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## Immersive technologies in the formation of musical audio space

**Abstract.** Immersive audio technology is increasingly used in music, with devices like cell phones and televisions replicating formats. The increasing adoption of immersive audio technologies by both consumers and professionals in the music industry has made this topic more relevant. The purpose of the research is to analyse immersive technologies that contribute to the creation of the musical audio environment. The research employed methods: literature and historical review, technical analysis, practical cases, statistical method, and the author's personal empirical experience. The article examines the function of audio space in relation to the perception of musical art and the characteristics of musical audio space. The proposed classification categories musical audio spaces into two distinct types: natural and artificial, as well as offline and online. The article's statistical data illustrates the changing patterns of growth in online audio consumers and the rivalry between radio stations and streaming platforms to enhance their impact on shaping listeners' audio spaces. The research demonstrates that streaming platforms actively encourage the incorporation of musical content in immersive formats as a means to expand their market share and evoke heightened emotional and perceptual responses in customers. The article outlines techniques used in immersive music spaces to provide a distinct aural experience for the listener. The article's practical analysis of immersive audio technologies encompasses the examination of requisite microphones and digital audio workstations that facilitate the transition from two-dimensional audio space formation to three-dimensional. In contemporary circumstances, the distribution of musical items is progressively employing three-dimensional immersive technologies. The article enumerates audio technologies that guarantee the creation of an immersive auditory environment for both listeners and musicians: Ambisonics, KLANG: technologies, and DPA 5100. The practical significance of this work rests in examining the perceptual attributes of users of immersive technologies and exploring the potential for developing immersive technologies, such as immersive musical instruments or immersive radio stations

**Keywords:** KLANG technology; spatial audio; sound recording; music art; Dolby Atmos

### Introduction

In 2022-2024, the production of music using immersive technologies, including Dolby Atmos, increased significantly, and leading streaming services began to actively implement support for spatial audio formats for listening. Thus, the study of the problems of integrating new immersive formats is quite relevant. In the global

scientific field, within the realms of musical art, cultural studies, and technical reviews, the issue of immersive technologies is increasingly being explored: the advantages of their application, the technical aspects of creation, and their impact on users. The advantages of immersive technologies, the technical aspects of

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creation, and their impact on users are all being increasingly investigated in the global scientific field, specifically within the domains of musical art, cultural studies, and technical reviews.

Among the scholars conducting research on immersive technologies in music in 2023, N. Shvets (2023) stands out, who classifies immersive technologies into technical and acoustic aspects. The author notes: "In the context of the specifics of musical culture, immersion can be discussed in several aspects: in the aspect of immersive sound, achieved by means of immersive technologies (virtual, augmented, and mixed reality) and in the aspect of immersive sound achieved through an appropriate manner of performance". The article "An Overview of Immersive Virtual Reality Music Experiences in Online Platforms" provides an overview of modern music applications and gaming platforms in the field of immersive technologies in music. It classifies VR music applications into four main categories: music creation and creative arrangements, rhythm games, music video experiences, and musical performances. The article also analyses available immersive music programs and highlights technical capabilities for enhancing creativity in music (Loveridge, 2023). The article "Cinematic Music Creation in Dolby Atmos" by S. Laine (2024) examines the creation and mixing of modern cinematic music in the Dolby Atmos format. The study investigates how ordinary consumers perceive music in immersive formats compared to traditional stereo. The article establishes Dolby Atmos as a viable alternative for consuming cinematic and orchestral music due to its immersive nature, allowing sound elements to be placed in three-dimensional space, creating a more natural and engaging result.

