Between Intimacy and Immensity: Composing Multilayered Immersive Live Music for Bone Conduction Headphones and a Speaker-Dome Array

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Figure 1: ***Concert augmenté,*** **SAT, Montreal, Canada. Credits: Caroline Campeau**

Abstract

This paper presents a research-creation framework for composing immersive live music in multilayered listening environments that combine bone conduction headphones (BCHs), a speaker-dome array (SDA), and acoustic sources, examined through a public concert case study. A group of composers created four new works for this setup. We situate BCHs within the broader context of audio augmented reality (AAR) experiences and detail the distinctive features of the case study. Using a multi-author autoethnographic approach, we provide practice-based reflections on the compositional and performance processes from the composers' perspective. The study explores an intimacy–immensity aesthetic continuum in immersive live music, where BCHs create a private, personal listening layer, and SDA enables a shared, collective sound environment. Acoustic sources move with the performers as their proximity to the audience shifts, enabling seamless transitions between individual and communal listening experiences. Challenges, strategies, limitations, and solutions are discussed, offering practical insights for composing multilayered AAR immersive live music.

Keywords

Composition, immersive live music, bone conduction headphones, speaker-dome array, audio augmented reality

1 Introduction

Bone conduction (BC) transmits sound vibrations directly through the skull to the cochlea, bypassing the outer and middle ear, and allowing simultaneous perception of ambient and mediated audio [16], [35]. Unlike air conduction (AC), which relies on the ear canal, ossicles, and tympanic membrane [7], BC leverages bones of the skull,

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mastoid, or teeth to stimulate cochlear hair cells [16], [35], preserving open-ear listening and situational awareness [8].

Already in antiquity, Pliny the Elder noted that sound could be transmitted through solid materials [31, p. 507], while Renaissance scientists such as Cardano and Capivacci experimented with dental vibration for auditory perception [6, p. 234], [5, p. 589]. Beethoven was later reported to have used a wooden rod held between his teeth to perceive piano vibrations [32, pp. 69–70], although the historical basis of this account remains uncertain [29]. These observations, experiments, and accounts provide historical context for the development of modern commercial bone conduction headphones (BCHs) [20].

Contemporary BCHs exploit BC to deliver spatial audio in augmented and virtual environments, supporting immersive experiences [42]. Audio augmented reality (AAR), in particular, aims to augment auditory perception by overlaying virtual spatialized sounds onto listeners' actual acoustic environment [44]. BCHs are highly suitable for applications in multimedia events and concert contexts, where layered auditory perception and proximity cues can enhance both engagement and the cognitive processing of complex acoustic environments [13]. Here, "immersion" is intended in a holistic sense, spanning technology, perception, and cognitive involvement [1].

Recent artistic projects have explored these possibilities. In 2019, composer Hollie Harding integrated BCHs into a live performance at the National Maritime Museum in London, allowing the audience to simultaneously hear a pre-recorded track via BCHs and live orchestral music [21]. In 2020, the Biancane Park in Monterotondo Marittimo, Italy, became the first UNESCO site to implement geolocated audio guides and immersive sound design using BCHs, developed by Mezzo Forte SAS (Meudon, France), a company specialising in AAR applications [13]. That same year, Mezzo Forte, in collaboration with IRCAM and the Philharmonie de Paris, produced a concert with the Ensemble Intercontemporain, equipping musicians with BCHs to receive metronome cues and conductor instructions [36].

Subsequent projects include two AAR concerts by Mezzo Forte in 2021: *Da Dalí a Dante* at the Livorno Music Festival [9] and *A-Live* at Montréal's Société des arts technologiques (SAT) [3]. In both, performers and audience members wore BCHs for dual-channel listening through a hybrid stereo speaker–BCH diffusion system. In 2022, Virginia Tech hosted *Liminal Spaces*, a research concert featuring BCHs and various speaker arrays placed at different distances [19]. In 2023, Le Centre Pompidou in Paris produced *Noire*, an audiovisual installation on Claudette Colvin and 1950s Alabama segregation, featuring BCHs [24]. That same year, the Canadian film *V F C* by C. S. Roy was presented in theatres, using conventional Dolby hall audio systems in combination with BCHs for the audience [40].

Nonetheless, despite their growing adoption, only limited literature addresses the properties and constraints of BCHs in non-medical AAR and musical applications [14].

2 *Concert augmenté*: the Case Study

The project represents a research-creation initiative that, to our knowledge, is the first to integrate BCHs within an electroacoustic concert setting for a large audience. This approach enables AAR experiences in immersive live music contexts, where BCHs are combined with a speaker-dome array (SDA) diffusion alongside live acoustic sources, creating a multilayered listening environment for both performers and audience members.

