises doubts about these claims. We have documented that individuals with music training differ systematically from other individuals in terms of demographics, personality, cognition, and natural musical ability (aptitude or talent), which are unlikely to be the consequence of any intervention or experiential factor. Moreover, evidence from twin studies points to a genetic component to musicality and music achievement, which raises further doubts about the proposed causal effect of music training, as do findings showing that transfer effects are rare. Rather, individuals from high-SES families who also have good cognitive abilities, high levels of the personality trait called openness-to-experience, and a facility for music are more likely than other individuals to take music lessons, particularly for years on end. Results in line with this view show that: (1) speech perception and grammatical ability have a stronger association with musical ability than with music training, (2) the association between music training and reading ability disappears when general cognitive ability is held constant, (3) the link between music training and cognitive ability disappears when musical ability is held constant, and (4) non-musical variables that predict music training also predict musical ability. In a five-year longitudinal study, musical ability at 8 years of age predicted the amount of music training taken subsequently. By contrast, at 13 years of age, links between music training and musical ability disappeared when musical ability at age 8 was held constant. These results, as well as those from independent laboratories, ensure that music training is a particularly poor model for the study of plasticity.

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First Name	Last Name	Affiliation
E. Glenn *	Schellenberg *	University of Toronto Mississauga

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Signature E. Glenn Schellenberg

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

To understand the benefits of musical training on speech perception we need to focus on the assessment of musical skills and the initiation of adequately powered intervention studies

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Frank Russo

Affiliation   Toronto Metropolitan University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract The evidence for the benefits of music training on speech processing and perception have been difficult to pin down. While correlation and cross-sectional studies abound, the evidence has been mixed and enthusiasm about positive findings are clouded by legitimate questions regarding confounding variables. The mixed evidence is not exactly surprising. The types of musical skills that a musician will possess as there is no accepted canon for musical training (e.g., learning percussion vs. violin; playing by ear or notation), and individuals will come to training with varying predispositions. Thus, I will argue that it is generally not satisfactory to simply count the number of years of musical training or to create a binary split between musicians and non-musicians when accounting for effects of music training. Correlational studies would be better served by modelling speech perception skills on the basis of specific musical skills that are assessed through experiment. The studies that have initiated a musical training intervention are more informative as they control the manor of training across participants and are able to take individual baselines into account. However, these studies have by-and-large been hindered by small and heterogenous samples. Moreover, the control conditions are often passive, leaving open the possibility that benefits accrue simply from adding a new activity or even worse, demand characteristics. In my own lab, we have completed three studies involving music training interventions, all in participants with some level of hearing loss. None of these studies is perfect and all suffer from relatively small sample sizes. Nevertheless, we have observed some positive outcomes. Our study on children who use cochlear implants showed benefits on perception of speech emotion. Our study on older adults with hearing loss showed benefits on speech perception in noise. Our study on older adults with hearing loss who use hearing aids, showed no benefits for speech perception in noise or emotion. However, in examining the baseline data we did observe

correlations between musical skills (e.g., rhythm perception) and speech perception in noise. My current view is that musical training may benefit speech processing and perception but the effects are highly variable. Future correlational studies should assess musical skills and speech perception in large cohorts of participants. In addition, multi-site training intervention studies should be undertaken allowing for larger sample sizes and the multi-level modelling of group- and individual-level predictors.

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First Name	Last Name	Affiliation
Frank *	Russo *	Toronto Metropolitan University

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Signature FAR

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Effects of Singing and Musical Training to Speech Perception and Language Skills of Children with Hearing Impairments

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Ritva Torppa

Affiliation   Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract There is growing body of evidence from follow-up studies and randomized controlled trials on the positive effects of musical training to perception of pitch, music and speech, to cognitive and language skills, and to associated brain networks in adults and children with normal hearing (NH). Musical training is expected to lead to similar effects for children with hearing impairments (HI) since they enjoy music and singing similarly to children with NH.
Even though the field of HI is still lacking large-scale randomized controlled trials, the current evidence shows that musical training and even informal singing at home can lead to similar positive effects in children with HI as found in children with NH. For instance, a longitudinal study showed that the attention-related P3a brain responses to changes in pitch and timbre were larger and developed more in children with CIs who sang regularly at home than in their peers with CIs who did not sing. In another study, the children with CIs who participated in musical hobbies were better in perception of pitch and prosodic stress and in expressive language skills (word finding, verbal IQ and phonological awareness measured with rhyming) compared to musically non-active children with CIs. Moreover, a longitudinal study showed that perception of speech in noise, timbre, question/statement prosody and spectral resolution improved only in the children with HI participating in musical training while not in the passive control group. The preliminary results from our new cross-over design study imply that musical intervention, which focused on singing, improved expressive language skills (e.g., semantic word fluency) of 2-6 years old children with HI. Regarding to pitch perception, the development during intervention varied in a sample of 3-6 years old children with HI, some of them showing clear development.

This presentation will show why music can improve speech and music processing and perception as

well as language skills of children with HI. The current evidence suggests that it would be beneficial for children with HI to sing at home and take part in musical hobbies and training.

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Ritva *	Torppa *	Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland
Lotta	Seppänen	Psychology and Logopedics, Cognitive Brain Research Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland
Seija	Pekkala	Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland
Valerie	Looi	The University of QLD, Australia

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Signature Ritva Torppa

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Association of Musical Training with Auditory and Speech Neural Coding and Perception

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Kelly Whiteford

Affiliation   University of Minnesota

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Numerous studies have reported a link between engagement in musical training and enhanced neural processing and perception of sound, ranging from fine-grained pitch discrimination to the perception of speech in noise, with training-related neural changes emerging as early in the auditory pathways as the brainstem or even the cochlea. Such findings suggest a role for experience-dependent plasticity in the early auditory system, which may have meaningful perceptual consequences. However, the generalizability of the musician advantage remains unclear. For example, small-sized samples often represent extreme ends of the musical spectrum; the nature and magnitudes of the musician advantage are sometimes small or inconsistent; and methodological differences and varying analytical techniques complicate comparisons between studies. This multi-site study aims to examine the robustness of the musician advantage across the adult lifespan by replicating and extending eight key experiments involving both perception and neural coding across a large sample of listeners (n > 300) at six universities in the US and Canada (Boston University, Carnegie Mellon University, Purdue University, University of Minnesota, University of Rochester, and University of Western Ontario). All participants were tested on all 8 experiments in a laboratory setting, including pitch discrimination, behavioral estimates of frequency tuning, speech and non-speech informational masking, speech perception in noise and babble, and two physiological measures of F0 encoding of speech sounds using electroencephalography. Data collection is ongoing, but so far data from over 200 participants have been collected. Participants also completed additional measures to control for potential confounding factors, including an objective measure of musical aptitude (melody discrimination from the Mini Profile of Music Perception Skills), a cognitive assessment (Ravens Advanced Progressive Matrices), a measure of extended high-frequency hearing, and survey questions related to personality and socio-economic status. Formal statistical analyses were preregistered on the

Open Science Framework and will be conducted once data collection is complete. The results will provide in-depth and high-powered insight on the nature and robustness of the musician advantage across the adult lifespan. [Supported by NSF-BCS grant 1840818.]

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First Name	Last Name	Affiliation
Kelly *	Whiteford *	University of Minnesota
Hari	Bharadwaj	Purdue University
Ingrid	Johnsrude	University of Western Ontario
Gerald	Kidd Jr.	Boston University
Anne	Luebke	University of Rochester
Ross	Maddox	University of Rochester
Elizabeth	Marvin	University of Rochester
Tyler	Perrachione	Boston University
Barbara	Shinn-Cunningham	Carnegie Mellon University
Andrew J.	Oxenham	University of Minnesota

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Signature Kelly Whiteford

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Deniz Başkent

Affiliation   University of Groningen, University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Session Description Music is found in every human culture. Performing involves fine-grained motor, cognitive, multimodal-integration, and aesthetic skills; listening critically involves almost as many. Perhaps most importantly, music is fun. The enjoyable and social aspects of music could make it a powerful and motivating vehicle for auditory training, particularly in a clinical setting among those with hearing loss and cochlear implants. But does musical training improve skills beyond music, such as speech perception in noise and more general cognitive abilities? Can musical training protect against some aging effects in these domains? Many studies have addressed these questions in recent years without reaching a common consensus. The purpose of this symposium is to bring together researchers who have been actively contributing to this debate, to assess current evidence and opinions, to seek common ground, and to chart a way forward to answer these important questions. The session will bring researchers bridging basic and clinical sciences from the fields of auditory and speech perception and neuroscience, musical training, hearing aids and cochlear implants, to explore together the potentials and limitations of effects of musical training throughout the lifespan. To our knowledge, ARO has not hosted such a session in recent years.

Presenter Diversity The proposed list of speakers is highly diverse in terms of gender, geographical location, ethnic/racial background, and academic career stage.

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Signature DB

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Musical Training and Hearing-In-Noise Perception

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Emily Coffey

Affiliation   Concordia University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Musical training is a powerful and well-studied model of human neuroplasticity, which harnesses emotional and reward networks and auditory-motor feedback loops to sharpen and reinforce practised skills. It is thought to improve the quality of basic auditory encoding and higher-level functions such as selective attention and working memory. Both sound encoding quality and higher-level functions are important for perceptual skills outside of a musical context, such as speech-in-noise perception, which strongly influences health and well-being. Musical training is an attractive avenue for potentially enhancing poor or degraded perceptual skills; however, the specific nature of musical training benefits, particularly for speech-in-noise perception, is not yet clear. I will present our lab's recent work using electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) to explore the relationship between musicianship, perceptual skills, and neurophysiology. I will also discuss the design of musical tasks for encouraging neuroplasticity, and present some of the Open Science tools we have developed to facilitate and encourage research progress in these areas.

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First Name	Last Name	Affiliation
Emily *	Coffey *	Concordia University

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Signature Emily Coffey

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Neural Correlates of Auditory Processing in Individuals Engaged in Music Training – a Perspective across the Lifespan

Submission ID 3003162

Submission Type Symposia

Topic Speech Perception

Status Submitted

Submitter Assal Habibi

Affiliation Univeristy of Southern California

Participant(s) Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Playing a musical instrument is a complex multisensory experience requiring several skills including reading and translating abstract musical notation to fine and coordinated motor movements in order to produce a sound. The mastering of this rich and demanding process requires regular and intense practice, often from a young age. While there is a growing body of evidence suggesting that music training benefits cognitive development, the associations between music training and health outcomes specifically in relation to improvement of auditory and language skills is not clear. This presentation will highlight a series of research studies on the role of music training and associated health outcomes across the lifespan. The results from the first two studies provide evidence that music training in children and adolescents leads to improvement of pitch and rhythm perception, speech in noise perception and neuroplastic functional changes in the associated auditory regions that may have long-term positive effects on language development and competency. Results from the third study provide evidence that participating in short-term musical activities leads to better speech in noise perception in older adults without prior music training – and adding to the accumulating evidence that engaging in enrichment activities, such as choir singing provide a cost-effective and sustainable community-based intervention to improve auditory and communication abilities in aging adults. These findings together demonstrate that brain-to-behavior changes induced by music training can positive health and well-being outcomes specifically in relation to auditory abilities, language, and communication skills in individuals across the lifespan.

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First Name	Last Name	Affiliation
Assal *	Habibi *	Univeristy of Southern California

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Signature Assal Habibi

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

What Benefits Can We Derive from Music Training for Cochlear-Implanted individuals?

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Eleanor Harding

Affiliation   University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Cochlear implant users report difficulties perceiving music and certain aspects of speech, such as vocal cues and emotions, and 'cocktail-party' speech in multi-talker noise. While evidence exists supporting music as a training tool to improve music and speech perception, results are not unanimous across studies and the precise mechanisms that may contribute to both near- (music domain) and far- (speech domain) transfer training effects are not well understood. Previous research, including from our group, has indicated that musically trained individuals show advantages in perceptual tasks that involve music and pitch. We have also observed beneficial effects for perception of speech in the presence of a speech masker, but not for other maskers (such as steady noise), and also not in all populations (adults vs. adolescents). In some situations, such as perception of voice gender, we have observed musician and non-musician groups weighting voice cues differently than each other, but with no clear benefit from being a musician. Taken together, this evidence suggests that musical training may be a beneficial tool for improving these areas of auditory perception in cochlear implant users. However, perhaps the overall picture is more complex than we can easily characterize: the influence of musical training on psychoacoustic tasks varies across the literature, moreover, musical training is reported to variably affect cognitive processes such as auditory working memory and neural tracking of the acoustic envelope of music and speech. These cognitive processes may influence performance on certain tasks, such as speech-on-speech perception, via top-down processes. In this talk, we will cover our previous and current work with musicians, on potential musician and music training effects and their mechanistic origins, and how we try to utilize this knowledge in developing new ways of using music as an auditory training tool.