In recent years, there has been significant activity in the global scientific community regarding the study of immersiveness in musical practices. In their article, researchers O. Hubernator & O. Krasnenko (2023) define the concept of immersiveness and its purpose. They also emphasise that modern immersive cultures of practice achieve an immersive effect through advanced technologies based on working with light, sound, video projections and virtual or augmented reality. Scholars such as A. Kravchenko (2023) and Yu. Trach (2023) have written about the manifestations of immersiveness in contemporary culture. The authors note that immersion takes place in the following industries: cinema, theatre, exhibition, gaming, and art installations. Scientists argue that the immersive musical component is a part of contemporary immersive cultural practices. In her research paper on the digitalisation of the Ivan Honchar Museum, researcher V. Illyusha (2023) draws attention to the role of immersive technologies in the successful representation of Ukrainian culture and folk art to the international community. Immersive technological solutions for music recording and reproduction have been

examined in the works of T. Mouterde *et al.* (2023) and D. Enyi (2024). These authors note that scientists are working on the research, and modern immersive music projects are being implemented using the latest technical tools and developments by engineers from major audio companies. In his dissertation M. Kyriacos (2023) explores how the combination of performance space with musical style and compositional techniques can create a unique sound experience with the effect of maximising the listener's immersion in the performance of music. V. Leischner & Z. Mikovec (2021) propose new tools and a simple web player for playing music in spatial formats, based on existing audio coding technologies. In the context of the study, the chapter by M. Spohrer (2022) is useful because it focuses on the sound configurations of modern computer games, in particular binaural ones, which allow users to achieve more pleasure and maximum immersion.

Immersive technologies have significantly redefined multiple fields in recent years; however, their utilisation in musical art has become particularly significant. Due to the exponential increase in the number of individuals consuming audio content and advancements in sound reproduction technology, contemporary gadgets like smartphones, televisions, and acoustic systems are capable of accommodating immersive forms. This promotes the spread and enhancement of immersive audio technologies in both personal and professional endeavours. Immersive audio technologies have the capacity to create unique audio environments that amplify the emotional influence of musical content on listeners, a crucial aspect for the music industry.

The purpose of this research is to analyse immersive technologies that ensure the formation of musical audio space. This includes examining both technical aspects and the impact on the listening experience, as well as the prospects for the future development of these technologies. Research objectives is to conduct a literary and historical review of the development of immersive audio technologies; to analyse modern technical solutions in the formation of immersive musical audio space and explore their application; to study the impact of immersive technologies on music content and consumer perception of sound and assess prospects.

The scientific novelty of this work lies in the comprehensive study of immersive technologies and their role in forming the musical audio space.

## Materials and Methods

The study on "Immersive Technologies in the Formation of Musical Audio Space" employed various methods that allowed for a comprehensive evaluation of the potential and impact of these technologies on music industry. The article involves the following methods:

- Literature Review: this method provided an analysis of scientific articles and publications, facilitating the

study of scientific papers, books, and conference materials dedicated to immersive technologies and their use in music production. In the context of the study, the research paper “Listening to the Space of Music” by E. Di Bona (2017) and his conclusions about the significant and minimal aesthetic role of space in music. Also important are the results of a study by scholar V. Kolosok (2023) in defining the term “audio space”, as stated in the work “Interaction of Music and Literary Word in the Formation of the Artistic Audio Space of Ukraine in the First Quarter of the 21<sup>st</sup> Century”. The division of the audio space into online and offline was introduced by the research of H. Kieberg & H. Spilker (2023). Useful conclusions about the difference between stereo sound and immersive sound were made by researcher Z. Bresler (2021) in his work “Immersed in Pop: 3D Music, Subject Positioning, and Compositional Design in The Weeknd’s “Blinding Lights” in Dolby Atmos”.

- **Historical Review:** this method involved researching the history of the development of immersive technologies and their integration into the music industry.

- **Practical Cases:** this approach helped to analyse real projects in which immersive technologies were applied, providing insights into practical applications.

- **Case Study:** this method provided a detailed analysis of specific instances of immersive technology use in music production and impact on the final product.

- **Technical Analysis:** through this method, the equipment and software used for creating and reproducing immersive audio were examined.

- **Statistical Analysis:** the statistical results of the Consumption and Trust in Media survey conducted by Info Sapiens at the request of Suspilne Movlennya (2023) in April 2023 with the support of the Swedish Radio Media Development Bureau. The anonymous individual survey used SMS-CAWI methods (74%, online questionnaires were completed via random invitations in SMS to Kyivstar and Vodafon subscribers) and an online panel (26%). The respondents are men and women aged 18-70 who use the Internet, radio or television at least once a week and live in Ukraine (except for the temporarily occupied territories and the Autonomous Republic of Crimea). A total of 5256 respondents took part in the survey in April 2023.