The concert took place at the SAT in Montréal, Québec, Canada, on 9 October 2025 [2]. The SDA surrounded the audience, which was oriented toward the performers; there was no raised stage, and performers occupied the same floor area as the audience. The day before, approximately one hundred students attended the dress rehearsal and an accompanying talk, while the concert itself was presented to a sold-out audience of over one hundred attendees. The program featured four newly commissioned live electroacoustic works by invited composers who are also co-authors of this paper: Nicola Giannini; the Catalão–Thibault duo, formed by João Sebastião Lessa Catalão and Dominic Thibault; Ana Dall'Ara-Majek; and Kevin Gironnay. The project was led by co-author Andrea Gozzi in collaboration with Akousma, the Laval Higher Education Cluster (PLAN), the Italian Cultural Institute of Montreal, and Mezzo Forte, which provided the BCHs used in the concert [26]. The collaboration between the project lead and the composers emerged within the digital music community at the Université de Montréal. This environment, characterised by established practices in spatial music composition, provided a shared artistic context and production resources.

Technical note: Front-of-house staff distributed BCHs at entry and assisted with fitting if needed. The BCHs feed was delivered to each audience member via stereo radio receivers, allowing listeners to adjust the volume individually. Before the concert, a guided calibration procedure was used to help audience members match perceived BCHs and SDA levels. A continuous, textural mono sound was sent to SDA, while a rhythmic binaural signal with right–left motion was sent to BCHs; both were presented simultaneously. Listeners were advised to adjust the BCHs volume until both references reached comparable perceived loudness.

3 Methodology: Autoethnography

Adopting an autoethnographic approach [4], we document and analyse a practice-based research process involving the integration of BCHs into an electroacoustic concert for a large audience, from the composers' perspective.

The project unfolded over several stages: initial discussions began in 2023; the hybrid BCHs–SDA setup was presented to the composers in 2024; the concert project was confirmed in June 2025, and the public concert took place on 9 October 2025; written reflections were collected during the article-writing process between December 2025 and February 2026.

The five composers were invited by the project lead because of their research-creation interests, their experience with spatial music, and the complementarity of their creative approaches. All had professional compositional experience and were active in, or had previously trained or collaborated within, academic research-creation environments. Although their specific backgrounds differed, they all had prior experience with spatialisation practices, while none had previously composed for a multilayered BCHs–SDA hybrid setup.

To document the process, three authors designed a questionnaire, which was answered by the five composers via email after the

concert. The questions addressed five main areas: initial engagement with the hybrid setup; intentions and compositional strategies; perceptual discoveries; technical, artistic, and workflow-related limitations; and future perspectives or advice for composers approaching similar systems.

One author then analysed the responses in order to identify recurring themes, convergences, and divergences. The aim was to synthesise individual post-concert reflections into transferable insights for other artists engaging with hybrid BCHs–SDA environments.

The resulting key thematic areas informed the structure of the article: initial engagement with this multilayered environment and emerging compositional themes (Section 4), practical and technical considerations (Section 5), compositional strategies (Section 6), discussion and conclusions (Section 7).

4 Composing for a Multilayered Environment: Emerging Themes

For all composers, this project marked a first experience with BCHs as a compositional medium within a hybrid BCHs–SDA concert setting. Prior familiarity varied, ranging from no prior exposure to occasional personal use or participation in perception studies involving BCHs. Because BCHs remain marginal in concert practice, most composers approached them without an established listening repertoire or shared BCHs–SDA mixing conventions. The project lead also brought prior research and production experience with BCHs-based systems, sharing relevant context from related projects during initial meetings. The following subsections synthesise the compositional themes that emerged from these reflections.

4.1 Intimacy–Immensity

The multilayer configuration combining BCHs and an SDA suggested a specific aesthetic direction. Despite their varied stylistic backgrounds, the composers converged on a central dialectic: the tension between intimacy and immensity. This direction was a direct response to the system's affordances, which suggested a compositional space stretching from an internal voice to a shared horizon—from personal inner worlds to outer, collective, large-scale worlds. This tension between individual and collective experience became a driving force behind the compositional decisions made throughout the project.

Thibault and Lessa Catalão noted that the hybrid setup offered the possibility of speaking directly inside the listener's head, transmitting sonic information that may feel profoundly personal, almost confidential, while maintaining the communal context of a public concert. Their aim was therefore to offer a sound perspective that would be impossible in a traditional concert: a form of AAR in which intracranial listening coexists with live acoustic sources and immersive diffusion through SDA.

Similarly, Gironnay sought to explore the transition between these states—specifically, the ability to move a sound from a shared external space to one that is "literally on the skin," collapsing the distance between the sound source and the listener's body.