Enter all co-authors. You may search for any co-authors by using the search box. If you

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First Name	Last Name	Affiliation
Eleanor *	Harding *	University Medical Center Groningen
Deniz	Başkent	University of Groningen, University Medical Center Groningen

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Signature Eleanor Harding

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Music Training and Nonmusical abilities: The Role of Natural Musical Ability

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   E. Glenn Schellenberg

Affiliation   University of Toronto Mississauga

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Music training is associated with many nonmusical abilities, including those involving listening to speech or other auditory stimuli, as well as general cognitive ability. Individuals with training often show an advantage on tasks that measure these skills, and such advantages are assumed to be a consequence of music training. In fact, music training is often claimed to be a good (even ideal) model for the study of changes in brain and behavior that occur as the result of experience (i.e., plasticity). In recent years, however, research from my laboratory raises doubts about these claims. We have documented that individuals with music training differ systematically from other individuals in terms of demographics, personality, cognition, and natural musical ability (aptitude or talent), which are unlikely to be the consequence of any intervention or experiential factor. Moreover, evidence from twin studies points to a genetic component to musicality and music achievement, which raises further doubts about the proposed causal effect of music training, as do findings showing that transfer effects are rare. Rather, individuals from high-SES families who also have good cognitive abilities, high levels of the personality trait called openness-to-experience, and a facility for music are more likely than other individuals to take music lessons, particularly for years on end. Results in line with this view show that: (1) speech perception and grammatical ability have a stronger association with musical ability than with music training, (2) the association between music training and reading ability disappears when general cognitive ability is held constant, (3) the link between music training and cognitive ability disappears when musical ability is held constant, and (4) non-musical variables that predict music training also predict musical ability. In a five-year longitudinal study, musical ability at 8 years of age predicted the amount of music training taken subsequently. By contrast, at 13 years of age, links between music training and musical ability disappeared when musical ability at age 8 was held constant. These results, as well as those from independent laboratories, ensure that music training is a particularly poor model for the study of plasticity.

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E. Glenn *	Schellenberg *	University of Toronto Mississauga

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Signature E. Glenn Schellenberg

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

To understand the benefits of musical training on speech perception we need to focus on the assessment of musical skills and the initiation of adequately powered intervention studies

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Frank Russo

Affiliation   Toronto Metropolitan University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract   The evidence for the benefits of music training on speech processing and perception have been difficult to pin down. While correlation and cross-sectional studies abound, the evidence has been mixed and enthusiasm about positive findings are clouded by legitimate questions regarding confounding variables. The mixed evidence is not exactly surprising. The types of musical skills that a musician will possess as there is no accepted canon for musical training (e.g., learning percussion vs. violin; playing by ear or notation), and individuals will come to training with varying predispositions. Thus, I will argue that it is generally not satisfactory to simply count the number of years of musical training or to create a binary split between musicians and non-musicians when accounting for effects of music training. Correlational studies would be better served by modelling speech perception skills on the basis of specific musical skills that are assessed through experiment. The studies that have initiated a musical training intervention are more informative as they control the manor of training across participants and are able to take individual baselines into account. However, these studies have by-and-large been hindered by small and heterogenous samples. Moreover, the control conditions are often passive, leaving open the possibility that benefits accrue simply from adding a new activity or even worse, demand characteristics. In my own lab, we have completed three studies involving music training interventions, all in participants with some level of hearing loss. None of these studies is perfect and all suffer from relatively small sample sizes. Nevertheless, we have observed some positive outcomes. Our study on children who use cochlear implants showed benefits on perception of speech emotion. Our study on older adults with hearing loss showed benefits on speech perception in noise. Our study on older adults with hearing loss who use hearing aids, showed no benefits for speech perception in noise or emotion. However, in examining the baseline data we did observe

correlations between musical skills (e.g., rhythm perception) and speech perception in noise. My current view is that musical training may benefit speech processing and perception but the effects are highly variable. Future correlational studies should assess musical skills and speech perception in large cohorts of participants. In addition, multi-site training intervention studies should be undertaken allowing for larger sample sizes and the multi-level modelling of group- and individual-level predictors.

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* Presenting Author

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Frank *	Russo *	Toronto Metropolitan University

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Signature FAR

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Effects of Singing and Musical Training to Speech Perception and Language Skills of Children with Hearing Impairments

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Ritva Torppa

Affiliation   Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract There is growing body of evidence from follow-up studies and randomized controlled trials on the positive effects of musical training to perception of pitch, music and speech, to cognitive and language skills, and to associated brain networks in adults and children with normal hearing (NH). Musical training is expected to lead to similar effects for children with hearing impairments (HI) since they enjoy music and singing similarly to children with NH.
Even though the field of HI is still lacking large-scale randomized controlled trials, the current evidence shows that musical training and even informal singing at home can lead to similar positive effects in children with HI as found in children with NH. For instance, a longitudinal study showed that the attention-related P3a brain responses to changes in pitch and timbre were larger and developed more in children with CIs who sang regularly at home than in their peers with CIs who did not sing. In another study, the children with CIs who participated in musical hobbies were better in perception of pitch and prosodic stress and in expressive language skills (word finding, verbal IQ and phonological awareness measured with rhyming) compared to musically non-active children with CIs. Moreover, a longitudinal study showed that perception of speech in noise, timbre, question/statement prosody and spectral resolution improved only in the children with HI participating in musical training while not in the passive control group. The preliminary results from our new cross-over design study imply that musical intervention, which focused on singing, improved expressive language skills (e.g., semantic word fluency) of 2-6 years old children with HI. Regarding to pitch perception, the development during intervention varied in a sample of 3-6 years old children with HI, some of them showing clear development.

This presentation will show why music can improve speech and music processing and perception as

well as language skills of children with HI. The current evidence suggests that it would be beneficial for children with HI to sing at home and take part in musical hobbies and training.

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Seija	Pekkala	Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland
Valerie	Looi	The University of QLD, Australia

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Signature Ritva Torppa

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Association of Musical Training with Auditory and Speech Neural Coding and Perception

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Kelly Whiteford

Affiliation   University of Minnesota

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Numerous studies have reported a link between engagement in musical training and enhanced neural processing and perception of sound, ranging from fine-grained pitch discrimination to the perception of speech in noise, with training-related neural changes emerging as early in the auditory pathways as the brainstem or even the cochlea. Such findings suggest a role for experience-dependent plasticity in the early auditory system, which may have meaningful perceptual consequences. However, the generalizability of the musician advantage remains unclear. For example, small-sized samples often represent extreme ends of the musical spectrum; the nature and magnitudes of the musician advantage are sometimes small or inconsistent; and methodological differences and varying analytical techniques complicate comparisons between studies. This multi-site study aims to examine the robustness of the musician advantage across the adult lifespan by replicating and extending eight key experiments involving both perception and neural coding across a large sample of listeners (n > 300) at six universities in the US and Canada (Boston University, Carnegie Mellon University, Purdue University, University of Minnesota, University of Rochester, and University of Western Ontario). All participants were tested on all 8 experiments in a laboratory setting, including pitch discrimination, behavioral estimates of frequency tuning, speech and non-speech informational masking, speech perception in noise and babble, and two physiological measures of F0 encoding of speech sounds using electroencephalography. Data collection is ongoing, but so far data from over 200 participants have been collected. Participants also completed additional measures to control for potential confounding factors, including an objective measure of musical aptitude (melody discrimination from the Mini Profile of Music Perception Skills), a cognitive assessment (Ravens Advanced Progressive Matrices), a measure of extended high-frequency hearing, and survey questions related to personality and socio-economic status. Formal statistical analyses were preregistered on the

Open Science Framework and will be conducted once data collection is complete. The results will provide in-depth and high-powered insight on the nature and robustness of the musician advantage across the adult lifespan. [Supported by NSF-BCS grant 1840818.]

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First Name	Last Name	Affiliation
Kelly *	Whiteford *	University of Minnesota
Hari	Bharadwaj	Purdue University
Ingrid	Johnsrude	University of Western Ontario
Gerald	Kidd Jr.	Boston University
Anne	Luebke	University of Rochester
Ross	Maddox	University of Rochester
Elizabeth	Marvin	University of Rochester
Tyler	Perrachione	Boston University
Barbara	Shinn-Cunningham	Carnegie Mellon University
Andrew J.	Oxenham	University of Minnesota

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Signature Kelly Whiteford

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Submission ID 3003162

Submission Type Symposia

Topic Speech Perception

Status Submitted

Submitter Deniz Başkent

Affiliation University of Groningen, University Medical Center Groningen

Participant(s) Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Session Description Music is found in every human culture. Performing involves fine-grained motor, cognitive, multimodal-integration, and aesthetic skills; listening critically involves almost as many. Perhaps most importantly, music is fun. The enjoyable and social aspects of music could make it a powerful and motivating vehicle for auditory training, particularly in a clinical setting among those with hearing loss and cochlear implants. But does musical training improve skills beyond music, such as speech perception in noise and more general cognitive abilities? Can musical training protect against some aging effects in these domains? Many studies have addressed these questions in recent years without reaching a common consensus. The purpose of this symposium is to bring together researchers who have been actively contributing to this debate, to assess current evidence and opinions, to seek common ground, and to chart a way forward to answer these important questions. The session will bring researchers bridging basic and clinical sciences from the fields of auditory and speech perception and neuroscience, musical training, hearing aids and cochlear implants, to explore together the potentials and limitations of effects of musical training throughout the lifespan. To our knowledge, ARO has not hosted such a session in recent years.

Presenter Diversity The proposed list of speakers is highly diverse in terms of gender, geographical location, ethnic/racial background, and academic career stage.

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Signature DB

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Musical Training and Hearing-In-Noise Perception

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Emily Coffey

Affiliation   Concordia University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Musical training is a powerful and well-studied model of human neuroplasticity, which harnesses emotional and reward networks and auditory-motor feedback loops to sharpen and reinforce practised skills. It is thought to improve the quality of basic auditory encoding and higher-level functions such as selective attention and working memory. Both sound encoding quality and higher-level functions are important for perceptual skills outside of a musical context, such as speech-in-noise perception, which strongly influences health and well-being. Musical training is an attractive avenue for potentially enhancing poor or degraded perceptual skills; however, the specific nature of musical training benefits, particularly for speech-in-noise perception, is not yet clear. I will present our lab's recent work using electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) to explore the relationship between musicianship, perceptual skills, and neurophysiology. I will also discuss the design of musical tasks for encouraging neuroplasticity, and present some of the Open Science tools we have developed to facilitate and encourage research progress in these areas.

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First Name	Last Name	Affiliation
Emily *	Coffey *	Concordia University

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Signature Emily Coffey

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Neural Correlates of Auditory Processing in Individuals Engaged in Music Training – a Perspective across the Lifespan

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Assal Habibi

Affiliation   Univeristy of Southern California

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Playing a musical instrument is a complex multisensory experience requiring several skills including reading and translating abstract musical notation to fine and coordinated motor movements in order to produce a sound. The mastering of this rich and demanding process requires regular and intense practice, often from a young age. While there is a growing body of evidence suggesting that music training benefits cognitive development, the associations between music training and health outcomes specifically in relation to improvement of auditory and language skills is not clear. This presentation will highlight a series of research studies on the role of music training and associated health outcomes across the lifespan. The results from the first two studies provide evidence that music training in children and adolescents leads to improvement of pitch and rhythm perception, speech in noise perception and neuroplastic functional changes in the associated auditory regions that may have long-term positive effects on language development and competency. Results from the third study provide evidence that participating in short-term musical activities leads to better speech in noise perception in older adults without prior music training – and adding to the accumulating evidence that engaging in enrichment activities, such as choir singing provide a cost-effective and sustainable community-based intervention to improve auditory and communication abilities in aging adults. These findings together demonstrate that brain-to-behavior changes induced by music training can positive health and well-being outcomes specifically in relation to auditory abilities, language, and communication skills in individuals across the lifespan.

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* Presenting Author

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Assal *	Habibi *	Univeristy of Southern California

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Signature Assal Habibi

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

What Benefits Can We Derive from Music Training for Cochlear-Implanted individuals?

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Eleanor Harding

Affiliation   University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

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Eleanor *	Harding *	University Medical Center Groningen
Deniz	Başkent	University of Groningen, University Medical Center Groningen

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Signature Eleanor Harding

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Music Training and Nonmusical abilities: The Role of Natural Musical Ability

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   E. Glenn Schellenberg

Affiliation   University of Toronto Mississauga

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

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E. Glenn *	Schellenberg *	University of Toronto Mississauga

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Signature E. Glenn Schellenberg

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To understand the benefits of musical training on speech perception we need to focus on the assessment of musical skills and the initiation of adequately powered intervention studies

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Frank Russo

Affiliation   Toronto Metropolitan University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

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correlations between musical skills (e.g., rhythm perception) and speech perception in noise. My current view is that musical training may benefit speech processing and perception but the effects are highly variable. Future correlational studies should assess musical skills and speech perception in large cohorts of participants. In addition, multi-site training intervention studies should be undertaken allowing for larger sample sizes and the multi-level modelling of group- and individual-level predictors.