The study also includes the results of the analysis of the Molfar OSINT community (2023), based on open source information on web traffic of popular streaming platforms among users in Ukraine. The statistics are presented from June to December 2022. In total, statistics on the 5 most popular streaming platforms and their share among Ukrainian users were processed.

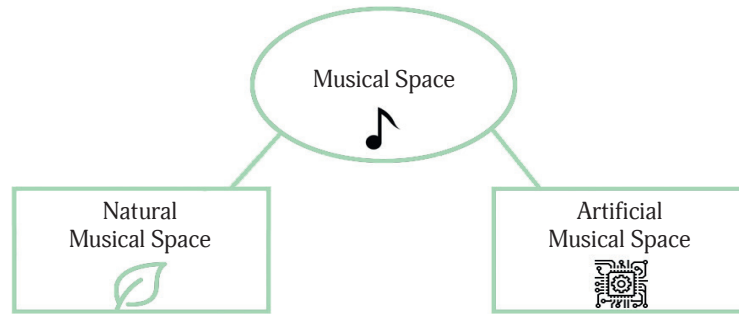
## Results and Discussion

The advancement of technologies in the 21<sup>st</sup> century associated with the creation of music products has achieved a fundamentally higher degree of quality.

Contemporary technology enable accurate and reliable recording without altering the sound of musical instruments and voice, as well as equally accurate playback of the recorded audio through loudspeakers or headphones. Currently, it is possible to achieve a high level of accuracy even while reproducing live music at various concert venues. In both instances, the process of interaction between the musical composition and the listener within a specific space, i.e., within a specific musical audio space.

Classical composers recognised the importance of space in musical creation by carefully considering the arrangement of instruments and the listener’s position when composing and arranging their pieces. The precise arrangement of musical instruments was determined by the acoustic characteristics of the performance venue and the listener’s location, in addition to the necessity of achieving the intended balance of volume levels. It indicates that composers considered both the metaphorical perception of space, in which music inspires the sensation of being in a specific area, and the physical element, in order to enhance impressions and increase immersion. For example, organ music or choral performances in a Catholic cathedral, where the acoustics enhance the audience’s perception of the images. Another example is when a composition’s musical techniques, elements, and shapes transport the listener to a different space from where the piece is being performed. In this context, researcher E. Di Bona (2017) examines the significant and minimal aesthetic roles of space in music: “In the first case – which is especially common in spatial or spatialised music – movement, direction, and distance of sound are compositional means that often generate the distribution of sources throughout the concert venue; in the second case, space is used in the sense of spatial reference, which evokes or reminds the listener of experiences in places different from where the music is performed”.

With the advent of sound recording and audio reproduction technologies, the term “audio space” and its variations became common in musicological terminology. According to V. Kolosok (2023), “audio space is a natural-technological integrity that unites various types of sound information (acoustic, broadcast, analog, digital) and exists both due to acoustic-natural components and as a result of targeted technological, socio-communicative, and creative-aesthetic activities of people using specially designed technical means for this purpose”. Consequently, the recipient’s physiological and psychological responses to the signal, in conjunction with the sound field formed by audio reproduction, collectively establish a personal audio space. In contrast to the sound field, audio space is entirely dependent on the presence of a listener and does not exist without one. Depending on the essence of the creative tasks, musical space can be divided into two distinct types (Fig. 1).