4.2 A Personal and Shared Experience

Gironnay had previously encountered a hybrid BCHs–SDA setup, handling sound diffusion during tests in 2021. That first exposure immediately raised compositional questions: what opportunities emerge when some sounds are shared by all listeners in the room, while others are experienced in a distinctly intimate, listener-dependent way? Gironnay noted that this introduced a tension between a more subjective perceptual experience and a shared one. In this framing, SDA provides a shared acoustic reference (a common external event), whereas the BCHs layer tends toward a more individual experience shaped by listener-specific conditions. In practice, this meant embracing the possibility that the same moment could not be perceived identically by everyone: listeners' experiences could diverge depending on their position, head orientation, and individually adjusted BCHs volume. This possibility also gave Gironnay the impression that audience members might wonder how their neighbours had experienced the same event. Rather than treating this perceptual blur as a problem to eliminate, Gironnay framed it as an aesthetic and poetic resource, embracing the uncertainty of source as a form of productive ambiguity that could foster a plurality of interpretations.

5 Practical and Technical Considerations

The absence of a shared creative and technical framework for such a multilayer environment required an initial pragmatic and experimental phase to map the affordances of BCHs—both on their own and in combination with SDA. Early tests highlighted that composing for this setup involves practical and technical constraints that became compositional parameters.

All composers worked with the same BCHs model later used in the public concert, ensuring continuity between studio and concert conditions.

Given the autoethnographic and practice-based nature of this study, the perceptual observations discussed in Sections 5 and 6 should be understood as composer-reported experiences and hypotheses, rather than as experimentally validated perceptual findings. Further perceptual studies involving larger participant samples would be needed to assess their generalisability.

5.1 Frequency Bandwidth and Timbral Characteristics

Early explorations suggested that BCHs rendering is most convincing within a mid to mid-high frequency band, partly consistent with previous research [14, p. 6]. Dall'Ara-Majek reported comfortable and convincing results approximately between 400 Hz and 15 kHz, while very low frequencies tended to produce excessive vibration (Section 5.5), and very high frequencies could elicit an unpleasant, tinnitus-like sensation. The composer therefore favoured using the mid and mid-high register for BCHs (approximately between 800 and 5000 Hz) and reserving spectral extremes for SDA. Dall'Ara-Majek also reported that placing articulated/gesture-like material in BCHs and sustained (drone-like) material in SDA often produced a more convincing musical result than swapping the roles. At the same time, the composer reported a recurring timbral divergence: identical sounds were often perceived as more "precise" or "crunchy" over BCHs—where mid-band detail is foregrounded—while sounding more diffuse through speakers (potentially influenced by room acoustics and speaker characteristics).

In parallel, Giannini established a personal operating range (approximately 130–13 kHz) and used by-ear corrective EQ to better align SDA and BCHs monitoring, including a broad attenuation

centred around ~360 Hz and an upper-mid boost around ~4.2 kHz (Figure 2). Similarly, Thibault and Lessa Catalão applied by-ear corrective EQ to the BCHs feed, including a high-pass filter around ~240 Hz, a boost around ~2.59 kHz, and a low-pass filter around ~15.6 kHz (Figure 3).

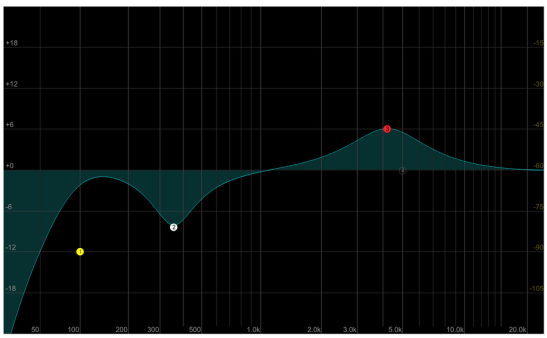

Figure 2: By-ear corrective EQ (Giannini)

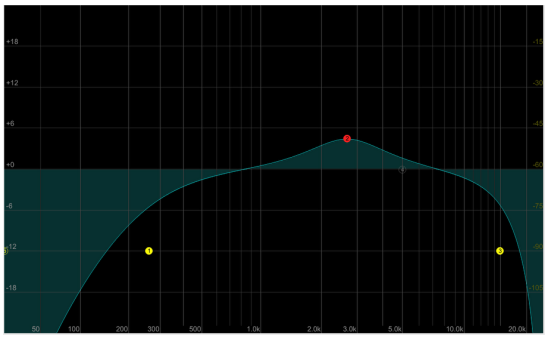

Figure 3: By-ear corrective EQ (Thibault and Lessa Catalão)

While some corrective EQ was used to narrow the gap (Giannini, Thibault and Lessa Catalão), this difference reinforced the idea that BCHs foreground midrange detail and articulation differently from SDA diffusion, informing subsequent decisions about spectral allocation and the selection and design of musical materials.