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Frank *	Russo *	Toronto Metropolitan University

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Signature FAR

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Effects of Singing and Musical Training to Speech Perception and Language Skills of Children with Hearing Impairments

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Ritva Torppa

Affiliation   Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract There is growing body of evidence from follow-up studies and randomized controlled trials on the positive effects of musical training to perception of pitch, music and speech, to cognitive and language skills, and to associated brain networks in adults and children with normal hearing (NH). Musical training is expected to lead to similar effects for children with hearing impairments (HI) since they enjoy music and singing similarly to children with NH.
Even though the field of HI is still lacking large-scale randomized controlled trials, the current evidence shows that musical training and even informal singing at home can lead to similar positive effects in children with HI as found in children with NH. For instance, a longitudinal study showed that the attention-related P3a brain responses to changes in pitch and timbre were larger and developed more in children with CIs who sang regularly at home than in their peers with CIs who did not sing. In another study, the children with CIs who participated in musical hobbies were better in perception of pitch and prosodic stress and in expressive language skills (word finding, verbal IQ and phonological awareness measured with rhyming) compared to musically non-active children with CIs. Moreover, a longitudinal study showed that perception of speech in noise, timbre, question/statement prosody and spectral resolution improved only in the children with HI participating in musical training while not in the passive control group. The preliminary results from our new cross-over design study imply that musical intervention, which focused on singing, improved expressive language skills (e.g., semantic word fluency) of 2-6 years old children with HI. Regarding to pitch perception, the development during intervention varied in a sample of 3-6 years old children with HI, some of them showing clear development.

This presentation will show why music can improve speech and music processing and perception as

well as language skills of children with HI. The current evidence suggests that it would be beneficial for children with HI to sing at home and take part in musical hobbies and training.

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Lotta	Seppänen	Psychology and Logopedics, Cognitive Brain Research Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland
Seija	Pekkala	Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland
Valerie	Looi	The University of QLD, Australia

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Signature Ritva Torppa

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Association of Musical Training with Auditory and Speech Neural Coding and Perception

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Kelly Whiteford

Affiliation   University of Minnesota

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Numerous studies have reported a link between engagement in musical training and enhanced neural processing and perception of sound, ranging from fine-grained pitch discrimination to the perception of speech in noise, with training-related neural changes emerging as early in the auditory pathways as the brainstem or even the cochlea. Such findings suggest a role for experience-dependent plasticity in the early auditory system, which may have meaningful perceptual consequences. However, the generalizability of the musician advantage remains unclear. For example, small-sized samples often represent extreme ends of the musical spectrum; the nature and magnitudes of the musician advantage are sometimes small or inconsistent; and methodological differences and varying analytical techniques complicate comparisons between studies. This multi-site study aims to examine the robustness of the musician advantage across the adult lifespan by replicating and extending eight key experiments involving both perception and neural coding across a large sample of listeners (n > 300) at six universities in the US and Canada (Boston University, Carnegie Mellon University, Purdue University, University of Minnesota, University of Rochester, and University of Western Ontario). All participants were tested on all 8 experiments in a laboratory setting, including pitch discrimination, behavioral estimates of frequency tuning, speech and non-speech informational masking, speech perception in noise and babble, and two physiological measures of F0 encoding of speech sounds using electroencephalography. Data collection is ongoing, but so far data from over 200 participants have been collected. Participants also completed additional measures to control for potential confounding factors, including an objective measure of musical aptitude (melody discrimination from the Mini Profile of Music Perception Skills), a cognitive assessment (Ravens Advanced Progressive Matrices), a measure of extended high-frequency hearing, and survey questions related to personality and socio-economic status. Formal statistical analyses were preregistered on the

Open Science Framework and will be conducted once data collection is complete. The results will provide in-depth and high-powered insight on the nature and robustness of the musician advantage across the adult lifespan. [Supported by NSF-BCS grant 1840818.]

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Kelly *	Whiteford *	University of Minnesota
Hari	Bharadwaj	Purdue University
Ingrid	Johnsrude	University of Western Ontario
Gerald	Kidd Jr.	Boston University
Anne	Luebke	University of Rochester
Ross	Maddox	University of Rochester
Elizabeth	Marvin	University of Rochester
Tyler	Perrachione	Boston University
Barbara	Shinn-Cunningham	Carnegie Mellon University
Andrew J.	Oxenham	University of Minnesota

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Signature Kelly Whiteford

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Deniz Başkent

Affiliation   University of Groningen, University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Session Description Music is found in every human culture. Performing involves fine-grained motor, cognitive, multimodal-integration, and aesthetic skills; listening critically involves almost as many. Perhaps most importantly, music is fun. The enjoyable and social aspects of music could make it a powerful and motivating vehicle for auditory training, particularly in a clinical setting among those with hearing loss and cochlear implants. But does musical training improve skills beyond music, such as speech perception in noise and more general cognitive abilities? Can musical training protect against some aging effects in these domains? Many studies have addressed these questions in recent years without reaching a common consensus. The purpose of this symposium is to bring together researchers who have been actively contributing to this debate, to assess current evidence and opinions, to seek common ground, and to chart a way forward to answer these important questions. The session will bring researchers bridging basic and clinical sciences from the fields of auditory and speech perception and neuroscience, musical training, hearing aids and cochlear implants, to explore together the potentials and limitations of effects of musical training throughout the lifespan. To our knowledge, ARO has not hosted such a session in recent years.

Presenter Diversity The proposed list of speakers is highly diverse in terms of gender, geographical location, ethnic/racial background, and academic career stage.

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Signature DB

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Musical Training and Hearing-In-Noise Perception

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Emily Coffey

Affiliation   Concordia University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Musical training is a powerful and well-studied model of human neuroplasticity, which harnesses emotional and reward networks and auditory-motor feedback loops to sharpen and reinforce practised skills. It is thought to improve the quality of basic auditory encoding and higher-level functions such as selective attention and working memory. Both sound encoding quality and higher-level functions are important for perceptual skills outside of a musical context, such as speech-in-noise perception, which strongly influences health and well-being. Musical training is an attractive avenue for potentially enhancing poor or degraded perceptual skills; however, the specific nature of musical training benefits, particularly for speech-in-noise perception, is not yet clear. I will present our lab's recent work using electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) to explore the relationship between musicianship, perceptual skills, and neurophysiology. I will also discuss the design of musical tasks for encouraging neuroplasticity, and present some of the Open Science tools we have developed to facilitate and encourage research progress in these areas.

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First Name	Last Name	Affiliation
Emily *	Coffey *	Concordia University

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Signature Emily Coffey

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Neural Correlates of Auditory Processing in Individuals Engaged in Music Training – a Perspective across the Lifespan

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Assal Habibi

Affiliation   Univeristy of Southern California

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Playing a musical instrument is a complex multisensory experience requiring several skills including reading and translating abstract musical notation to fine and coordinated motor movements in order to produce a sound. The mastering of this rich and demanding process requires regular and intense practice, often from a young age. While there is a growing body of evidence suggesting that music training benefits cognitive development, the associations between music training and health outcomes specifically in relation to improvement of auditory and language skills is not clear. This presentation will highlight a series of research studies on the role of music training and associated health outcomes across the lifespan. The results from the first two studies provide evidence that music training in children and adolescents leads to improvement of pitch and rhythm perception, speech in noise perception and neuroplastic functional changes in the associated auditory regions that may have long-term positive effects on language development and competency. Results from the third study provide evidence that participating in short-term musical activities leads to better speech in noise perception in older adults without prior music training – and adding to the accumulating evidence that engaging in enrichment activities, such as choir singing provide a cost-effective and sustainable community-based intervention to improve auditory and communication abilities in aging adults. These findings together demonstrate that brain-to-behavior changes induced by music training can positive health and well-being outcomes specifically in relation to auditory abilities, language, and communication skills in individuals across the lifespan.

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Assal *	Habibi *	Univeristy of Southern California

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Signature Assal Habibi

* Presenting Author

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

What Benefits Can We Derive from Music Training for Cochlear-Implanted individuals?

Submission ID	3003162
Submission Type	Symposia
Topic	Speech Perception
Status	Submitted
Submitter	Eleanor Harding
Affiliation	University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Cochlear implant users report difficulties perceiving music and certain aspects of speech, such as vocal cues and emotions, and 'cocktail-party' speech in multi-talker noise. While evidence exists supporting music as a training tool to improve music and speech perception, results are not unanimous across studies and the precise mechanisms that may contribute to both near- (music domain) and far- (speech domain) transfer training effects are not well understood. Previous research, including from our group, has indicated that musically trained individuals show advantages in perceptual tasks that involve music and pitch. We have also observed beneficial effects for perception of speech in the presence of a speech masker, but not for other maskers (such as steady noise), and also not in all populations (adults vs. adolescents). In some situations, such as perception of voice gender, we have observed musician and non-musician groups weighting voice cues differently than each other, but with no clear benefit from being a musician. Taken together, this evidence suggests that musical training may be a beneficial tool for improving these areas of auditory perception in cochlear implant users. However, perhaps the overall picture is more complex than we can easily characterize: the influence of musical training on psychoacoustic tasks varies across the literature, moreover, musical training is reported to variably affect cognitive processes such as auditory working memory and neural tracking of the acoustic envelope of music and speech. These cognitive processes may influence performance on certain tasks, such as speech-on-speech perception, via top-down processes. In this talk, we will cover our previous and current work with musicians, on potential musician and music training effects and their mechanistic origins, and how we try to utilize this knowledge in developing new ways of using music as an auditory training tool.

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Eleanor *	Harding *	University Medical Center Groningen
Deniz	Başkent	University of Groningen, University Medical Center Groningen

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Signature Eleanor Harding

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Music Training and Nonmusical abilities: The Role of Natural Musical Ability

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   E. Glenn Schellenberg

Affiliation   University of Toronto Mississauga

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Music training is associated with many nonmusical abilities, including those involving listening to speech or other auditory stimuli, as well as general cognitive ability. Individuals with training often show an advantage on tasks that measure these skills, and such advantages are assumed to be a consequence of music training. In fact, music training is often claimed to be a good (even ideal) model for the study of changes in brain and behavior that occur as the result of experience (i.e., plasticity). In recent years, however, research from my laboratory raises doubts about these claims. We have documented that individuals with music training differ systematically from other individuals in terms of demographics, personality, cognition, and natural musical ability (aptitude or talent), which are unlikely to be the consequence of any intervention or experiential factor. Moreover, evidence from twin studies points to a genetic component to musicality and music achievement, which raises further doubts about the proposed causal effect of music training, as do findings showing that transfer effects are rare. Rather, individuals from high-SES families who also have good cognitive abilities, high levels of the personality trait called openness-to-experience, and a facility for music are more likely than other individuals to take music lessons, particularly for years on end. Results in line with this view show that: (1) speech perception and grammatical ability have a stronger association with musical ability than with music training, (2) the association between music training and reading ability disappears when general cognitive ability is held constant, (3) the link between music training and cognitive ability disappears when musical ability is held constant, and (4) non-musical variables that predict music training also predict musical ability. In a five-year longitudinal study, musical ability at 8 years of age predicted the amount of music training taken subsequently. By contrast, at 13 years of age, links between music training and musical ability disappeared when musical ability at age 8 was held constant. These results, as well as those from independent laboratories, ensure that music training is a particularly poor model for the study of plasticity.

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E. Glenn *	Schellenberg *	University of Toronto Mississauga

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Signature E. Glenn Schellenberg

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

To understand the benefits of musical training on speech perception we need to focus on the assessment of musical skills and the initiation of adequately powered intervention studies

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Frank Russo

Affiliation   Toronto Metropolitan University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract The evidence for the benefits of music training on speech processing and perception have been difficult to pin down. While correlation and cross-sectional studies abound, the evidence has been mixed and enthusiasm about positive findings are clouded by legitimate questions regarding confounding variables. The mixed evidence is not exactly surprising. The types of musical skills that a musician will possess as there is no accepted canon for musical training (e.g., learning percussion vs. violin; playing by ear or notation), and individuals will come to training with varying predispositions. Thus, I will argue that it is generally not satisfactory to simply count the number of years of musical training or to create a binary split between musicians and non-musicians when accounting for effects of music training. Correlational studies would be better served by modelling speech perception skills on the basis of specific musical skills that are assessed through experiment. The studies that have initiated a musical training intervention are more informative as they control the manor of training across participants and are able to take individual baselines into account. However, these studies have by-and-large been hindered by small and heterogenous samples. Moreover, the control conditions are often passive, leaving open the possibility that benefits accrue simply from adding a new activity or even worse, demand characteristics. In my own lab, we have completed three studies involving music training interventions, all in participants with some level of hearing loss. None of these studies is perfect and all suffer from relatively small sample sizes. Nevertheless, we have observed some positive outcomes. Our study on children who use cochlear implants showed benefits on perception of speech emotion. Our study on older adults with hearing loss showed benefits on speech perception in noise. Our study on older adults with hearing loss who use hearing aids, showed no benefits for speech perception in noise or emotion. However, in examining the baseline data we did observe

correlations between musical skills (e.g., rhythm perception) and speech perception in noise. My current view is that musical training may benefit speech processing and perception but the effects are highly variable. Future correlational studies should assess musical skills and speech perception in large cohorts of participants. In addition, multi-site training intervention studies should be undertaken allowing for larger sample sizes and the multi-level modelling of group- and individual-level predictors.