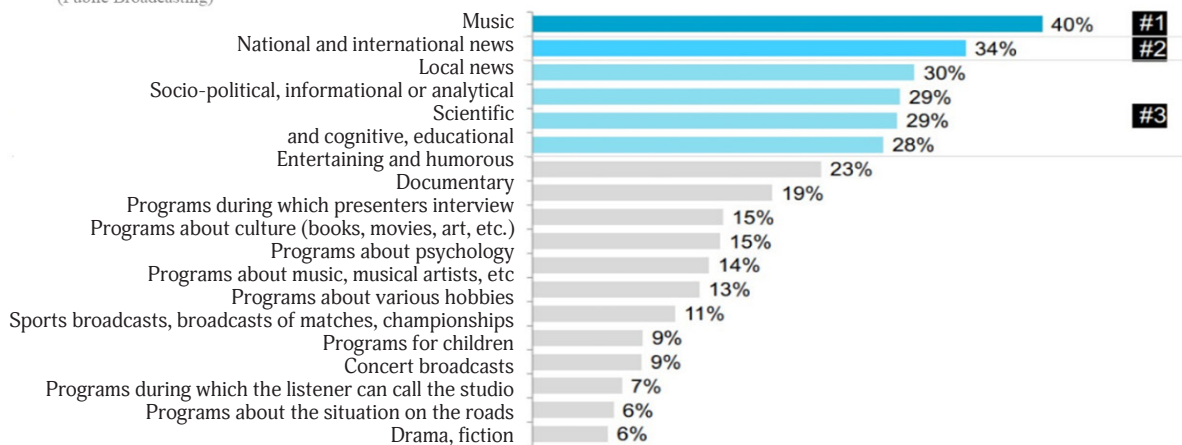
**Figure 1.** Dividing music space into natural and artificial

Source: developed by the author

Natural Musical Space this is a musical space in which a musical work is immediately performed or recorded and reproduced utilising sound equipment, with no further spatial sound processing. Artificial Musical Space – this is a musical space generated using additional spatial sound processing that differs dramatically from the space where the musical composition was performed or recorded when played back.

When categorising and interpreting audio space, Western scholars H. Kieberg & H. Spilker (2023) distinguish between offline audio space and online audio

space. Offline audio space refers to instances in which the sound source is physically present in the same space as the consumer, whereas online audio space refers to instances where the sound source is not physically present in the same space as the consumer. It is important to acknowledge that the musical audio space of users has been the subject of active competition as a result of the expansion of streaming platforms and radio broadcasting. The concepts of colonialism in musical online audio spaces form the basis of every online platform or radio station (Fig. 2).



Base: weekly radio or podcast listeners N = 3564

Q7 What radio programs or types of audio content (podcast) do you like more?

Source: Research commissioned by Suspilne was conducted by Info Sapiens in April 2023 with the support of the Swedish Radio Media Development Bureau, using the SMS-CAWI method, the average population of Ukraine aged 18-70, except for the temporarily occupied territories and the Autonomous Republic of Crimea.

National sample H=5256

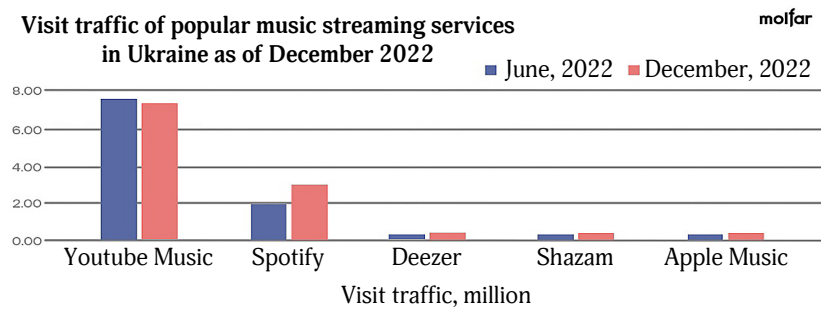
**Figure 2.** Weekly listeners of radio or podcasts

Source: Official website of Suspilne Movlennya (2024)

Radio station and online platform owners actively monitor their market share of consumer broadcasts by commissioning surveys and research. The main content that consumers choose for themselves using online platforms is music. This information is confirmed by the

results of a survey conducted in April 2023 commissioned by “Suspilne Movlennya”.

The Molnar platform conducted a study in 2022 to investigate the most popular music streaming services used by Ukrainians (Fig. 3).



**Figure 3.** Traffic to streaming platforms

**Source:** Molfar OSINT community. Popular music streaming services in Ukraine as of December 2022 (2023)

Analysing Figure 2 and Figure 3, it can be concluded that Ukrainians are active users of online music content, thereby creating their own online audio spaces. When using online platforms for music listening, users periodically demand fundamentally new technological solutions to achieve more realistic and immersive emotional experiences. Initially, audio playback outside of concert halls was in mono with a limited frequency spectrum, which gradually expanded to cover the full range of human hearing. Subsequently, users were able to listen to music in stereo. Later, the addition of inaudible frequencies to stereo music evoked stronger impressions in listeners. The demand for ever-new technological audio solutions grew, leading to the development of conditions for immersive audio reproduction.