5.2 Level Balance, Spatial Clarity, and Attentional Load

The workflow required manual calibration between BCHs and SDA to achieve comparable perceived loudness across layers. This calibration served as a recurring reference throughout the compositional process and remained a key step for rehearsals and the concert performance. Dall'Ara-Majek reported a perceptual threshold effect: beyond a certain BCHs level, the headphone layer seemed to take precedence over the SDA one, regardless of whether materials were designed for contrast or fusion, suggesting that preserving the perceptual presence of SDA required particularly fine-grained balancing. Similarly, Giannini reported that small level adjustments seemed to have notable perceptual consequences, leading him to focus on level subtleties as a central compositional strategy.

Beyond loudness matching, composers also described how BCHs usage and level balance could affect perceptual precision and the legibility of spatial information. Although the ear canal remains open, Thibault and Lessa Catalão noted that BCHs seemed to generate substantial masking of the acoustic world, potentially altering perceptual accuracy. During composition, Giannini associated BCHs monitoring with the impression of perceiving sound diffused from elevated speakers with less clarity, possibly in relation to the overall density of simultaneous information. In parallel, Dall'Ara-Majek observed that, in a studio setup, material diffused from elevated speakers seemed to mask the BCHs feed more quickly as the speakers' level increased, compared to material from speakers at ear level; however, the composer noted the opposite tendency in the concert venue, possibly reflecting the much greater distance of the elevated speakers in that space. Giannini and Gozzi further hypothesised that these effects could occur in part due to changes in HRTF-related spectral cues that support elevated sound localisation [43, p. 38], potentially modulated by the physical placement of BCHs on the head. These reports could suggest that perceived spatial clarity—particularly for elevated sources—may be affected by BCHs use, and may depend on a range of factors, including level matching, layout, venue conditions, and overall informational load.

More broadly, the multilayer configuration raised questions of musical legibility and attentional capacity. Giannini, Thibault and Dall'Ara-Majek noted that the quantity of simultaneous information across performance, SDA, and BCHs seemed to quickly saturate attention if not managed carefully. Giannini likewise reported deciding to limit concurrent sound events and favour slower, more sustained materials with the aim of avoiding overload.

5.3 Interlayer Temporal Alignment

Dall'Ara-Majek raised the question of whether "true simultaneity" can be perceived across layers when bone-conducted content reaches the auditory system more "directly," while sound radiated from speakers necessarily takes longer to reach the listener. The composer reported that in small-studio conditions, simultaneity could often be perceived clearly, whereas in the concert venue, the speaker layer felt more diffuse and "took much longer to arrive than expected," suggesting that venue-scale geometry and propagation conditions may modulate perceived interlayer alignment even without intentionally applied delay. Giannini did not notice a systematic time offset between SDA and BCHs during studio work and reported creating interlayer abrupt shifts (Section 6.3) without perceived desynchronisation. At the venue, this aspect was not assessed systematically by Giannini, as studio tests had not suggested a salient issue, and rehearsal time was limited. In another approach, Thibault delayed the signal sent to BCHs to improve perceived temporal alignment with SDA. The impact of this compensation should be investigated further to evaluate its effectiveness. Taken together, these accounts suggest that any intrinsic interlayer time delay may be context-dependent and remains to be explored more systematically.

5.4 Source Ambiguity and Head Movement

Gironnay reported that it was not always clear whether a sound was perceived as coming from SDA or from BCHs. Giannini similarly found that, when playing the same sound through both systems, distinguishing the source could become difficult. Giannini, Thibault, Lessa Catalão and Gironnay framed this perceived ambiguity as a productive condition that could be composed with.

Giannini also reported that when the same sound was presented simultaneously over SDA and BCHs, subtle filtering artefacts became

apparent when turning the head. The composer hypothesised that two coupled effects may be involved. First, head rotation may change HRTF filtering [43, p. 38] of the airborne SDA sound, whereas the BCHs signal reaches the listener primarily through BC and may therefore be less subject to head-rotation-dependent HRTF changes. It is worth noting that BCHs can also produce some airborne leakage [14]. Second, because the BCHs feed did not implement head-tracking, the spatial image in the BCHs layer was head-locked (moving with the listener), while the SDA image remained room-locked (fixed in the venue). During head movements, these differences could increase the perceived divergence between layers.

5.5 Vibro-tactile Experience

Finally, composers repeatedly noted the vibro-tactile component of bone conduction. Thibault and Lessa Catalão described their initial encounters with BCHs as "disorienting," with temple vibration seeming to sit between touch and hearing and to blur sensory boundaries. Dall'Ara-Majek reported that low frequencies could quickly become uncomfortable due to excessive vibration, reinforcing the preference for mid to mid-high BCHs content. Composers therefore filtered low frequencies in the BCHs feed to limit vibro-tactile salience and improve comfort (Section 5.1).

