

**Faculté des lettres et sciences
humaines**

École de musique

Andrea Gozzi
Professeur adjoint
(électroacoustique et sound design)

Bureau : C3-2157
Telephone : 819 821-8000
Poste : 61068
Andrea.Gozzi@USherbrooke.ca

Sherbrooke, 6 May 2025

Objet: Agile Seed Funding - end of award summary report

Recipient: Andrea Gozzi (Université de Montréal et Université de Sherbrooke), Dominic Thibault (Université de Montréal), Martha de Francisco and Gianluca Grazioli (McGill University)

Project Title: *Music performance in audio augmented reality: new acoustic spaces using bone conduction headphones*

Award Period: April 25, 2024 – May 6, 2025

Purpose of the funds

The funds were employed according to the budget submitted with the project proposal, with minor adjustments (table 1). Specifically, \$1,480 were allocated to Gianluca Grazioli (PhD student, McGill University) for 40 hours of research assistance. His role included immersive recordings in multiple formats (binaural, ambisonic, etc.), and technical setup in both Tanna Schulich Hall and the Immersive Lab (ImLab, McGill). Seven musicians were recruited for the study (a vocalist, a pianist, a string quartet, and a trumpet player), each receiving \$250 for their participation, totaling \$1,750. Equipment rental costs for bone conduction headphones (AfterShokz Sportz Titanium) and radio receivers/transmitters (MIPRO 909R RX/TX) amounted to \$1,560. An additional \$210 covered batteries, cables, and miscellaneous hardware needed throughout the research process. In total, \$5,000 were fully utilized.

Achievement of the main goal

The principal objective of the project was to collect and analyze data from musicians performing with virtual acoustics via bone conduction headphones (BCHs), and to compare these performances with other virtual acoustic systems and a reference concert hall. This goal was fully achieved. Seven musicians participated in two experimental sessions (November 14 and December 5, 2024), performing the same piece under five different conditions.

Staff costs	N.	
Research assistant	1 (40h)	1,480 \$
Professional and technical services		
Quartet	4 (4h)	(250) 1,000 \$
Singer	1 (4h)	250 \$
Pianist	1 (4h)	250 \$
Trumpeter	1 (4h)	250 \$
Equipment purchase		
Rent BCHs wired “Aftershokz Sportz Titanium” (1 year)	14	490 \$
Rent radio receivers RX MIPRO 909R (1 year)	14	770 \$
Rent audio transmitters (1 year)	2	300 \$
Miscellaneous hardware		
Batteries, cables, adapters, etc.		210 \$
TOT.		5,000 \$

Table 1: budget

Tests took place in: studio ImLab without reverberation; studio ImLab using real-time convolution reverb via BCHs; studio ImLab using real-time convolution reverb via loudspeakers Virtual Acoustics Technology (VAT); studio ImLab using real-time convolution reverb via traditional air conduction headphones (ACHs); and in Tanna Schulich Hall (performance in the actual concert hall).

Impulse responses (IR) for convolution were measured in Tanna Schulich Hall and used consistently across conditions. Audio levels were calibrated identically across all conditions. Musicians also completed a questionnaire after their tests.

Challenges and unexpected developments

In addition to the planned activities, spontaneous collaboration with postdoctoral researcher Alessandro Braga (École de technologie supérieure, ÉTS, Montréal) allowed for supplementary EEG recordings of musicians during the tests. To conduct these, we successfully obtained ethical approval from the *Comité d'éthique de la recherche en arts et humanités* (CERAH), Université de Montréal. This additional dataset has enriched our understanding of performer perception in augmented acoustic environments and

provided valuable insight into refining experimental protocols and identifying future research directions (notably, focusing on vocalists).

Additional outcomes

The preliminary results enabled the submission of a larger-scale grant application (CRSH *Développement Savoir* program) in collaboration with Université de Montréal (Faculté de musique) and Université de Sherbrooke (école de musique and faculté de génie), currently under review (decision expected June 2025).

Furthermore, prototypes of audio augmented reality experiences for musicians were showcased to both researchers and the public at the *CIRMMT@UdS Agora* event (March 2025): <https://www.cirmmt.org/en/events/workshops/research/cirmmt-udes-14mar2025>.

Our research abstract was also selected for presentation at the *188th Meeting of the Acoustical Society of America (ASA)* in New Orleans (May 2025) : <https://acousticalsociety.org/new-orleans-2025/>

A full article on our findings will be published in the *Proceedings of Meetings on Acoustics (POMA)* in 2026.

Impact on CIRMMT and its community

This project has advanced CIRMMT's research agenda in the underexplored field of audio augmented reality using bone conduction, establishing novel practices and methodologies. It has strengthened inter-university collaborations and contributed to securing new funding opportunities, positioning CIRMMT at the forefront of innovative research in spatial audio: this is the first research in our knowledge on auralization in real time for musical practice via BCHs.

Conclusion

In summary, the Agile Seed Funding provided essential support that enabled meaningful advancements in the field of audio augmented reality through bone conduction technology. The outcomes have laid a solid foundation for future research, collaborations, and dissemination.

We express our sincere gratitude to CIRMMT for its support of this initiative.

Best regards,
Andrea Gozzi