In the context of audio space, it is paramount to examine the utilisation of immersive technologies for the recording, mixing, and reproduction of audio in detail. Initially, these techniques were utilised by audio engineers in the field of film production specifically for the purpose of sound design. The successful implementation of these methods in the cinema sector served as a catalyst for other professionals, such as producers and audio engineers, to explore immersive audio techniques.

The first significant achievement in immersive audio was the introduction of the surround format 5.1 in the late 1970s, realised in the film *Apocalypse Now*. This technology was revolutionary and laid a solid foundation for the research and development of new spatial formats. Ultimately, the pinnacle of technological advancement and digitisation of processes is the new spatial audio format Dolby Atmos. In 2012, during the premiere of the film *Brave* in Los Angeles, audiences were presented with audio in the Dolby Atmos format. The newly acquired audio experience soon found its realisation in the music industry with the release of the remastered version of R.E.M.'s album *Automatic for the People* in 2017. Thus, a new format of musical audio space emerged in musicological circles.

Over the course of history, listeners have been able to have more immersive experiences with the introduction of advanced audio recording and playback technologies. Such experiences serve as motivation for makers

of sound equipment and audio software to create technological solutions that ensure a unique and different experience compared to previous ones. These solutions focus on improving the precision of capturing and reproducing the amplitude-frequency characteristics, dynamic range, and accurate transmission of sound inside the space where music was performed or recorded.

Just like it was 100 years ago, the cinema industry continues to set trends in new technical and technological advancements, which are later successfully applied in other artistic fields. Humanity has rapidly advanced from the inception of the first sound film to the use of immersive technology that can replicate sound in particular natural environments or generate sound of artificial ones.

In the context of musical spaces, contemporary immersive technologies provide an unlimited toolkit for addressing creative tasks and forming new ones. This has become possible through multichannel sound recording and multichannel sound reproduction. Several factors play a crucial role in forming the musical space: acoustic properties of the space/room; reverberation in the space/room; sound pressure formed by sound sources; dynamic range of sound sources; amplitude-frequency characteristics of sound sources; tempo and rhythm of the musical piece; composition of musical instruments; external noises.

Traditional techniques for creating a musical environment involve using two large-diaphragm condenser microphones with an omnidirectional pattern. These microphones are placed in the room using either the A-B configuration or the XY configuration. Alternatively, both configurations can be used at once. The recorded acoustic environment is replicated by the utilisation of two channels – specifically, the right and left channels. This is achieved by employing two acoustic systems or a line array system in concert venues, placed on the right and left sides of the stage. The conventional methods and technology used to create musical space are limited in their capacity to accurately reproduce the acoustic characteristics and reverberation of the original recording space or room. As a consequence, the listener's immersion in a particular musical spaces is only partial,

or they might imagine a different space from what the composer intended.

Unlike classical technologies, immersive technologies use both multichannel sound recording and multichannel sound reproduction. Typically, the recording process involves an average of 4 to 10 small-diaphragm condenser microphones with an omnidirectional pattern. It is essential that the microphones are of the same model and have nearly identical technical characteristics. Additionally, for such multichannel sound recording, microphones with, for example, four capsules positioned at 90-degree angles to each other (such as the Sennheiser AMBEO VR Mic) are used. Generally, the microphones are placed in the center of the room, with the musicians positioned either around or in a semicircle relative to the microphones.

Such microphone placement scheme and sound sources positioning allows for a recording that captures the acoustic properties of the space, reverberation, dynamic range, and amplitude-frequency characteristics of the sound sources with maximum accuracy. Also the relative positions of each sound source to one another and to the microphones are precisely captured. The considered microphone setup emphasises the concept of immersion, where the listener is placed in the center of the musical space, with all events occurring around them.