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Frank *	Russo *	Toronto Metropolitan University

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Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Effects of Singing and Musical Training to Speech Perception and Language Skills of Children with Hearing Impairments

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Ritva Torppa

Affiliation   Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

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Lotta	Seppänen	Psychology and Logopedics, Cognitive Brain Research Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland
Seija	Pekkala	Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland
Valerie	Looi	The University of QLD, Australia

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Signature Ritva Torppa

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Association of Musical Training with Auditory and Speech Neural Coding and Perception

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Kelly Whiteford

Affiliation   University of Minnesota

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

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First Name	Last Name	Affiliation
Kelly *	Whiteford *	University of Minnesota
Hari	Bharadwaj	Purdue University
Ingrid	Johnsrude	University of Western Ontario
Gerald	Kidd Jr.	Boston University
Anne	Luebke	University of Rochester
Ross	Maddox	University of Rochester
Elizabeth	Marvin	University of Rochester
Tyler	Perrachione	Boston University
Barbara	Shinn-Cunningham	Carnegie Mellon University
Andrew J.	Oxenham	University of Minnesota

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Signature Kelly Whiteford

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Deniz Başkent

Affiliation   University of Groningen, University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Session Description Music is found in every human culture. Performing involves fine-grained motor, cognitive, multimodal-integration, and aesthetic skills; listening critically involves almost as many. Perhaps most importantly, music is fun. The enjoyable and social aspects of music could make it a powerful and motivating vehicle for auditory training, particularly in a clinical setting among those with hearing loss and cochlear implants. But does musical training improve skills beyond music, such as speech perception in noise and more general cognitive abilities? Can musical training protect against some aging effects in these domains? Many studies have addressed these questions in recent years without reaching a common consensus. The purpose of this symposium is to bring together researchers who have been actively contributing to this debate, to assess current evidence and opinions, to seek common ground, and to chart a way forward to answer these important questions. The session will bring researchers bridging basic and clinical sciences from the fields of auditory and speech perception and neuroscience, musical training, hearing aids and cochlear implants, to explore together the potentials and limitations of effects of musical training throughout the lifespan. To our knowledge, ARO has not hosted such a session in recent years.

Presenter Diversity The proposed list of speakers is highly diverse in terms of gender, geographical location, ethnic/racial background, and academic career stage.

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Signature DB

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Musical Training and Hearing-In-Noise Perception

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Emily Coffey

Affiliation   Concordia University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Musical training is a powerful and well-studied model of human neuroplasticity, which harnesses emotional and reward networks and auditory-motor feedback loops to sharpen and reinforce practised skills. It is thought to improve the quality of basic auditory encoding and higher-level functions such as selective attention and working memory. Both sound encoding quality and higher-level functions are important for perceptual skills outside of a musical context, such as speech-in-noise perception, which strongly influences health and well-being. Musical training is an attractive avenue for potentially enhancing poor or degraded perceptual skills; however, the specific nature of musical training benefits, particularly for speech-in-noise perception, is not yet clear. I will present our lab's recent work using electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) to explore the relationship between musicianship, perceptual skills, and neurophysiology. I will also discuss the design of musical tasks for encouraging neuroplasticity, and present some of the Open Science tools we have developed to facilitate and encourage research progress in these areas.

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* Presenting Author

First Name	Last Name	Affiliation
Emily *	Coffey *	Concordia University

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Signature Emily Coffey

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Neural Correlates of Auditory Processing in Individuals Engaged in Music Training – a Perspective across the Lifespan

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Assal Habibi

Affiliation   Univeristy of Southern California

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Playing a musical instrument is a complex multisensory experience requiring several skills including reading and translating abstract musical notation to fine and coordinated motor movements in order to produce a sound. The mastering of this rich and demanding process requires regular and intense practice, often from a young age. While there is a growing body of evidence suggesting that music training benefits cognitive development, the associations between music training and health outcomes specifically in relation to improvement of auditory and language skills is not clear. This presentation will highlight a series of research studies on the role of music training and associated health outcomes across the lifespan. The results from the first two studies provide evidence that music training in children and adolescents leads to improvement of pitch and rhythm perception, speech in noise perception and neuroplastic functional changes in the associated auditory regions that may have long-term positive effects on language development and competency. Results from the third study provide evidence that participating in short-term musical activities leads to better speech in noise perception in older adults without prior music training – and adding to the accumulating evidence that engaging in enrichment activities, such as choir singing provide a cost-effective and sustainable community-based intervention to improve auditory and communication abilities in aging adults. These findings together demonstrate that brain-to-behavior changes induced by music training can positive health and well-being outcomes specifically in relation to auditory abilities, language, and communication skills in individuals across the lifespan.

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* Presenting Author

First Name	Last Name	Affiliation
Assal *	Habibi *	Univeristy of Southern California

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Signature Assal Habibi

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

What Benefits Can We Derive from Music Training for Cochlear-Implanted individuals?

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Eleanor Harding

Affiliation   University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Cochlear implant users report difficulties perceiving music and certain aspects of speech, such as vocal cues and emotions, and 'cocktail-party' speech in multi-talker noise. While evidence exists supporting music as a training tool to improve music and speech perception, results are not unanimous across studies and the precise mechanisms that may contribute to both near- (music domain) and far- (speech domain) transfer training effects are not well understood. Previous research, including from our group, has indicated that musically trained individuals show advantages in perceptual tasks that involve music and pitch. We have also observed beneficial effects for perception of speech in the presence of a speech masker, but not for other maskers (such as steady noise), and also not in all populations (adults vs. adolescents). In some situations, such as perception of voice gender, we have observed musician and non-musician groups weighting voice cues differently than each other, but with no clear benefit from being a musician. Taken together, this evidence suggests that musical training may be a beneficial tool for improving these areas of auditory perception in cochlear implant users. However, perhaps the overall picture is more complex than we can easily characterize: the influence of musical training on psychoacoustic tasks varies across the literature, moreover, musical training is reported to variably affect cognitive processes such as auditory working memory and neural tracking of the acoustic envelope of music and speech. These cognitive processes may influence performance on certain tasks, such as speech-on-speech perception, via top-down processes. In this talk, we will cover our previous and current work with musicians, on potential musician and music training effects and their mechanistic origins, and how we try to utilize this knowledge in developing new ways of using music as an auditory training tool.

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* Presenting Author

First Name	Last Name	Affiliation
Eleanor *	Harding *	University Medical Center Groningen
Deniz	Başkent	University of Groningen, University Medical Center Groningen

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Signature Eleanor Harding

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Music Training and Nonmusical abilities: The Role of Natural Musical Ability

Submission ID 3003162

Submission Type Symposia

Topic Speech Perception

Status Submitted

Submitter E. Glenn Schellenberg

Affiliation University of Toronto Mississauga

Participant(s) Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Music training is associated with many nonmusical abilities, including those involving listening to speech or other auditory stimuli, as well as general cognitive ability. Individuals with training often show an advantage on tasks that measure these skills, and such advantages are assumed to be a consequence of music training. In fact, music training is often claimed to be a good (even ideal) model for the study of changes in brain and behavior that occur as the result of experience (i.e., plasticity). In recent years, however, research from my laboratory raises doubts about these claims. We have documented that individuals with music training differ systematically from other individuals in terms of demographics, personality, cognition, and natural musical ability (aptitude or talent), which are unlikely to be the consequence of any intervention or experiential factor. Moreover, evidence from twin studies points to a genetic component to musicality and music achievement, which raises further doubts about the proposed causal effect of music training, as do findings showing that transfer effects are rare. Rather, individuals from high-SES families who also have good cognitive abilities, high levels of the personality trait called openness-to-experience, and a facility for music are more likely than other individuals to take music lessons, particularly for years on end. Results in line with this view show that: (1) speech perception and grammatical ability have a stronger association with musical ability than with music training, (2) the association between music training and reading ability disappears when general cognitive ability is held constant, (3) the link between music training and cognitive ability disappears when musical ability is held constant, and (4) non-musical variables that predict music training also predict musical ability. In a five-year longitudinal study, musical ability at 8 years of age predicted the amount of music training taken subsequently. By contrast, at 13 years of age, links between music training and musical ability disappeared when musical ability at age 8 was held constant. These results, as well as those from independent laboratories, ensure that music training is a particularly poor model for the study of plasticity.

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* Presenting Author

First Name	Last Name	Affiliation
E. Glenn *	Schellenberg *	University of Toronto Mississauga

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Signature E. Glenn Schellenberg

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

To understand the benefits of musical training on speech perception we need to focus on the assessment of musical skills and the initiation of adequately powered intervention studies

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Frank Russo

Affiliation   Toronto Metropolitan University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract The evidence for the benefits of music training on speech processing and perception have been difficult to pin down. While correlation and cross-sectional studies abound, the evidence has been mixed and enthusiasm about positive findings are clouded by legitimate questions regarding confounding variables. The mixed evidence is not exactly surprising. The types of musical skills that a musician will possess as there is no accepted canon for musical training (e.g., learning percussion vs. violin; playing by ear or notation), and individuals will come to training with varying predispositions. Thus, I will argue that it is generally not satisfactory to simply count the number of years of musical training or to create a binary split between musicians and non-musicians when accounting for effects of music training. Correlational studies would be better served by modelling speech perception skills on the basis of specific musical skills that are assessed through experiment. The studies that have initiated a musical training intervention are more informative as they control the manor of training across participants and are able to take individual baselines into account. However, these studies have by-and-large been hindered by small and heterogenous samples. Moreover, the control conditions are often passive, leaving open the possibility that benefits accrue simply from adding a new activity or even worse, demand characteristics. In my own lab, we have completed three studies involving music training interventions, all in participants with some level of hearing loss. None of these studies is perfect and all suffer from relatively small sample sizes. Nevertheless, we have observed some positive outcomes. Our study on children who use cochlear implants showed benefits on perception of speech emotion. Our study on older adults with hearing loss showed benefits on speech perception in noise. Our study on older adults with hearing loss who use hearing aids, showed no benefits for speech perception in noise or emotion. However, in examining the baseline data we did observe

correlations between musical skills (e.g., rhythm perception) and speech perception in noise. My current view is that musical training may benefit speech processing and perception but the effects are highly variable. Future correlational studies should assess musical skills and speech perception in large cohorts of participants. In addition, multi-site training intervention studies should be undertaken allowing for larger sample sizes and the multi-level modelling of group- and individual-level predictors.

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* Presenting Author

First Name	Last Name	Affiliation
Frank *	Russo *	Toronto Metropolitan University

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Signature FAR

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Effects of Singing and Musical Training to Speech Perception and Language Skills of Children with Hearing Impairments

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Ritva Torppa

Affiliation   Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract There is growing body of evidence from follow-up studies and randomized controlled trials on the positive effects of musical training to perception of pitch, music and speech, to cognitive and language skills, and to associated brain networks in adults and children with normal hearing (NH). Musical training is expected to lead to similar effects for children with hearing impairments (HI) since they enjoy music and singing similarly to children with NH.
Even though the field of HI is still lacking large-scale randomized controlled trials, the current evidence shows that musical training and even informal singing at home can lead to similar positive effects in children with HI as found in children with NH. For instance, a longitudinal study showed that the attention-related P3a brain responses to changes in pitch and timbre were larger and developed more in children with CIs who sang regularly at home than in their peers with CIs who did not sing. In another study, the children with CIs who participated in musical hobbies were better in perception of pitch and prosodic stress and in expressive language skills (word finding, verbal IQ and phonological awareness measured with rhyming) compared to musically non-active children with CIs. Moreover, a longitudinal study showed that perception of speech in noise, timbre, question/statement prosody and spectral resolution improved only in the children with HI participating in musical training while not in the passive control group. The preliminary results from our new cross-over design study imply that musical intervention, which focused on singing, improved expressive language skills (e.g., semantic word fluency) of 2-6 years old children with HI. Regarding to pitch perception, the development during intervention varied in a sample of 3-6 years old children with HI, some of them showing clear development.

This presentation will show why music can improve speech and music processing and perception as

well as language skills of children with HI. The current evidence suggests that it would be beneficial for children with HI to sing at home and take part in musical hobbies and training.

