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Educational computer game supporting skills development in timbre solfege

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***Abstract*—This paper presents Sound Jobs, an educational computer game designed to develop timbre solfege skills for sound engineers and audio professionals. Unlike existing ear-training tools that operate as standalone applications or web-based services, Sound Jobs integrates listening exercises within an engaging game narrative set in the 1970s hacking culture. The system was developed using the Unity game engine integrated with FMOD Studio middleware, enabling precise control over audio signal processing parameters essential for timbre discrimination tasks. The game offers three modes (Jobs, Training, and Testing) with exercises covering equalization recognition, dynamic range discrimination, distortion detection, reverb characterization, and delay identification. Evaluation through user surveys with Music in Multimedia students and professional audio engineers revealed positive reception, with participants particularly appreciating the gamification approach and the progressive difficulty system. Based on feedback, a second version was developed incorporating game save functionality and interface improvements. The tool is currently employed in timbre solfege instruction at the University of Silesia. Future development plans include expanding the sound material library and establishing a public repository for broader accessibility.**

***Keywords*—timbre solfege; educational game; formants; sound spectrum; sound engineering; technical ear training**

I. Introduction

TIMBRE solfege is a technical ear training discipline designed specifically for sound engineers, sound designers, multimedia creators, and other professionals working with audio. While traditional music education focuses on developing the ability to hear pitch and rhythm analytically, timbre solfege trains listeners to distinguish spectral characteristics of sound—for example, recognizing specific frequency bands, evaluating dynamic range, or identifying the acoustic properties of various signal processing effects [3, 5].

The importance of timbre solfege extends beyond professional audio production. Analytical listening skills enable sound engineers to produce higher quality work, make informed decisions about electroacoustic equipment, and consciously apply tools such as equalizers, compressors, and various effects [4]. Moreover, conscious timbre differentiation has applications in everyday life, from interpreting environmental sounds to understanding non-verbal acoustic communication.

A. Review of Existing Ear-Training Tools

Several approaches to technical ear training currently exist. The foundational methodology developed by Letowski and Miśkiewicz established systematic frameworks for timbre solfege education [3, 4, 5]. In Poland, academic programs at institutions in Warsaw and Poznań incorporate timbre recognition training using various software tools. The Shinji program, employed at the Adam Mickiewicz University in Poznań, represents one such implementation focused on spectral analysis exercises.

Commercial services such as SoundGym offer web-based ear training through subscription models. Dave Molton's Golden Ears provides comprehensive hearing tests on CD with accompanying written explanations. While these tools effectively develop listening skills, they typically operate as isolated exercise environments without engaging narrative frameworks or gamification elements that could enhance learning motivation and retention.

Online resources have proliferated with the increasing accessibility of audio production tools. Many websites offer timbre discrimination exercises, and young people show growing interest in acoustic and psychoacoustic matters. However, these resources often lack the systematic pedagogical structure and professional-grade audio processing capabilities necessary for comprehensive technical ear training.

B. Research Objectives

The primary objective of this project was to investigate the feasibility of creating an innovative computer environment that combines professional ear-training exercises with the engaging elements of computer games. Specifically, the research aimed to: (1) develop a technical framework capable of precise audio

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signal manipulation required for timbre solfege exercises; (2) integrate listening tasks within a coherent game narrative to enhance learning engagement; (3) evaluate user reception and pedagogical effectiveness through systematic feedback collection; and (4) establish a foundation for continued development and broader accessibility of the tool.

II. Computer Games in Modern Culture

Computer games have become an integral part of contemporary culture, experiencing tremendous growth as a medium that transcends pure entertainment. Video games are no longer merely electronic diversions; they have evolved into a field of artistic expression encompassing sophisticated graphics, music, and interactive storytelling. Importantly, games have established their place in science and education, offering unique opportunities for engagement and skill development [1, 9].

The game medium combines technology and art in ways particularly relevant to audio education. Gamification—the application of game-design elements in non-game contexts—has demonstrated effectiveness in educational settings by increasing motivation, providing immediate feedback, and creating progressive challenge structures. For technical ear training, where repetitive exercises can lead to learner fatigue, the narrative and competitive elements of games offer potential solutions to engagement challenges.