Immersive technologies in music production are integrated not only during the recording of musical material but also in all subsequent processes, including playback by the listener on audio devices. Thus, the mixing of audio recorded using immersive technologies is not done following classical traditions, where each instrument occupies a single track in the DAW (Digital Audio Workstation) and is played back either in the right, left, or both channels simultaneously. Modern formats of immersive audio reproduction are already adapted for working with recorded material in DAWs such as ProTools by Avid and DaVinci Resolve. This software allows for working with up to 128 channels, reproducing the musical space using up to 64 acoustic systems placed around the sound engineer in the recording studio.

Manufacturers of modern audio reproduction equipment also pay attention to the capabilities of reproducing immersive audio, or partial reproduction, in their devices, such as headphones, home theaters, and even smartphones. These immersive technologies for recording, mixing, and playback allow for precisely positioning the listener's imagination in a specific natural or artificial musical space, fully immersing their consciousness in it. In his work, researcher Z. Bresler (2021) expresses the following perspective from the standpoint of proxemic perception of distance: "In three-dimensional pop mixes, spatial placement of musical elements and acoustic modeling serve to increase or decrease the apparent size and distance to performers and sounds, which, in turn, can create different opportunities for understanding and interpreting the musical content.

Typically, acoustic modeling results in distancing (i.e., intimate becomes personal; social becomes public, and so on). Changes in proxemic perception inevitably broaden or narrow the possible meanings that can be extracted from the text. Finally, the frame of reference is crucial in this context, as perceived differences between stereo sound and immersive music will vary significantly depending on the domain of activity".

It is important to acknowledge that contemporary technologies allow for the creation of a personal musical audio space in immersive formats, even when listening in stereo mode. It is sufficient to utilise high-quality personal headphones to attain the required results. Therefore, specialised audio equipment is not necessarily essential when creating a personal musical audio experience using immersive technology. This is made possible by immersive technology's capacity to localise sound sources within a musical composition's audio space.

Leading music streaming platforms, such as YouTube Music, Spotify, and Apple Music, have also recognised this capability by supporting immersive audio playback. The primary immersive format supported by these streaming platforms is Dolby Atmos. For music content creators who upload their material to streaming platforms in Dolby Atmos format, a commercially more advantageous rate applies than for those uploading in stereo format at the time of writing this article.

The developers of the Dolby Atmos format at Dolby Laboratories comment on the use of immersive technology for creating musical audio spaces as follows: "Music created in Dolby Atmos® goes beyond the ordinary listening experience, fully immersing you so that every detail of the sound is revealed with unparalleled clarity and depth. ... Sounds envelop you to create a spatial sound environment designed all around you, bringing you right into their world" (Dolby Laboratories, Inc., 2024). In particular, the paper of H.O. Mikkonen (2022) investigated the work with impressionistic audio using Dolby Atmos.

Ambisonics is one of the most powerful and promising immersive technologies in the field of audio space formation, enabling the creation of three-dimensional sound environments. Unlike traditional stereo or even multichannel systems, Ambisonics provides a more realistic and immersive sound perception. The theoretical foundation of this technology is based on the theory of spherical harmonics, which allows representing sound environments as mathematical functions. This enables the accurate capture and reproduction of sound in three dimensions. Ambisonic microphones are used to record sound from all directions simultaneously. These microphones have multiple capsules arranged in a special configuration that allows capturing sound waves from different angles. Special decoders are used to play back Ambisonic sound, converting Ambisonic recordings into formats supported by conventional stereo systems or headphones, ensuring realistic sound reproduction in three dimensions. Also, research on three-dimensional

audio spaces includes studies by R.J. McCrindle & D. Symons (2022). Scientists point to the importance of moving from stereo audio recording and playback to three-dimensional audio technologies. Such technologies can provide the naturalness of audio space for the listener, including music content.

Musicians and producers use Ambisonics technology when creating immersive musical works, resulting in unique musical audio spaces. In cinema and the gaming industry, Ambisonics is used to generate realistic sound effects in movies and video games, adding depth and realism to audiovisual products. Modern art forms increasingly integrate Ambisonics technology to enhance perceptual zones and provoke intense emotions in the audience. This technology is implemented in sound installations and experimental audio projects, exploring new manifestations and forms of sound art in creating unique types of audio spaces. An example of such implementation can be seen in the concert hall of the Royal College of Music in Stockholm. It should be considered that synthesised musical sounds will soon be generated in immersive forms, meaning users will immediately experience three-dimensional audio directly from musical instruments or equipment.