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First Name	Last Name	Affiliation
Ritva *	Torppa *	Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland
Lotta	Seppänen	Psychology and Logopedics, Cognitive Brain Research Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland
Seija	Pekkala	Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland
Valerie	Looi	The University of QLD, Australia

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Signature Ritva Torppa

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Association of Musical Training with Auditory and Speech Neural Coding and Perception

Submission ID 3003162

Submission Type Symposia

Topic Speech Perception

Status Submitted

Submitter Kelly Whiteford

Affiliation University of Minnesota

Participant(s) Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Numerous studies have reported a link between engagement in musical training and enhanced neural processing and perception of sound, ranging from fine-grained pitch discrimination to the perception of speech in noise, with training-related neural changes emerging as early in the auditory pathways as the brainstem or even the cochlea. Such findings suggest a role for experience-dependent plasticity in the early auditory system, which may have meaningful perceptual consequences. However, the generalizability of the musician advantage remains unclear. For example, small-sized samples often represent extreme ends of the musical spectrum; the nature and magnitudes of the musician advantage are sometimes small or inconsistent; and methodological differences and varying analytical techniques complicate comparisons between studies. This multi-site study aims to examine the robustness of the musician advantage across the adult lifespan by replicating and extending eight key experiments involving both perception and neural coding across a large sample of listeners (n > 300) at six universities in the US and Canada (Boston University, Carnegie Mellon University, Purdue University, University of Minnesota, University of Rochester, and University of Western Ontario). All participants were tested on all 8 experiments in a laboratory setting, including pitch discrimination, behavioral estimates of frequency tuning, speech and non-speech informational masking, speech perception in noise and babble, and two physiological measures of F0 encoding of speech sounds using electroencephalography. Data collection is ongoing, but so far data from over 200 participants have been collected. Participants also completed additional measures to control for potential confounding factors, including an objective measure of musical aptitude (melody discrimination from the Mini Profile of Music Perception Skills), a cognitive assessment (Ravens Advanced Progressive Matrices), a measure of extended high-frequency hearing, and survey questions related to personality and socio-economic status. Formal statistical analyses were preregistered on the

Open Science Framework and will be conducted once data collection is complete. The results will provide in-depth and high-powered insight on the nature and robustness of the musician advantage across the adult lifespan. [Supported by NSF-BCS grant 1840818.]

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* Presenting Author

First Name	Last Name	Affiliation
Kelly *	Whiteford *	University of Minnesota
Hari	Bharadwaj	Purdue University
Ingrid	Johnsrude	University of Western Ontario
Gerald	Kidd Jr.	Boston University
Anne	Luebke	University of Rochester
Ross	Maddox	University of Rochester
Elizabeth	Marvin	University of Rochester
Tyler	Perrachione	Boston University
Barbara	Shinn-Cunningham	Carnegie Mellon University
Andrew J.	Oxenham	University of Minnesota

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Signature Kelly Whiteford

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Submission ID 3003162

Submission Type Symposia

Topic Speech Perception

Status Submitted

Submitter Deniz Başkent

Affiliation University of Groningen, University Medical Center Groningen

Participant(s) Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Session Description Music is found in every human culture. Performing involves fine-grained motor, cognitive, multimodal-integration, and aesthetic skills; listening critically involves almost as many. Perhaps most importantly, music is fun. The enjoyable and social aspects of music could make it a powerful and motivating vehicle for auditory training, particularly in a clinical setting among those with hearing loss and cochlear implants. But does musical training improve skills beyond music, such as speech perception in noise and more general cognitive abilities? Can musical training protect against some aging effects in these domains? Many studies have addressed these questions in recent years without reaching a common consensus. The purpose of this symposium is to bring together researchers who have been actively contributing to this debate, to assess current evidence and opinions, to seek common ground, and to chart a way forward to answer these important questions. The session will bring researchers bridging basic and clinical sciences from the fields of auditory and speech perception and neuroscience, musical training, hearing aids and cochlear implants, to explore together the potentials and limitations of effects of musical training throughout the lifespan. To our knowledge, ARO has not hosted such a session in recent years.

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Signature DB

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Musical Training and Hearing-In-Noise Perception

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Emily Coffey

Affiliation   Concordia University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

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First Name	Last Name	Affiliation
Emily *	Coffey *	Concordia University

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Signature Emily Coffey

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Neural Correlates of Auditory Processing in Individuals Engaged in Music Training – a Perspective across the Lifespan

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Assal Habibi

Affiliation   Univeristy of Southern California

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Playing a musical instrument is a complex multisensory experience requiring several skills including reading and translating abstract musical notation to fine and coordinated motor movements in order to produce a sound. The mastering of this rich and demanding process requires regular and intense practice, often from a young age. While there is a growing body of evidence suggesting that music training benefits cognitive development, the associations between music training and health outcomes specifically in relation to improvement of auditory and language skills is not clear. This presentation will highlight a series of research studies on the role of music training and associated health outcomes across the lifespan. The results from the first two studies provide evidence that music training in children and adolescents leads to improvement of pitch and rhythm perception, speech in noise perception and neuroplastic functional changes in the associated auditory regions that may have long-term positive effects on language development and competency. Results from the third study provide evidence that participating in short-term musical activities leads to better speech in noise perception in older adults without prior music training – and adding to the accumulating evidence that engaging in enrichment activities, such as choir singing provide a cost-effective and sustainable community-based intervention to improve auditory and communication abilities in aging adults. These findings together demonstrate that brain-to-behavior changes induced by music training can positive health and well-being outcomes specifically in relation to auditory abilities, language, and communication skills in individuals across the lifespan.

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* Presenting Author

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Assal *	Habibi *	Univeristy of Southern California

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Signature Assal Habibi

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

What Benefits Can We Derive from Music Training for Cochlear-Implanted individuals?

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Eleanor Harding

Affiliation   University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Cochlear implant users report difficulties perceiving music and certain aspects of speech, such as vocal cues and emotions, and 'cocktail-party' speech in multi-talker noise. While evidence exists supporting music as a training tool to improve music and speech perception, results are not unanimous across studies and the precise mechanisms that may contribute to both near- (music domain) and far- (speech domain) transfer training effects are not well understood. Previous research, including from our group, has indicated that musically trained individuals show advantages in perceptual tasks that involve music and pitch. We have also observed beneficial effects for perception of speech in the presence of a speech masker, but not for other maskers (such as steady noise), and also not in all populations (adults vs. adolescents). In some situations, such as perception of voice gender, we have observed musician and non-musician groups weighting voice cues differently than each other, but with no clear benefit from being a musician. Taken together, this evidence suggests that musical training may be a beneficial tool for improving these areas of auditory perception in cochlear implant users. However, perhaps the overall picture is more complex than we can easily characterize: the influence of musical training on psychoacoustic tasks varies across the literature, moreover, musical training is reported to variably affect cognitive processes such as auditory working memory and neural tracking of the acoustic envelope of music and speech. These cognitive processes may influence performance on certain tasks, such as speech-on-speech perception, via top-down processes. In this talk, we will cover our previous and current work with musicians, on potential musician and music training effects and their mechanistic origins, and how we try to utilize this knowledge in developing new ways of using music as an auditory training tool.

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First Name	Last Name	Affiliation
Eleanor *	Harding *	University Medical Center Groningen
Deniz	Başkent	University of Groningen, University Medical Center Groningen

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Signature Eleanor Harding

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Music Training and Nonmusical abilities: The Role of Natural Musical Ability

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   E. Glenn Schellenberg

Affiliation   University of Toronto Mississauga

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Music training is associated with many nonmusical abilities, including those involving listening to speech or other auditory stimuli, as well as general cognitive ability. Individuals with training often show an advantage on tasks that measure these skills, and such advantages are assumed to be a consequence of music training. In fact, music training is often claimed to be a good (even ideal) model for the study of changes in brain and behavior that occur as the result of experience (i.e., plasticity). In recent years, however, research from my laboratory raises doubts about these claims. We have documented that individuals with music training differ systematically from other individuals in terms of demographics, personality, cognition, and natural musical ability (aptitude or talent), which are unlikely to be the consequence of any intervention or experiential factor. Moreover, evidence from twin studies points to a genetic component to musicality and music achievement, which raises further doubts about the proposed causal effect of music training, as do findings showing that transfer effects are rare. Rather, individuals from high-SES families who also have good cognitive abilities, high levels of the personality trait called openness-to-experience, and a facility for music are more likely than other individuals to take music lessons, particularly for years on end. Results in line with this view show that: (1) speech perception and grammatical ability have a stronger association with musical ability than with music training, (2) the association between music training and reading ability disappears when general cognitive ability is held constant, (3) the link between music training and cognitive ability disappears when musical ability is held constant, and (4) non-musical variables that predict music training also predict musical ability. In a five-year longitudinal study, musical ability at 8 years of age predicted the amount of music training taken subsequently. By contrast, at 13 years of age, links between music training and musical ability disappeared when musical ability at age 8 was held constant. These results, as well as those from independent laboratories, ensure that music training is a particularly poor model for the study of plasticity.

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* Presenting Author

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E. Glenn *	Schellenberg *	University of Toronto Mississauga

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Signature E. Glenn Schellenberg

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

To understand the benefits of musical training on speech perception we need to focus on the assessment of musical skills and the initiation of adequately powered intervention studies

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Frank Russo

Affiliation   Toronto Metropolitan University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract The evidence for the benefits of music training on speech processing and perception have been difficult to pin down. While correlation and cross-sectional studies abound, the evidence has been mixed and enthusiasm about positive findings are clouded by legitimate questions regarding confounding variables. The mixed evidence is not exactly surprising. The types of musical skills that a musician will possess as there is no accepted canon for musical training (e.g., learning percussion vs. violin; playing by ear or notation), and individuals will come to training with varying predispositions. Thus, I will argue that it is generally not satisfactory to simply count the number of years of musical training or to create a binary split between musicians and non-musicians when accounting for effects of music training. Correlational studies would be better served by modelling speech perception skills on the basis of specific musical skills that are assessed through experiment. The studies that have initiated a musical training intervention are more informative as they control the manor of training across participants and are able to take individual baselines into account. However, these studies have by-and-large been hindered by small and heterogenous samples. Moreover, the control conditions are often passive, leaving open the possibility that benefits accrue simply from adding a new activity or even worse, demand characteristics. In my own lab, we have completed three studies involving music training interventions, all in participants with some level of hearing loss. None of these studies is perfect and all suffer from relatively small sample sizes. Nevertheless, we have observed some positive outcomes. Our study on children who use cochlear implants showed benefits on perception of speech emotion. Our study on older adults with hearing loss showed benefits on speech perception in noise. Our study on older adults with hearing loss who use hearing aids, showed no benefits for speech perception in noise or emotion. However, in examining the baseline data we did observe

correlations between musical skills (e.g., rhythm perception) and speech perception in noise. My current view is that musical training may benefit speech processing and perception but the effects are highly variable. Future correlational studies should assess musical skills and speech perception in large cohorts of participants. In addition, multi-site training intervention studies should be undertaken allowing for larger sample sizes and the multi-level modelling of group- and individual-level predictors.

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Frank *	Russo *	Toronto Metropolitan University

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Signature FAR

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Effects of Singing and Musical Training to Speech Perception and Language Skills of Children with Hearing Impairments

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Ritva Torppa

Affiliation   Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract There is growing body of evidence from follow-up studies and randomized controlled trials on the positive effects of musical training to perception of pitch, music and speech, to cognitive and language skills, and to associated brain networks in adults and children with normal hearing (NH). Musical training is expected to lead to similar effects for children with hearing impairments (HI) since they enjoy music and singing similarly to children with NH.
Even though the field of HI is still lacking large-scale randomized controlled trials, the current evidence shows that musical training and even informal singing at home can lead to similar positive effects in children with HI as found in children with NH. For instance, a longitudinal study showed that the attention-related P3a brain responses to changes in pitch and timbre were larger and developed more in children with CIs who sang regularly at home than in their peers with CIs who did not sing. In another study, the children with CIs who participated in musical hobbies were better in perception of pitch and prosodic stress and in expressive language skills (word finding, verbal IQ and phonological awareness measured with rhyming) compared to musically non-active children with CIs. Moreover, a longitudinal study showed that perception of speech in noise, timbre, question/statement prosody and spectral resolution improved only in the children with HI participating in musical training while not in the passive control group. The preliminary results from our new cross-over design study imply that musical intervention, which focused on singing, improved expressive language skills (e.g., semantic word fluency) of 2-6 years old children with HI. Regarding to pitch perception, the development during intervention varied in a sample of 3-6 years old children with HI, some of them showing clear development.

This presentation will show why music can improve speech and music processing and perception as

well as language skills of children with HI. The current evidence suggests that it would be beneficial for children with HI to sing at home and take part in musical hobbies and training.