Alongside this spectral shaping, Giannini treated perceived vibration as a practical upper bound for the BCHs level. The composer kept this feed below the point where vibration becomes overly salient, associating stronger vibration with discomfort and occasional distortion. Giannini hypothesised that, in a concert context, BCHs listening may be unfamiliar to many audience members. The composer also considered that listeners could not know in advance the sounds and levels they would encounter, making strongly felt vibration potentially less comfortable in this non-habitual listening situation. Over longer studio sessions, composers also reported physiological limits (e.g., fatigue and discomfort), at times requiring them to interrupt or adapt their monitoring practices (Thibault, Lessa Catalão and Dall'Ara-Majek).

5.6 Composition and Venue Environments

To support comparison with the concert venue, we summarise the main characteristics of the environments in which the composition process took place.

- Giannini worked in the Performance Research Laboratory at the Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT), a 69 m^2 space equipped with an SDA, and in an approximately 80 m^2 multipurpose space at the Université du Québec à Montréal (UQAM), equipped with a 7.1 system.
- Thibault and Lessa Catalão composed in the Percussion Studio and the Multichannel Studio at Université de Montréal. In both cases, the rooms were approximately 100 m^2. The Multichannel Studio provided an SDA, whereas the Percussion Studio had a stereo system.
- Dall'Ara-Majek worked in two studios: the Hexa Studio at Université de Montréal, equipped with an SDA (approximately 24 m^2), and a personal studio configured for octophony (approximately 12 m^2).
- Gironnay composed primarily in the Virage Sonore professional studio (approximately 4.5 m^2) and in a personal studio (approximately 6 m^2). Monitoring combined two nearfield speaker pairs and a closed-back headphone for testing spatialisation.
- Concert venue: the Satosphere at the SAT, a large immersive dome of approximately 255 m^2, equipped with a large-format SDA.

6 Compositional Strategies

Building on Sections 4 and 5, we synthesise the compositional strategies used across the works. Several strategies were conceptually framed through the intimacy–immensity continuum (Section 4.1) — for instance, in instrumentation and material choices (Section 6.1), in interlayer trajectories (Section 6.3), in the foregrounding of microscopic sonic detail (Section 6.5), and in spatial mappings and staging (Section 6.6). Other strategies were connected to the practical and technical considerations identified earlier: source ambiguity (Section 5.4) and level balance (Section 5.2) became creative resources in shaping interlayer relationships (Section 6.2), and the question of interlayer temporal alignment raised in Section 5.3 was explored as a compositional parameter through micro-offsets and delays (Section 6.4). Some strategies also stemmed from preparatory meetings led by Gozzi, who shared a list of approaches drawn from earlier projects involving BCHs [39], [27], [22].

Rather than describing each piece exhaustively, we focus on strategies composers identified as significant and potentially generalisable to other BCHs–SDA contexts, addressing interlayer relations primarily in terms of fusion, contrast, alternation, and intended ambiguity.

Dall'Ara-Majek began with exploratory tests to compare perceived fusion versus contrast between BCHs and SDA, leading to strategies involving time differences and an approach described as "caress the ear."

Giannini explored relations of spatial distance, developing strategies centred on interlayer trajectories, layer shifts, intensity nuances, and sound doubling.

Thibault and Lessa Catalão framed their work as a three-way interplay between acoustic sources, BCHs, and SDA, with acoustic performance as a core driver. They organised their approach around three axes: coexistence of acoustic sound and its diffusion across layers (raw or processed), differentiated temporal/rhythmic organisation, and sensory augmentation of microscopic sounds.

Gironnay also adopted a three-way framework between acoustic sources, BCHs, and SDA. The composer's work treats source indeterminacy as a compositional parameter, developing strategies to blur source attribution across layers.

Audio recordings of the performances are provided at this Zenodo data repository: https://zenodo.org/records/19826060 [12]. Recordings were captured during the concert with a binaural head (acoustic sources + SDA), with BCHs mounted at the ear positions and recorded via contact microphones [14] (Figure 4). The binaural and BCHs streams are mixed in the uploaded audio materials. The time references in the following sections refer to these recordings.

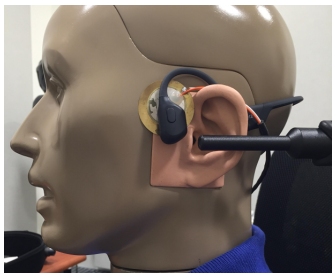

Figure 4: Prototype of the concert recording setup

Sound Works

- Nicola Giannini — *La dialectique de la proximité*
- Catalão–Thibault duo — *Intimité infinité*
- Ana Dall'Ara-Majek — *Polyhedral Rhythms*
- Kevin Gironnay — *Espèces d'espaces*