The accessibility of computers and music production software has sparked interest in audio production among young people, creating an audience receptive to educational tools that combine learning with entertainment. This cultural context provided the motivation for developing Sound Jobs as a game-based approach to timbre solfege education.

III. Importance of Timbre Solfege

Timbre represents the perceptual quality that allows listeners to distinguish between different sound sources producing the same pitch at the same loudness. A violin, trumpet, and electric guitar can all play the same note at identical loudness, yet listeners instantly identify which instrument produces the sound. This discrimination ability relies on perceiving the spectral content—the physical properties underlying timbral perception [6].

For sound engineers, timbre solfege develops essential professional competencies. The discipline encompasses identifying equalization characteristics, distinguishing dynamic range variations, evaluating sound quality, and recognizing the effects of various audio processors. When engineers mix, master, or perform post-production work, they constantly make decisions based on timbral assessment. Unclear voices, fatiguing sound effects, or inappropriate music negatively influence audience reception of any audio-visual work [8].

Beyond professional applications, analytical listening skills benefit broader audiences. Conscious timbre differentiation can assist visually impaired individuals in navigating public spaces. Everyday situations—such as interpreting warning signals from vehicles—rely on universal sound communication that transcends language barriers. These non-verbal acoustic signals demonstrate how timbre recognition applies to practical life circumstances.

IV. Sound Jobs Game

Sound Jobs is an educational computer game designed to possess all characteristic features of the gaming medium—graphics, storyline, and competition—while simultaneously serving as an effective didactic tool for timbre solfege training. The development process involved examining existing game engines and audio middleware for their suitability in creating listening exercises requiring precise control over sound timbre.

Two versions of the game have been developed. The first prototype, currently employed in classroom instruction, represents a complete playable game (Fig. 1). Based on user feedback, a second version (Fig.2) was created incorporating additional features including game save functionality, interface refinements, and an expanded modal structure. The original two modes (Jobs mode and Game mode) were reorganized into three distinct modes: Jobs mode, Training mode, and Testing mode (Fig. 3).

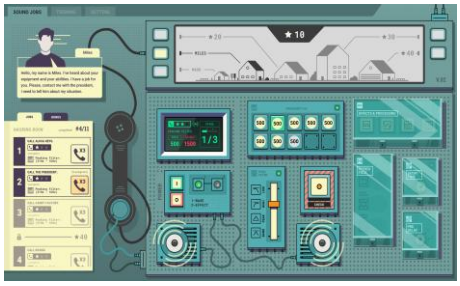

Fig. 1. Game screen of the first Sound Jobs prototype showing the main interface with job assignments, audio controls, and response options.

Fig. 2. Sound Jobs game modes selection screen: Jobs mode (narrative-driven exercises), Training mode (practice with feedback), and Testing mode (assessment without hints).

Fig. 3 Game screen in Unity Engine - the second version (the new one)

A. Technical Framework

The development framework combines the Unity game engine with FMOD Studio middleware, a selection driven by the specific technical requirements of interactive ear training applications [7].

Unity is a widely-used game engine and development platform for creating 2D and 3D games as well as interactive experiences across multiple platforms including PC, mobile devices, consoles, and virtual reality systems (Fig. 4). Unity offers a user-friendly interface, powerful rendering capabilities, and extensive support for scripting in C#, making it popular among both independent developers and large studios. However, Unity's native audio system provides limited capabilities for shaping sound timbre with the precision required for professional ear training exercises.

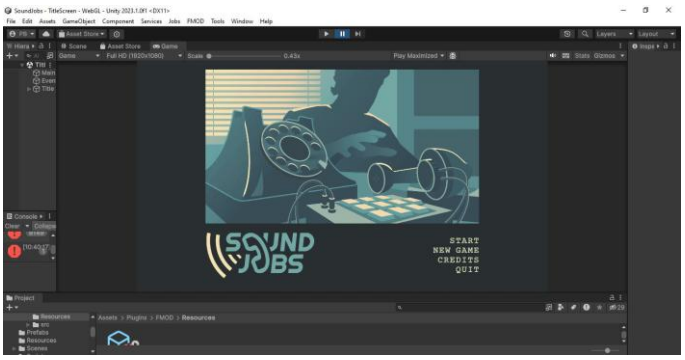

Fig. 4. Sound Jobs menu screen in the Unity Engine development environment.