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Lotta	Seppänen	Psychology and Logopedics, Cognitive Brain Research Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland
Seija	Pekkala	Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland
Valerie	Looi	The University of QLD, Australia

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Signature Ritva Torppa

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Association of Musical Training with Auditory and Speech Neural Coding and Perception

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Kelly Whiteford

Affiliation   University of Minnesota

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Numerous studies have reported a link between engagement in musical training and enhanced neural processing and perception of sound, ranging from fine-grained pitch discrimination to the perception of speech in noise, with training-related neural changes emerging as early in the auditory pathways as the brainstem or even the cochlea. Such findings suggest a role for experience-dependent plasticity in the early auditory system, which may have meaningful perceptual consequences. However, the generalizability of the musician advantage remains unclear. For example, small-sized samples often represent extreme ends of the musical spectrum; the nature and magnitudes of the musician advantage are sometimes small or inconsistent; and methodological differences and varying analytical techniques complicate comparisons between studies. This multi-site study aims to examine the robustness of the musician advantage across the adult lifespan by replicating and extending eight key experiments involving both perception and neural coding across a large sample of listeners (n > 300) at six universities in the US and Canada (Boston University, Carnegie Mellon University, Purdue University, University of Minnesota, University of Rochester, and University of Western Ontario). All participants were tested on all 8 experiments in a laboratory setting, including pitch discrimination, behavioral estimates of frequency tuning, speech and non-speech informational masking, speech perception in noise and babble, and two physiological measures of F0 encoding of speech sounds using electroencephalography. Data collection is ongoing, but so far data from over 200 participants have been collected. Participants also completed additional measures to control for potential confounding factors, including an objective measure of musical aptitude (melody discrimination from the Mini Profile of Music Perception Skills), a cognitive assessment (Ravens Advanced Progressive Matrices), a measure of extended high-frequency hearing, and survey questions related to personality and socio-economic status. Formal statistical analyses were preregistered on the

Open Science Framework and will be conducted once data collection is complete. The results will provide in-depth and high-powered insight on the nature and robustness of the musician advantage across the adult lifespan. [Supported by NSF-BCS grant 1840818.]

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* Presenting Author

First Name	Last Name	Affiliation
Kelly *	Whiteford *	University of Minnesota
Hari	Bharadwaj	Purdue University
Ingrid	Johnsrude	University of Western Ontario
Gerald	Kidd Jr.	Boston University
Anne	Luebke	University of Rochester
Ross	Maddox	University of Rochester
Elizabeth	Marvin	University of Rochester
Tyler	Perrachione	Boston University
Barbara	Shinn-Cunningham	Carnegie Mellon University
Andrew J.	Oxenham	University of Minnesota

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Signature Kelly Whiteford

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Deniz Başkent

Affiliation   University of Groningen, University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Session Description Music is found in every human culture. Performing involves fine-grained motor, cognitive, multimodal-integration, and aesthetic skills; listening critically involves almost as many. Perhaps most importantly, music is fun. The enjoyable and social aspects of music could make it a powerful and motivating vehicle for auditory training, particularly in a clinical setting among those with hearing loss and cochlear implants. But does musical training improve skills beyond music, such as speech perception in noise and more general cognitive abilities? Can musical training protect against some aging effects in these domains? Many studies have addressed these questions in recent years without reaching a common consensus. The purpose of this symposium is to bring together researchers who have been actively contributing to this debate, to assess current evidence and opinions, to seek common ground, and to chart a way forward to answer these important questions. The session will bring researchers bridging basic and clinical sciences from the fields of auditory and speech perception and neuroscience, musical training, hearing aids and cochlear implants, to explore together the potentials and limitations of effects of musical training throughout the lifespan. To our knowledge, ARO has not hosted such a session in recent years.

Presenter Diversity The proposed list of speakers is highly diverse in terms of gender, geographical location, ethnic/racial background, and academic career stage.

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Signature DB

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Musical Training and Hearing-In-Noise Perception

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Emily Coffey

Affiliation   Concordia University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Musical training is a powerful and well-studied model of human neuroplasticity, which harnesses emotional and reward networks and auditory-motor feedback loops to sharpen and reinforce practised skills. It is thought to improve the quality of basic auditory encoding and higher-level functions such as selective attention and working memory. Both sound encoding quality and higher-level functions are important for perceptual skills outside of a musical context, such as speech-in-noise perception, which strongly influences health and well-being. Musical training is an attractive avenue for potentially enhancing poor or degraded perceptual skills; however, the specific nature of musical training benefits, particularly for speech-in-noise perception, is not yet clear. I will present our lab's recent work using electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) to explore the relationship between musicianship, perceptual skills, and neurophysiology. I will also discuss the design of musical tasks for encouraging neuroplasticity, and present some of the Open Science tools we have developed to facilitate and encourage research progress in these areas.

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First Name	Last Name	Affiliation
Emily *	Coffey *	Concordia University

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Signature Emily Coffey

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Neural Correlates of Auditory Processing in Individuals Engaged in Music Training – a Perspective across the Lifespan

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Assal Habibi

Affiliation   Univeristy of Southern California

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Playing a musical instrument is a complex multisensory experience requiring several skills including reading and translating abstract musical notation to fine and coordinated motor movements in order to produce a sound. The mastering of this rich and demanding process requires regular and intense practice, often from a young age. While there is a growing body of evidence suggesting that music training benefits cognitive development, the associations between music training and health outcomes specifically in relation to improvement of auditory and language skills is not clear. This presentation will highlight a series of research studies on the role of music training and associated health outcomes across the lifespan. The results from the first two studies provide evidence that music training in children and adolescents leads to improvement of pitch and rhythm perception, speech in noise perception and neuroplastic functional changes in the associated auditory regions that may have long-term positive effects on language development and competency. Results from the third study provide evidence that participating in short-term musical activities leads to better speech in noise perception in older adults without prior music training – and adding to the accumulating evidence that engaging in enrichment activities, such as choir singing provide a cost-effective and sustainable community-based intervention to improve auditory and communication abilities in aging adults. These findings together demonstrate that brain-to-behavior changes induced by music training can positive health and well-being outcomes specifically in relation to auditory abilities, language, and communication skills in individuals across the lifespan.

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Assal *	Habibi *	Univeristy of Southern California

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Signature Assal Habibi

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

What Benefits Can We Derive from Music Training for Cochlear-Implanted individuals?

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Eleanor Harding

Affiliation   University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Cochlear implant users report difficulties perceiving music and certain aspects of speech, such as vocal cues and emotions, and 'cocktail-party' speech in multi-talker noise. While evidence exists supporting music as a training tool to improve music and speech perception, results are not unanimous across studies and the precise mechanisms that may contribute to both near- (music domain) and far- (speech domain) transfer training effects are not well understood. Previous research, including from our group, has indicated that musically trained individuals show advantages in perceptual tasks that involve music and pitch. We have also observed beneficial effects for perception of speech in the presence of a speech masker, but not for other maskers (such as steady noise), and also not in all populations (adults vs. adolescents). In some situations, such as perception of voice gender, we have observed musician and non-musician groups weighting voice cues differently than each other, but with no clear benefit from being a musician. Taken together, this evidence suggests that musical training may be a beneficial tool for improving these areas of auditory perception in cochlear implant users. However, perhaps the overall picture is more complex than we can easily characterize: the influence of musical training on psychoacoustic tasks varies across the literature, moreover, musical training is reported to variably affect cognitive processes such as auditory working memory and neural tracking of the acoustic envelope of music and speech. These cognitive processes may influence performance on certain tasks, such as speech-on-speech perception, via top-down processes. In this talk, we will cover our previous and current work with musicians, on potential musician and music training effects and their mechanistic origins, and how we try to utilize this knowledge in developing new ways of using music as an auditory training tool.

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First Name	Last Name	Affiliation
Eleanor *	Harding *	University Medical Center Groningen
Deniz	Başkent	University of Groningen, University Medical Center Groningen

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Signature Eleanor Harding

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Music Training and Nonmusical abilities: The Role of Natural Musical Ability

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   E. Glenn Schellenberg

Affiliation   University of Toronto Mississauga

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Music training is associated with many nonmusical abilities, including those involving listening to speech or other auditory stimuli, as well as general cognitive ability. Individuals with training often show an advantage on tasks that measure these skills, and such advantages are assumed to be a consequence of music training. In fact, music training is often claimed to be a good (even ideal) model for the study of changes in brain and behavior that occur as the result of experience (i.e., plasticity). In recent years, however, research from my laboratory raises doubts about these claims. We have documented that individuals with music training differ systematically from other individuals in terms of demographics, personality, cognition, and natural musical ability (aptitude or talent), which are unlikely to be the consequence of any intervention or experiential factor. Moreover, evidence from twin studies points to a genetic component to musicality and music achievement, which raises further doubts about the proposed causal effect of music training, as do findings showing that transfer effects are rare. Rather, individuals from high-SES families who also have good cognitive abilities, high levels of the personality trait called openness-to-experience, and a facility for music are more likely than other individuals to take music lessons, particularly for years on end. Results in line with this view show that: (1) speech perception and grammatical ability have a stronger association with musical ability than with music training, (2) the association between music training and reading ability disappears when general cognitive ability is held constant, (3) the link between music training and cognitive ability disappears when musical ability is held constant, and (4) non-musical variables that predict music training also predict musical ability. In a five-year longitudinal study, musical ability at 8 years of age predicted the amount of music training taken subsequently. By contrast, at 13 years of age, links between music training and musical ability disappeared when musical ability at age 8 was held constant. These results, as well as those from independent laboratories, ensure that music training is a particularly poor model for the study of plasticity.

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E. Glenn *	Schellenberg *	University of Toronto Mississauga

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Signature E. Glenn Schellenberg

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To understand the benefits of musical training on speech perception we need to focus on the assessment of musical skills and the initiation of adequately powered intervention studies

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Frank Russo

Affiliation   Toronto Metropolitan University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract The evidence for the benefits of music training on speech processing and perception have been difficult to pin down. While correlation and cross-sectional studies abound, the evidence has been mixed and enthusiasm about positive findings are clouded by legitimate questions regarding confounding variables. The mixed evidence is not exactly surprising. The types of musical skills that a musician will possess as there is no accepted canon for musical training (e.g., learning percussion vs. violin; playing by ear or notation), and individuals will come to training with varying predispositions. Thus, I will argue that it is generally not satisfactory to simply count the number of years of musical training or to create a binary split between musicians and non-musicians when accounting for effects of music training. Correlational studies would be better served by modelling speech perception skills on the basis of specific musical skills that are assessed through experiment. The studies that have initiated a musical training intervention are more informative as they control the manor of training across participants and are able to take individual baselines into account. However, these studies have by-and-large been hindered by small and heterogenous samples. Moreover, the control conditions are often passive, leaving open the possibility that benefits accrue simply from adding a new activity or even worse, demand characteristics. In my own lab, we have completed three studies involving music training interventions, all in participants with some level of hearing loss. None of these studies is perfect and all suffer from relatively small sample sizes. Nevertheless, we have observed some positive outcomes. Our study on children who use cochlear implants showed benefits on perception of speech emotion. Our study on older adults with hearing loss showed benefits on speech perception in noise. Our study on older adults with hearing loss who use hearing aids, showed no benefits for speech perception in noise or emotion. However, in examining the baseline data we did observe

correlations between musical skills (e.g., rhythm perception) and speech perception in noise. My current view is that musical training may benefit speech processing and perception but the effects are highly variable. Future correlational studies should assess musical skills and speech perception in large cohorts of participants. In addition, multi-site training intervention studies should be undertaken allowing for larger sample sizes and the multi-level modelling of group- and individual-level predictors.

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Frank *	Russo *	Toronto Metropolitan University

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Signature FAR

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Effects of Singing and Musical Training to Speech Perception and Language Skills of Children with Hearing Impairments

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Ritva Torppa

Affiliation   Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract There is growing body of evidence from follow-up studies and randomized controlled trials on the positive effects of musical training to perception of pitch, music and speech, to cognitive and language skills, and to associated brain networks in adults and children with normal hearing (NH). Musical training is expected to lead to similar effects for children with hearing impairments (HI) since they enjoy music and singing similarly to children with NH.
Even though the field of HI is still lacking large-scale randomized controlled trials, the current evidence shows that musical training and even informal singing at home can lead to similar positive effects in children with HI as found in children with NH. For instance, a longitudinal study showed that the attention-related P3a brain responses to changes in pitch and timbre were larger and developed more in children with CIs who sang regularly at home than in their peers with CIs who did not sing. In another study, the children with CIs who participated in musical hobbies were better in perception of pitch and prosodic stress and in expressive language skills (word finding, verbal IQ and phonological awareness measured with rhyming) compared to musically non-active children with CIs. Moreover, a longitudinal study showed that perception of speech in noise, timbre, question/statement prosody and spectral resolution improved only in the children with HI participating in musical training while not in the passive control group. The preliminary results from our new cross-over design study imply that musical intervention, which focused on singing, improved expressive language skills (e.g., semantic word fluency) of 2-6 years old children with HI. Regarding to pitch perception, the development during intervention varied in a sample of 3-6 years old children with HI, some of them showing clear development.

This presentation will show why music can improve speech and music processing and perception as

well as language skills of children with HI. The current evidence suggests that it would be beneficial for children with HI to sing at home and take part in musical hobbies and training.