Analysing the development of immersive technologies for audio space formation, one can predict that the next step in enhancing listener experiences and increasing audience impact could be the creation of immersive radio stations. One particular area of interest in the study of musical immersive space is the performer's perception on stage during a performance and the intricacy of their interaction with the audience. Contemporary large performance spaces prohibit performers from sharing the same acoustic space as the audience. The presence of two distinct sound zones, one for the audience and one for the performer, can be attributed to the placement of acoustic equipment at the front of the stage, directed towards the audience. The players, positioned at the rear of these systems, just get sound wave reflections, which hampers their ability to create music effectively. Small acoustic performance venues are an exception, as both the audience and the artists share the same sonic environment.

To ensure the musicians comfort on large stages and precise ensemble intonation, stage monitoring was introduced: initially, floor monitors in the form of stage monitors, and later, personal in-ear monitors. This technology solved the problem of auditory precision for pitch, attack, and other nuances of performance. However, it also created issues, such as the lack of interaction with the audience and a two-dimensional (sometimes one-dimensional) audio space for performers. Thus, the artist on stage could not hear the audience's emotions and could only perceive them visually, and the musical content was received in mono or stereo format without considering the hall's acoustic properties. The emotional aspect of the musician impacted the quality of their emotional expression in the musical material.

The artist's performance on stage was hindered by the dull sound in the stage monitors and the absence of audience reaction, which prevented them from effectively showcasing their talent. Despite musicians' attempts to adapt to the technology, they were unable to achieve a genuine stage presence.

Scientists have invented and proposed the KLANG immersive technology to create a realistic musical audio space. When interacting with other sound equipment, this technology can form a comfortable three-dimensional audio space for each individual musician on stage. The creators of KLANG comment on their development: "A natural and intuitive placement of sound, with pristine sonic quality that lets musicians focus on their art – not on their monitor sound" (KLANG: Technologies GmbH, 2024). The technology allows for the creation of a realistic audio space, conditionally placing the musician's auditory apparatus in the same audio space as other performers and the audience. This enables the musician to feel the emotional atmosphere in the hall along with the room's acoustic characteristics. Moreover, the audio space of each musician changes based on their movement on stage, providing the same auditory sensations as without headphones, but with precise musical quality, detail, and appropriate volume levels.

The company DPA has embraced the ideas of the developers behind the KLANG immersive technology and proposed a solution not only for professional artists but also for enthusiasts, by introducing the new DPA 5100 microphone for immersive recording. The manufacturers commented on their invention: "DPA Microphones and KLANG: technologies have teamed up to create a system that allows live event teams to immerse singers and musicians in their onstage performances" (DPA microphones A/S, 2021). The mutual integration of the new microphone and KLANG technology allows musicians using headphones to experience the acoustic space of the concert venue, their geolocation while moving on stage, and the audience's emotions. This immersive technology creates a unified musical audio space for both the audience in the hall and the performers on stage, enabling the artists to hear what the audience hears, but with even greater refinement. This technology is utilised by concert sound engineers for renowned performers such as Aerosmith, Paul McCartney, and Ozzy Osbourne.

Immersive technologies are specifically engineered to create emotions and provide unique experiences. They are employed not just to generate musical auditory environments for individuals at home or audiences in a concert hall, but also for artists on stage. Research on immersive technologies in musical art since 2023 holds a significant place in the studies and practices of scholars. The Audio Engineering Society initiated the Immersive Audio Academy project, highlighting the importance of this research. In 2023, the largest global conference for audio engineers featured a dedicated section, the AES 2023 International Conference on

Spatial and Immersive Audio. The perspectives of P. Geluso *et al.* (2023) in their presentation “Creating In-air 3D sound objects for immersive sound applications and electroacoustic music” affirm the relevance of the findings in this study. Furthermore, A.B. Lopes (2023), in the article “Instrument position in immersive audio: A study on good practices and comparison with stereo approaches” demonstrates the transition from stereo to immersive audio in widespread applications. In 2019, the Recording Academy introduced the “Immersive audio” category in the annual Grammy Awards, which solidified the necessity for further research on immersive technologies in musical art.