6.1 Instrumentation and Material Palette

Composers utilised distinct performance setups. Giannini's instrumentation combined sound synthesis, a recorded voice played back from a cassette recorder, and a felt-tip marker amplified with two contact microphones (Figure 5). Voice (11:25), in spoken-word style, was selected as a material that may evoke a private dialogue with listeners [34, pp. 126–127]. To reinforce this, the voice was kept exclusive to BCHs and not diffused through SDA. The cassette recorder was selected as a device from another era, with the aim of evoking auditory memories and potentially suggesting a form of "private sound". Marker was used to foreground the materiality of its bristles: first on an expanded scale (SDA), then on an intimate scale (BCHs), and then on both, to suggest simultaneity between private and shared listening. Voice and marker were also linked in performance: Giannini wrote with the marker the same words spoken through BCHs—a short reflection on spatial proximity. Synthesis was chosen because it offered fine control over spectrum and dynamics and, as relatively abstract material, could afford freedom for spatial motion—including abrupt shifts—without the expectation of spatial stability often associated with traditional instruments, especially when visible on stage.

Figure 5: Giannini's performance setup. Credits: Caroline Campeau

Thibault and Lessa Catalão chose percussion instruments, including an orchestral bass drum and other instruments (Figure 6), because they considered them particularly well suited to explore the intimacy–immensity continuum. Through close miking and diffusion via BCHs, micro-gestures and textures produced by percussion can be foregrounded, encouraging intimate listening; conversely, instruments such as the bass drum can project a broader, shared acoustic presence. Moreover, percussion can be simultaneously perceived acoustically in the room and captured, processed, and diffused via BCHs and SDA, enabling continuities—and sometimes ambiguities—between layers.

Figure 6: Thibault and Lessa Catalão's performance setup. Credits: Caroline Campeau

Dall'Ara-Majek chose the *PhotoTable*, a digital music instrument (DMI) consisting of a responsive physical interface with sensors, mapped in Max to control synthesis, sample playback, and audio processing (Figure 7). This choice reflects Dall'Ara-Majek's research on gestural instrument performance, and the concert provided an opportunity to test a new DMI iteration. Links with BCHs were not the initial motivation but came later through the creative process.

Figure 7: Dall'Ara-Majek's performance setup. Credits: Caroline Campeau

Gironnay chose voice as the central acoustic source, performed by lyric singer Amy Grainger (Figure 8). The singer's technique supported both unamplified singing and close-miked work. This made it possible to shift between singing into the microphone and projecting the voice directly into the room. The setup relied on a handheld microphone, allowing the performer to navigate between close-miked intimacy (the only source diffused via BCHs) and acoustic projection in the hall. Alongside the vocal performance, spatialised computer-based synthesis was diffused exclusively through SDA. The electronic part comprised multiple concurrent layers, mixed in real time and articulated sometimes as counterpoint, sometimes as call-and-response with the acoustic and amplified voice. It also included a pre-recorded layer of the singer's sighs (~7:00). Spatialisation was performed live, with control over motion speed and elevation. For the text, Gironnay drew on poems and literary excerpts exploring the concept of space in its many forms and in the collective imagination. The piece contained excerpts from Perec's *Espèces d'espaces* [30], which inspired its title, as well as from

Rimbaud [33], Michaux [23], Desbordes-Valmore [10], Haddam [15], Tardieu [37], and Tarkos [38]. Framed through a poetic lens, the text and sonic gestures were designed to evoke different possible interpretations across listeners. For example, the same material could appear clear to some and elusive to others.

Figure 8: Gironnay's performance setup. Credits: Caroline Campeau

6.2 Interlayer Relationships: Doubling, Cross-layer Processing and Coexistence

Across the works, the relationship between layers was treated as a primary compositional dimension. The pieces explored multiple modes of interlayer interaction: fusion (blending into a single auditory object), contrast (polyphonic separation), alternation (foreground–background switching), and intentional ambiguity (uncertain attribution).

Giannini developed strategies based on **sound doubling**, presenting related or identical material across layers with the aim of creating perceptual cohesion or source ambiguity. For example, at the beginning of the work, a pad slowly fades into SDA and, about 20 seconds later, is gradually doubled in BCHs (left side), generating perceptual ambiguity and timbral colourations akin to a phasing/flanging effect, possibly due to subtle differences between the SDA and BCHs layers (Section 5.4). At 1:48, a sound from SDA was routed to BCHs using **cross-layer processing** (distortion and panning tremolo). The aim was to produce a perceptual unity characterised by timbral–spatial variation, inspired by the timbral spatialisation technique [25]. At 8:37, doubling served as a level strategy (Section 5.2): the SDA signal was added to BCHs to increase perceived loudness.

Similarly, Thibault and Lessa Catalão defined one of their strategies as the **coexistence of acoustic sounds and their diffusion across the layers**, in either raw or processed form. The sounds captured by microphones can be heard simultaneously in their raw form in the acoustic space and transformed via BCHs and/or SDA. This supports source ambiguity and perceptual continuity across layers. For instance, straw-stick crackles previously played live are reintroduced at 5:14 as samples only in BCHs, with cross-layer timbral modification, creating a distance between the live-played and recorded material through the shift from acoustic event to BCHs-only replay. At 11:25, a recorded rubbing melody is introduced through BCHs; it recalls rubbing acoustic sounds heard earlier, and, at 12:20, it is complemented by rubbing gestures performed live and projected acoustically in the venue. The recorded layer then gradually shifts toward SDA, becoming increasingly distant.