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Lotta	Seppänen	Psychology and Logopedics, Cognitive Brain Research Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland
Seija	Pekkala	Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland
Valerie	Looi	The University of QLD, Australia

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Signature Ritva Torppa

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Association of Musical Training with Auditory and Speech Neural Coding and Perception

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Kelly Whiteford

Affiliation   University of Minnesota

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Numerous studies have reported a link between engagement in musical training and enhanced neural processing and perception of sound, ranging from fine-grained pitch discrimination to the perception of speech in noise, with training-related neural changes emerging as early in the auditory pathways as the brainstem or even the cochlea. Such findings suggest a role for experience-dependent plasticity in the early auditory system, which may have meaningful perceptual consequences. However, the generalizability of the musician advantage remains unclear. For example, small-sized samples often represent extreme ends of the musical spectrum; the nature and magnitudes of the musician advantage are sometimes small or inconsistent; and methodological differences and varying analytical techniques complicate comparisons between studies. This multi-site study aims to examine the robustness of the musician advantage across the adult lifespan by replicating and extending eight key experiments involving both perception and neural coding across a large sample of listeners (n > 300) at six universities in the US and Canada (Boston University, Carnegie Mellon University, Purdue University, University of Minnesota, University of Rochester, and University of Western Ontario). All participants were tested on all 8 experiments in a laboratory setting, including pitch discrimination, behavioral estimates of frequency tuning, speech and non-speech informational masking, speech perception in noise and babble, and two physiological measures of F0 encoding of speech sounds using electroencephalography. Data collection is ongoing, but so far data from over 200 participants have been collected. Participants also completed additional measures to control for potential confounding factors, including an objective measure of musical aptitude (melody discrimination from the Mini Profile of Music Perception Skills), a cognitive assessment (Ravens Advanced Progressive Matrices), a measure of extended high-frequency hearing, and survey questions related to personality and socio-economic status. Formal statistical analyses were preregistered on the

Open Science Framework and will be conducted once data collection is complete. The results will provide in-depth and high-powered insight on the nature and robustness of the musician advantage across the adult lifespan. [Supported by NSF-BCS grant 1840818.]

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Kelly *	Whiteford *	University of Minnesota
Hari	Bharadwaj	Purdue University
Ingrid	Johnsrude	University of Western Ontario
Gerald	Kidd Jr.	Boston University
Anne	Luebke	University of Rochester
Ross	Maddox	University of Rochester
Elizabeth	Marvin	University of Rochester
Tyler	Perrachione	Boston University
Barbara	Shinn-Cunningham	Carnegie Mellon University
Andrew J.	Oxenham	University of Minnesota

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Signature Kelly Whiteford

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Deniz Başkent

Affiliation   University of Groningen, University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Session Description Music is found in every human culture. Performing involves fine-grained motor, cognitive, multimodal-integration, and aesthetic skills; listening critically involves almost as many. Perhaps most importantly, music is fun. The enjoyable and social aspects of music could make it a powerful and motivating vehicle for auditory training, particularly in a clinical setting among those with hearing loss and cochlear implants. But does musical training improve skills beyond music, such as speech perception in noise and more general cognitive abilities? Can musical training protect against some aging effects in these domains? Many studies have addressed these questions in recent years without reaching a common consensus. The purpose of this symposium is to bring together researchers who have been actively contributing to this debate, to assess current evidence and opinions, to seek common ground, and to chart a way forward to answer these important questions. The session will bring researchers bridging basic and clinical sciences from the fields of auditory and speech perception and neuroscience, musical training, hearing aids and cochlear implants, to explore together the potentials and limitations of effects of musical training throughout the lifespan. To our knowledge, ARO has not hosted such a session in recent years.

Presenter Diversity The proposed list of speakers is highly diverse in terms of gender, geographical location, ethnic/racial background, and academic career stage.

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Signature DB

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Musical Training and Hearing-In-Noise Perception

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Emily Coffey

Affiliation   Concordia University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Musical training is a powerful and well-studied model of human neuroplasticity, which harnesses emotional and reward networks and auditory-motor feedback loops to sharpen and reinforce practised skills. It is thought to improve the quality of basic auditory encoding and higher-level functions such as selective attention and working memory. Both sound encoding quality and higher-level functions are important for perceptual skills outside of a musical context, such as speech-in-noise perception, which strongly influences health and well-being. Musical training is an attractive avenue for potentially enhancing poor or degraded perceptual skills; however, the specific nature of musical training benefits, particularly for speech-in-noise perception, is not yet clear. I will present our lab's recent work using electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) to explore the relationship between musicianship, perceptual skills, and neurophysiology. I will also discuss the design of musical tasks for encouraging neuroplasticity, and present some of the Open Science tools we have developed to facilitate and encourage research progress in these areas.

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First Name	Last Name	Affiliation
Emily *	Coffey *	Concordia University

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Signature Emily Coffey

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Neural Correlates of Auditory Processing in Individuals Engaged in Music Training – a Perspective across the Lifespan

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Assal Habibi

Affiliation   Univeristy of Southern California

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Playing a musical instrument is a complex multisensory experience requiring several skills including reading and translating abstract musical notation to fine and coordinated motor movements in order to produce a sound. The mastering of this rich and demanding process requires regular and intense practice, often from a young age. While there is a growing body of evidence suggesting that music training benefits cognitive development, the associations between music training and health outcomes specifically in relation to improvement of auditory and language skills is not clear. This presentation will highlight a series of research studies on the role of music training and associated health outcomes across the lifespan. The results from the first two studies provide evidence that music training in children and adolescents leads to improvement of pitch and rhythm perception, speech in noise perception and neuroplastic functional changes in the associated auditory regions that may have long-term positive effects on language development and competency. Results from the third study provide evidence that participating in short-term musical activities leads to better speech in noise perception in older adults without prior music training – and adding to the accumulating evidence that engaging in enrichment activities, such as choir singing provide a cost-effective and sustainable community-based intervention to improve auditory and communication abilities in aging adults. These findings together demonstrate that brain-to-behavior changes induced by music training can positive health and well-being outcomes specifically in relation to auditory abilities, language, and communication skills in individuals across the lifespan.

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Assal *	Habibi *	Univeristy of Southern California

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Signature Assal Habibi

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

What Benefits Can We Derive from Music Training for Cochlear-Implanted individuals?

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Eleanor Harding

Affiliation   University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Cochlear implant users report difficulties perceiving music and certain aspects of speech, such as vocal cues and emotions, and 'cocktail-party' speech in multi-talker noise. While evidence exists supporting music as a training tool to improve music and speech perception, results are not unanimous across studies and the precise mechanisms that may contribute to both near- (music domain) and far- (speech domain) transfer training effects are not well understood. Previous research, including from our group, has indicated that musically trained individuals show advantages in perceptual tasks that involve music and pitch. We have also observed beneficial effects for perception of speech in the presence of a speech masker, but not for other maskers (such as steady noise), and also not in all populations (adults vs. adolescents). In some situations, such as perception of voice gender, we have observed musician and non-musician groups weighting voice cues differently than each other, but with no clear benefit from being a musician. Taken together, this evidence suggests that musical training may be a beneficial tool for improving these areas of auditory perception in cochlear implant users. However, perhaps the overall picture is more complex than we can easily characterize: the influence of musical training on psychoacoustic tasks varies across the literature, moreover, musical training is reported to variably affect cognitive processes such as auditory working memory and neural tracking of the acoustic envelope of music and speech. These cognitive processes may influence performance on certain tasks, such as speech-on-speech perception, via top-down processes. In this talk, we will cover our previous and current work with musicians, on potential musician and music training effects and their mechanistic origins, and how we try to utilize this knowledge in developing new ways of using music as an auditory training tool.

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Deniz	Başkent	University of Groningen, University Medical Center Groningen

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Signature Eleanor Harding

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Music Training and Nonmusical abilities: The Role of Natural Musical Ability

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   E. Glenn Schellenberg

Affiliation   University of Toronto Mississauga

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Music training is associated with many nonmusical abilities, including those involving listening to speech or other auditory stimuli, as well as general cognitive ability. Individuals with training often show an advantage on tasks that measure these skills, and such advantages are assumed to be a consequence of music training. In fact, music training is often claimed to be a good (even ideal) model for the study of changes in brain and behavior that occur as the result of experience (i.e., plasticity). In recent years, however, research from my laboratory raises doubts about these claims. We have documented that individuals with music training differ systematically from other individuals in terms of demographics, personality, cognition, and natural musical ability (aptitude or talent), which are unlikely to be the consequence of any intervention or experiential factor. Moreover, evidence from twin studies points to a genetic component to musicality and music achievement, which raises further doubts about the proposed causal effect of music training, as do findings showing that transfer effects are rare. Rather, individuals from high-SES families who also have good cognitive abilities, high levels of the personality trait called openness-to-experience, and a facility for music are more likely than other individuals to take music lessons, particularly for years on end. Results in line with this view show that: (1) speech perception and grammatical ability have a stronger association with musical ability than with music training, (2) the association between music training and reading ability disappears when general cognitive ability is held constant, (3) the link between music training and cognitive ability disappears when musical ability is held constant, and (4) non-musical variables that predict music training also predict musical ability. In a five-year longitudinal study, musical ability at 8 years of age predicted the amount of music training taken subsequently. By contrast, at 13 years of age, links between music training and musical ability disappeared when musical ability at age 8 was held constant. These results, as well as those from independent laboratories, ensure that music training is a particularly poor model for the study of plasticity.

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E. Glenn *	Schellenberg *	University of Toronto Mississauga

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Signature E. Glenn Schellenberg

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

To understand the benefits of musical training on speech perception we need to focus on the assessment of musical skills and the initiation of adequately powered intervention studies

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Frank Russo

Affiliation   Toronto Metropolitan University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract The evidence for the benefits of music training on speech processing and perception have been difficult to pin down. While correlation and cross-sectional studies abound, the evidence has been mixed and enthusiasm about positive findings are clouded by legitimate questions regarding confounding variables. The mixed evidence is not exactly surprising. The types of musical skills that a musician will possess as there is no accepted canon for musical training (e.g., learning percussion vs. violin; playing by ear or notation), and individuals will come to training with varying predispositions. Thus, I will argue that it is generally not satisfactory to simply count the number of years of musical training or to create a binary split between musicians and non-musicians when accounting for effects of music training. Correlational studies would be better served by modelling speech perception skills on the basis of specific musical skills that are assessed through experiment. The studies that have initiated a musical training intervention are more informative as they control the manor of training across participants and are able to take individual baselines into account. However, these studies have by-and-large been hindered by small and heterogenous samples. Moreover, the control conditions are often passive, leaving open the possibility that benefits accrue simply from adding a new activity or even worse, demand characteristics. In my own lab, we have completed three studies involving music training interventions, all in participants with some level of hearing loss. None of these studies is perfect and all suffer from relatively small sample sizes. Nevertheless, we have observed some positive outcomes. Our study on children who use cochlear implants showed benefits on perception of speech emotion. Our study on older adults with hearing loss showed benefits on speech perception in noise. Our study on older adults with hearing loss who use hearing aids, showed no benefits for speech perception in noise or emotion. However, in examining the baseline data we did observe

correlations between musical skills (e.g., rhythm perception) and speech perception in noise. My current view is that musical training may benefit speech processing and perception but the effects are highly variable. Future correlational studies should assess musical skills and speech perception in large cohorts of participants. In addition, multi-site training intervention studies should be undertaken allowing for larger sample sizes and the multi-level modelling of group- and individual-level predictors.

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Signature FAR

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Effects of Singing and Musical Training to Speech Perception and Language Skills of Children with Hearing Impairments

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Ritva Torppa

Affiliation   Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

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Lotta	Seppänen	Psychology and Logopedics, Cognitive Brain Research Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland
Seija	Pekkala	Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland
Valerie	Looi	The University of QLD, Australia

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Signature Ritva Torppa

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Association of Musical Training with Auditory and Speech Neural Coding and Perception

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Kelly Whiteford

Affiliation   University of Minnesota

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

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Open Science Framework and will be conducted once data collection is complete. The results will provide in-depth and high-powered insight on the nature and robustness of the musician advantage across the adult lifespan. [Supported by NSF-BCS grant 1840818.]