### Conclusions

Based on the conducted research, several important conclusions can be drawn about the role of immersive technologies in the formation of musical audio space. Immersive audio technologies have a significant impact on the modern music industry. They enable the creation of unique musical audio spaces that enhance the emotional impact on listeners. This has become possible due to the development of multichannel recording and playback systems. Immersive technologies such as Ambisonics, KLANG: technologies, and DPA 5100 ensure high-quality recording and reproduction of sound. They allow for precise capture of the acoustic properties of space and the location of sound sources, ultimately creating a three-dimensional audio space. Streaming platforms like YouTube Music, Spotify, and Apple Music actively support immersive audio formats, allowing users to create their own online audio spaces. This contributes to the growth of the music listener market and the formation of new emotional experiences. Immersive technologies are not only applied in sound recording but also in live concert performances. The KLANG technology, for instance,

provides a comfortable three-dimensional audio space for musicians on stage, improving the quality of performance and interaction with the audience. Immersive technologies have significant development prospects. They could lead to the creation of new musical instruments, immersive radio stations, and other innovative solutions in the music industry. This opens up new opportunities for musicians, producers, and music consumers.

Consequently, immersive technologies are essential in the development of the contemporary musical audio landscape, as they facilitate the development of distinctive auditory experiences and emotions. Further research into and advancement of these technologies expand the possibilities for the music industry and improve its ability to compete. Prospects for research are seen in the analysis of the activities of composers who write music for immersive formats and their interaction with audio engineers. Also worthy of attention are separate studies of the recipients' impressions when listening to music using immersive technologies.

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### Conflict of Interest

None.

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## Імерсивні технології у формуванні музичного аудіопростору

■ **Анотація.** Технологія імерсивного аудіо все частіше використовується в музиці, а такі пристрої, як мобільні телефони та телевізори, відтворюють формати. Зростання популярності імерсивних аудіотехнологій як серед споживачів, так і серед професіоналів музичної індустрії зробило цю тему більш актуальною. Мета дослідження – проаналізувати імерсивні технології, які сприяють створенню музичного аудіосередовища. У дослідженні використано методи: літературно-історичний огляд, технічний аналіз, практичні кейси, статистичний метод, а також особистий емпіричний досвід автора. У статті розглянуто функції аудіопростору щодо сприйняття музичного мистецтва та характеристики музичного аудіопростору. Запропонована класифікація поділяє музичні аудіопростори на два окремі типи: природні та штучні, а також офлайн та онлайн. Статистичні дані статті ілюструють зміну тенденцій зростання кількості споживачів аудіо онлайн, а також конкуренцію між радіостанціями та стрімінговими платформами за посилення впливу на формування аудіопростору слухачів. Дослідження демонструє, що стрімінгові платформи активно заохочують включення музичного контенту в імерсивні формати, щоб розширити свою частку ринку та викликати підвищену емоційну та перцептивну реакцію у клієнтів. У статті окреслено методи, що використовуються в імерсивних музичних просторах для створення особливого звукового досвіду для слухача. У статті здійснено практичний аналіз технологій імерсивного аудіо, розглянуто необхідні мікрофони та цифрові аудіо робочі станції, які сприяють переходу від формування двовимірного аудіопростору до тривимірного. У сучасних умовах дистрибуція музичних творів все частіше використовує тривимірні імерсивні технології. У статті перераховані аудіотехнології, які гарантують створення імерсивного слухового середовища як для слухачів, так і для музикантів: Ambisonics, KLANG: technologies та DPA 5100. Практичне значення роботи полягає у вивченні особливостей сприйняття користувачів імерсивних технологій та дослідженні потенціалу для розробки імерсивних технологій, таких як імерсивні музичні інструменти або імерсивні радіостанції

■ **Ключові слова:** технологія KLANG; просторове аудіо; звукозапис; музичне мистецтво; Dolby Atmos