Gironnay explored this ambiguity through cross-layer processing, sending the handheld-mic voice to BCHs while adding a light reverberation in SDA (10:30–12:30).

6.3 Interlayer Trajectories and Abrupt Shifts

Another strategy for exploring the intimacy–immensity continuum was to use **interlayer trajectories**. A clear instance appears around 1:24 in Giannini's work, where a spectrally rich bouncing sound [11] is interpolated between BCHs and SDA by gradually crossfading the two layers. Because of its repeated re-attacks, this sound material is easily localisable [18, p. 38]. To make the result more convincing to Giannini's ears, only one BCHs channel was used, and, in SDA, the sound was rendered at a precise, point-like position. Giannini reported perceiving sound paths extending from SDA toward the ears, with intermediate, phantom-like images seeming to emerge between SDA and BCHs (Figure 9). The composer explored this aspect as a way of working with perceived sound depth.

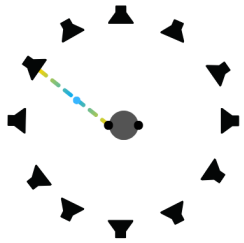

Figure 9: Interlayer trajectories

Giannini also explored **abrupt shifts** by sharply alternating a sound between SDA and BCHs (3:29). Each layer was rendered as a point-like source placed 180° apart in azimuth (Figure 10), so the sound could be perceived as either extremely close or distant. The composer varied the alternation rate live, moving from slower to faster rates and back, with the aim, at higher rates, of evoking a stroboscopic-light effect. Giannini observed that, at higher rates, the SDA-BCHs alternation could become less perceptible as discrete sound displacement and more as a timbral-spatial texture. For the composer, this perceived effect recalled the description of the high-rate spatial-motion phenomena discussed in [17] as well as high-rate amplitude modulation, where sidebands can affect timbre [28]. At 4:22, the two sounds rotate coherently while maintaining their opposed relative positions.

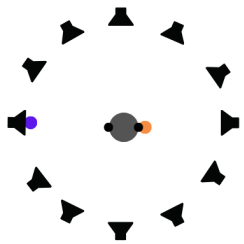

Figure 10: Interlayer abrupt shifts

6.4 Time Differences: Micro-offsets and Delays Across Layers

Starting from the questions of interlayer temporal alignment discussed in Section 5.3, time differences between BCHs and SDA

were explored as a compositional resource. We use *time differences* here as an umbrella term spanning **micro-temporal offsets** (on the order of a few milliseconds)—including what the literature often describes as micro-temporal decorrelation [41]—and **delays** in the range of hundreds of milliseconds to a few seconds.

Dall'Ara-Majek used interlayer time differences to explore how the relationship between layers could shift from simultaneity to chorus-like effects and, with longer time differences, to echo-like effects. From 0:00 to 5:30, the same water sound was presented simultaneously across BCHs and SDA, then a progressive time offset was introduced by manually varying the playback speed. From 11:34 to 13:11, the same "crystalline" synthesis sound was presented across SDA and BCHs with preprogrammed micro-offsets (five values between 5–50 ms), to produce subtle micro-delay relationships between layers.

Thibault and Lessa Catalão similarly articulated differentiated temporal and rhythmic organisations across the acoustic space, SDA, and BCHs. Percussive sounds are routed through distinct delay lines—one associated with BCHs and another with SDA—creating temporal differences between layers. Around 15:45, acoustic percussion gestures are juxtaposed with delayed responses in SDA and with other responses (with different delay times) in BCHs. This produced a spatially distributed polyrhythmic texture, described by Thibault and Lessa Catalão as captivating yet perceptually disorienting.

6.5 Sensory Augmentation of Microscopic Sounds

An affordance of BCHs is the ability to foreground microscopic sonic detail and encourage intimate listening modes. This was explored by Thibault and Lessa Catalão in the work involving percussion and close miking, where frictions, crackles, fine vibrations, and other low-amplitude textures were highlighted. In this context, BCHs were used with the aim of augmenting the perception of sounds that might otherwise remain difficult to perceive in a concert hall. By placing microscopic textures in the BCHs layer, Thibault and Lessa Catalão sought to create a deliberate mismatch between what is visible on stage and what is privately audible, with the aim of reconfiguring the audience's sense of proximity to the performers and to the instruments' materiality. For instance, at 10:55, a controlled feedback process between microphones and a transducer attached to a metal bowl produces very high frequencies at a low level; routing this to BCHs made otherwise hard-to-perceive intensity and timbral subtleties in the hall audible.