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First Name	Last Name	Affiliation
Kelly *	Whiteford *	University of Minnesota
Hari	Bharadwaj	Purdue University
Ingrid	Johnsrude	University of Western Ontario
Gerald	Kidd Jr.	Boston University
Anne	Luebke	University of Rochester
Ross	Maddox	University of Rochester
Elizabeth	Marvin	University of Rochester
Tyler	Perrachione	Boston University
Barbara	Shinn-Cunningham	Carnegie Mellon University
Andrew J.	Oxenham	University of Minnesota

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Signature Kelly Whiteford

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Deniz Başkent

Affiliation   University of Groningen, University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Session Description Music is found in every human culture. Performing involves fine-grained motor, cognitive, multimodal-integration, and aesthetic skills; listening critically involves almost as many. Perhaps most importantly, music is fun. The enjoyable and social aspects of music could make it a powerful and motivating vehicle for auditory training, particularly in a clinical setting among those with hearing loss and cochlear implants. But does musical training improve skills beyond music, such as speech perception in noise and more general cognitive abilities? Can musical training protect against some aging effects in these domains? Many studies have addressed these questions in recent years without reaching a common consensus. The purpose of this symposium is to bring together researchers who have been actively contributing to this debate, to assess current evidence and opinions, to seek common ground, and to chart a way forward to answer these important questions. The session will bring researchers bridging basic and clinical sciences from the fields of auditory and speech perception and neuroscience, musical training, hearing aids and cochlear implants, to explore together the potentials and limitations of effects of musical training throughout the lifespan. To our knowledge, ARO has not hosted such a session in recent years.

Presenter Diversity The proposed list of speakers is highly diverse in terms of gender, geographical location, ethnic/racial background, and academic career stage.

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Signature DB

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Musical Training and Hearing-In-Noise Perception

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Emily Coffey

Affiliation   Concordia University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Musical training is a powerful and well-studied model of human neuroplasticity, which harnesses emotional and reward networks and auditory-motor feedback loops to sharpen and reinforce practised skills. It is thought to improve the quality of basic auditory encoding and higher-level functions such as selective attention and working memory. Both sound encoding quality and higher-level functions are important for perceptual skills outside of a musical context, such as speech-in-noise perception, which strongly influences health and well-being. Musical training is an attractive avenue for potentially enhancing poor or degraded perceptual skills; however, the specific nature of musical training benefits, particularly for speech-in-noise perception, is not yet clear. I will present our lab's recent work using electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) to explore the relationship between musicianship, perceptual skills, and neurophysiology. I will also discuss the design of musical tasks for encouraging neuroplasticity, and present some of the Open Science tools we have developed to facilitate and encourage research progress in these areas.

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Signature Emily Coffey

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Neural Correlates of Auditory Processing in Individuals Engaged in Music Training – a Perspective across the Lifespan

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Assal Habibi

Affiliation   Univeristy of Southern California

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Playing a musical instrument is a complex multisensory experience requiring several skills including reading and translating abstract musical notation to fine and coordinated motor movements in order to produce a sound. The mastering of this rich and demanding process requires regular and intense practice, often from a young age. While there is a growing body of evidence suggesting that music training benefits cognitive development, the associations between music training and health outcomes specifically in relation to improvement of auditory and language skills is not clear. This presentation will highlight a series of research studies on the role of music training and associated health outcomes across the lifespan. The results from the first two studies provide evidence that music training in children and adolescents leads to improvement of pitch and rhythm perception, speech in noise perception and neuroplastic functional changes in the associated auditory regions that may have long-term positive effects on language development and competency. Results from the third study provide evidence that participating in short-term musical activities leads to better speech in noise perception in older adults without prior music training – and adding to the accumulating evidence that engaging in enrichment activities, such as choir singing provide a cost-effective and sustainable community-based intervention to improve auditory and communication abilities in aging adults. These findings together demonstrate that brain-to-behavior changes induced by music training can positive health and well-being outcomes specifically in relation to auditory abilities, language, and communication skills in individuals across the lifespan.

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Signature Assal Habibi

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

What Benefits Can We Derive from Music Training for Cochlear-Implanted individuals?

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Eleanor Harding

Affiliation   University Medical Center Groningen

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Cochlear implant users report difficulties perceiving music and certain aspects of speech, such as vocal cues and emotions, and 'cocktail-party' speech in multi-talker noise. While evidence exists supporting music as a training tool to improve music and speech perception, results are not unanimous across studies and the precise mechanisms that may contribute to both near- (music domain) and far- (speech domain) transfer training effects are not well understood. Previous research, including from our group, has indicated that musically trained individuals show advantages in perceptual tasks that involve music and pitch. We have also observed beneficial effects for perception of speech in the presence of a speech masker, but not for other maskers (such as steady noise), and also not in all populations (adults vs. adolescents). In some situations, such as perception of voice gender, we have observed musician and non-musician groups weighting voice cues differently than each other, but with no clear benefit from being a musician. Taken together, this evidence suggests that musical training may be a beneficial tool for improving these areas of auditory perception in cochlear implant users. However, perhaps the overall picture is more complex than we can easily characterize: the influence of musical training on psychoacoustic tasks varies across the literature, moreover, musical training is reported to variably affect cognitive processes such as auditory working memory and neural tracking of the acoustic envelope of music and speech. These cognitive processes may influence performance on certain tasks, such as speech-on-speech perception, via top-down processes. In this talk, we will cover our previous and current work with musicians, on potential musician and music training effects and their mechanistic origins, and how we try to utilize this knowledge in developing new ways of using music as an auditory training tool.

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Signature Eleanor Harding

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Music Training and Nonmusical abilities: The Role of Natural Musical Ability

Submission ID   3003162

Submission Type Symposia

Topic   Speech Perception

Status   Submitted

Submitter   E. Glenn Schellenberg

Affiliation   University of Toronto Mississauga

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Music training is associated with many nonmusical abilities, including those involving listening to speech or other auditory stimuli, as well as general cognitive ability. Individuals with training often show an advantage on tasks that measure these skills, and such advantages are assumed to be a consequence of music training. In fact, music training is often claimed to be a good (even ideal) model for the study of changes in brain and behavior that occur as the result of experience (i.e., plasticity). In recent years, however, research from my laboratory raises doubts about these claims. We have documented that individuals with music training differ systematically from other individuals in terms of demographics, personality, cognition, and natural musical ability (aptitude or talent), which are unlikely to be the consequence of any intervention or experiential factor. Moreover, evidence from twin studies points to a genetic component to musicality and music achievement, which raises further doubts about the proposed causal effect of music training, as do findings showing that transfer effects are rare. Rather, individuals from high-SES families who also have good cognitive abilities, high levels of the personality trait called openness-to-experience, and a facility for music are more likely than other individuals to take music lessons, particularly for years on end. Results in line with this view show that: (1) speech perception and grammatical ability have a stronger association with musical ability than with music training, (2) the association between music training and reading ability disappears when general cognitive ability is held constant, (3) the link between music training and cognitive ability disappears when musical ability is held constant, and (4) non-musical variables that predict music training also predict musical ability. In a five-year longitudinal study, musical ability at 8 years of age predicted the amount of music training taken subsequently. By contrast, at 13 years of age, links between music training and musical ability disappeared when musical ability at age 8 was held constant. These results, as well as those from independent laboratories, ensure that music training is a particularly poor model for the study of plasticity.

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Signature E. Glenn Schellenberg

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

To understand the benefits of musical training on speech perception we need to focus on the assessment of musical skills and the initiation of adequately powered intervention studies

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Frank Russo

Affiliation   Toronto Metropolitan University

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract The evidence for the benefits of music training on speech processing and perception have been difficult to pin down. While correlation and cross-sectional studies abound, the evidence has been mixed and enthusiasm about positive findings are clouded by legitimate questions regarding confounding variables. The mixed evidence is not exactly surprising. The types of musical skills that a musician will possess as there is no accepted canon for musical training (e.g., learning percussion vs. violin; playing by ear or notation), and individuals will come to training with varying predispositions. Thus, I will argue that it is generally not satisfactory to simply count the number of years of musical training or to create a binary split between musicians and non-musicians when accounting for effects of music training. Correlational studies would be better served by modelling speech perception skills on the basis of specific musical skills that are assessed through experiment. The studies that have initiated a musical training intervention are more informative as they control the manor of training across participants and are able to take individual baselines into account. However, these studies have by-and-large been hindered by small and heterogenous samples. Moreover, the control conditions are often passive, leaving open the possibility that benefits accrue simply from adding a new activity or even worse, demand characteristics. In my own lab, we have completed three studies involving music training interventions, all in participants with some level of hearing loss. None of these studies is perfect and all suffer from relatively small sample sizes. Nevertheless, we have observed some positive outcomes. Our study on children who use cochlear implants showed benefits on perception of speech emotion. Our study on older adults with hearing loss showed benefits on speech perception in noise. Our study on older adults with hearing loss who use hearing aids, showed no benefits for speech perception in noise or emotion. However, in examining the baseline data we did observe

correlations between musical skills (e.g., rhythm perception) and speech perception in noise. My current view is that musical training may benefit speech processing and perception but the effects are highly variable. Future correlational studies should assess musical skills and speech perception in large cohorts of participants. In addition, multi-site training intervention studies should be undertaken allowing for larger sample sizes and the multi-level modelling of group- and individual-level predictors.

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Signature FAR

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Effects of Singing and Musical Training to Speech Perception and Language Skills of Children with Hearing Impairments

Submission ID 3003162

Submission Type Symposia

Topic Speech Perception

Status Submitted

Submitter Ritva Torppa

Affiliation Psychology and Logopedics, Cognitive Brain Unit (CBRU), Faculty of Medicine, University of Helsinki, Finland

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SUBMISSION DETAILS

Individual Abstract There is growing body of evidence from follow-up studies and randomized controlled trials on the positive effects of musical training to perception of pitch, music and speech, to cognitive and language skills, and to associated brain networks in adults and children with normal hearing (NH). Musical training is expected to lead to similar effects for children with hearing impairments (HI) since they enjoy music and singing similarly to children with NH.
Even though the field of HI is still lacking large-scale randomized controlled trials, the current evidence shows that musical training and even informal singing at home can lead to similar positive effects in children with HI as found in children with NH. For instance, a longitudinal study showed that the attention-related P3a brain responses to changes in pitch and timbre were larger and developed more in children with CIs who sang regularly at home than in their peers with CIs who did not sing. In another study, the children with CIs who participated in musical hobbies were better in perception of pitch and prosodic stress and in expressive language skills (word finding, verbal IQ and phonological awareness measured with rhyming) compared to musically non-active children with CIs. Moreover, a longitudinal study showed that perception of speech in noise, timbre, question/statement prosody and spectral resolution improved only in the children with HI participating in musical training while not in the passive control group. The preliminary results from our new cross-over design study imply that musical intervention, which focused on singing, improved expressive language skills (e.g., semantic word fluency) of 2-6 years old children with HI. Regarding to pitch perception, the development during intervention varied in a sample of 3-6 years old children with HI, some of them showing clear development.

This presentation will show why music can improve speech and music processing and perception as

well as language skills of children with HI. The current evidence suggests that it would be beneficial for children with HI to sing at home and take part in musical hobbies and training.

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Signature Ritva Torppa

Music to Our ears: Does Musical Training Improve Auditory and Speech Processing and Perception?

Association of Musical Training with Auditory and Speech Neural Coding and Perception

Submission ID   3003162

Submission Type   Symposia

Topic   Speech Perception

Status   Submitted

Submitter   Kelly Whiteford

Affiliation   University of Minnesota

Participant(s)   Deniz Başkent (Chair), Andrew Oxenham (Co-chair), Emily Coffey (Presenter), Assal Habibi (Presenter), Eleanor Harding (Presenter), Frank Russo (Presenter), E. Glenn Schellenberg (Presenter), Ritva Torppa (Presenter), Kelly Whiteford (Presenter)

SUBMISSION DETAILS

Individual Abstract Numerous studies have reported a link between engagement in musical training and enhanced neural processing and perception of sound, ranging from fine-grained pitch discrimination to the perception of speech in noise, with training-related neural changes emerging as early in the auditory pathways as the brainstem or even the cochlea. Such findings suggest a role for experience-dependent plasticity in the early auditory system, which may have meaningful perceptual consequences. However, the generalizability of the musician advantage remains unclear. For example, small-sized samples often represent extreme ends of the musical spectrum; the nature and magnitudes of the musician advantage are sometimes small or inconsistent; and methodological differences and varying analytical techniques complicate comparisons between studies. This multi-site study aims to examine the robustness of the musician advantage across the adult lifespan by replicating and extending eight key experiments involving both perception and neural coding across a large sample of listeners (n > 300) at six universities in the US and Canada (Boston University, Carnegie Mellon University, Purdue University, University of Minnesota, University of Rochester, and University of Western Ontario). All participants were tested on all 8 experiments in a laboratory setting, including pitch discrimination, behavioral estimates of frequency tuning, speech and non-speech informational masking, speech perception in noise and babble, and two physiological measures of F0 encoding of speech sounds using electroencephalography. Data collection is ongoing, but so far data from over 200 participants have been collected. Participants also completed additional measures to control for potential confounding factors, including an objective measure of musical aptitude (melody discrimination from the Mini Profile of Music Perception Skills), a cognitive assessment (Ravens Advanced Progressive Matrices), a measure of extended high-frequency hearing, and survey questions related to personality and socio-economic status. Formal statistical analyses were preregistered on the

Open Science Framework and will be conducted once data collection is complete. The results will provide in-depth and high-powered insight on the nature and robustness of the musician advantage across the adult lifespan. [Supported by NSF-BCS grant 1840818.]

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