Giannini's amplified marker similarly leveraged this logic: diffusion through BCHs was used to make the physical grain of the gesture audible.

6.6 Spatial Mappings and Staging

In addition to sound-based strategies, several works treated performance spatial mappings and staging as part of the compositional system.

Dall'Ara-Majek adopted an approach in which the performer's gesture was intended to clarify spatial information. To align visible action with perceived space, the composer spatially mapped DMI sensors to corresponding spatial zones in SDA, so that gestural motion on the instrument visually "revealed" the space (e.g., right-side gesture corresponds to right-side diffusion, Figure 11).

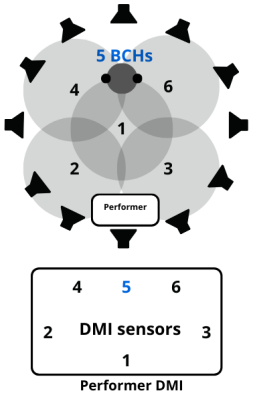

Figure 11: Dall'Ara-Majek's DMI mapping to SDA/BCHs

To increase the legibility of the BCHs layer, one sensor was assigned to the BCHs feed, providing a visual cue intended to help the audience anticipate BCHs events. This was further explored through a gesture metaphor described as "caress the ear," in which triggering the BCHs layer through a visibly "caressing" gesture was intended to produce a corresponding sensation of caressing via sound. The metaphor was broadly ASMR-inspired, without aiming to produce an actual ASMR effect. For instance, the looped rhythmic high-pitched sounds at 13:38–14:20 are triggered by a "caressing" gesture.

Thibault and Lessa Catalão noted that the immersive concert context—without a raised stage and with performers sharing the space with the audience—challenged the traditional concert convention. Throughout the compositional process, the composers integrated their own movement in space and attention to physical proximity to articulate form and reinforce intimacy while dialoguing with the large-scale SDA.

Similarly, Gironnay's staging contributed directly to the spatialisation of the voice: the singer was not fixed in a frontal position but moved among the audience, so that vocal proximity and movement became part of the piece's spatial dramaturgy.

Taken together, these strategies suggest that the BCHs–SDA configuration can function as a unified expressive medium. By navigating the tension between intimacy and immensity, the composers were able to articulate a new grammar of spatial live music composition and listening.

7 Discussion and Conclusions

This paper presents a research-creation framework for composing immersive live music in a multilayered environment combining BCHs, SDA, and acoustic sources, documented through a multi-author autoethnography from the composers' perspective. Across four new commissions, composers converged on an intimacy–immensity aesthetic continuum and developed strategies to shape interlayer relationships. By synthesising individual post-concert reflections, the article identifies practical and technical considerations as well as compositional strategies that may be transferable to other artists engaging with BCHs–SDA environments.

For the composers, working with this multilayer setup proved highly stimulating. First encounters with BCHs were often striking and disorienting, foregrounding vibro-tactile sensations and a blurred boundary between "inside" and "outside." While these encounters temporarily destabilised habitual listening cues, they opened a fertile

exploratory field; as the works evolved, composers also reported perceptual surprises.

Concert rehearsals and the public performance revealed additional constraints that were difficult to anticipate from smaller studios. Observations pointed to scale-dependent differences in perceived propagation and timing. In the concert venue, the SDA layer was perceived as arriving later and more diffusely than in studio conditions. In the work by the Catalão-Thibault duo, which relied on the acoustic dispersion of percussion, the acoustics of the concert venue proved challenging because the acoustic sounds were not supported by sufficient natural reverberation.

These venue-scale differences also made level matching between BCHs and SDA particularly critical. Accordingly, we suggest complementing the simultaneous-reference calibration procedure with a method that presents the same sound first through SDA and then through BCHs, so that balance can be refined by comparing non-simultaneous presentations.

As advice for artists approaching this multilayer environment, we recommend testing the devices together from the earliest explorations, allocating sufficient venue time for rehearsal, and keeping in mind that the expressive potential often lies in subtlety and careful articulation between layers.

This project demonstrates the potential of BCHs–SDA configurations for creating immersive, spatialised, and multilayered auditory experiences. The present practice-based account opens several directions for future work. Because this article is grounded in composer self-reflection, several perceptual observations remain hypotheses to be investigated further and would benefit from dedicated studies with larger samples. Audience-centred evaluation, for example through post-concert questionnaires or interviews, will also be essential to understand how compositional choices in hybrid BCHs–SDA environments translate into listeners' experiences. On the artistic side, further development could explore individualised experiences for each listener through differentiated BCHs streams, opening additional possibilities for this hybrid setup.

Ethical Standards

This work complies with the NIME ethical standards; no participants were recruited beyond the author team. The authors do not recognise any potential conflicts of interest in this research project.

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