FMOD Studio is professional audio middleware that enables precise timbre manipulation essential for the described project (Fig. 5). Its user interface resembles commonly-used Digital Audio Workstations (DAWs), providing familiar workflows for audio professionals. FMOD supports audio mixing, multi-track sound effect creation, and interactive soundtrack implementation. The software includes built-in plugins such as parametric equalizers, compressors, distortion, reverb, and delay effects with precise parameter control—for example, early reflection parameters in reverb effects crucial for spatial perception exercises.

Fig. 5. Sound Jobs project in FMOD Studio showing the event hierarchy, parameter automation, and audio routing.

The integration of these platforms addresses the core technical challenge: unlike traditional audio education software operating within linear environments, timbre solfege demands real-time audio processing and precise control over acoustic parameters. FMOD's event-based audio system decouples audio logic from game logic, enabling systematic exercise design while Unity handles visual presentation and user interaction.

Audio sources were preprocessed to ensure consistent loudness levels according to ITU-R BS.1770 standards [2], preventing perceptual bias based on level differences—an essential condition when designing tasks focused on timbre discrimination rather than volume perception. Sample rate and bit depth were standardized at 48 kHz/24-bit, matching professional audio production standards. Through careful buffer management, the system achieves audio response times below 20 milliseconds, ensuring immediate feedback during exercises.

B. Exercise Design Methodology

The pedagogical effectiveness of Sound Jobs depends on careful exercise design grounded in established timbre solfege methodology [3, 5, 8]. Five core exercise categories address fundamental skills required in professional audio production: equalization recognition (Fig. 6), dynamic range discrimination, distortion detection, reverb characterization, and delay identification. These categories were selected because they correspond to the most common audio processing operations encountered in professional practice.

For equalization exercises, frequencies are presented at octave intervals: 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz. Gain is set at ±12 dB with a filter bandwidth of one octave, representing realistic parameters encountered in audio production while remaining perceptible for training purposes. Similar parameter ranges were established for compression (ratios from 2:1 to 10:1), distortion, and reverb (decay times from 0.2s to 4.0s).

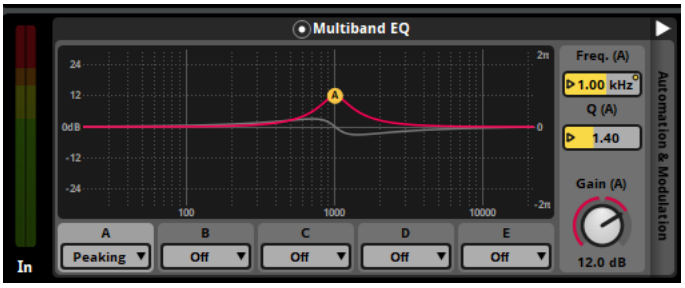

Fig. 6. Multiband EQ configuration in FMOD Studio showing parametric filter settings for frequency recognition exercises.

Source material employs three categories: pink noise provides spectral neutrality for frequency-based exercises; musical excerpts offer complex spectral content across various genres; and voice-over recordings present unique challenges due to the human voice's complex harmonic structure [5]. Musical selections span classical music (solo piano, organ, harp, chamber ensembles, choir), jazz (brass orchestra, quartet, quintet), and popular music (folk ensemble), with plans to expand into rock and metal genres characterized by full-spectrum frequency content.

The three-tiered difficulty system aligns with established pedagogical frameworks for skill acquisition [4]: Training mode presents exaggerated parameters to establish perceptual anchors; Jobs mode (game mode) uses moderate values within narrative contexts; and Testing mode employs subtle variations for assessment purposes. Exercise design incorporates psychoacoustic principles including frequency masking considerations, temporal resolution (5-10 second duration based on auditory working memory research [6]), reference anchoring through A/B comparison format, and level matching to prevent loudness cues from revealing answers.

C. Game Narrative

The game narrative is inspired by actual historical events. The setting is the 1970s, an era without mobile phones when only 60% of the population had landline telephones. Long-distance calls were extremely expensive, placing them beyond the means of ordinary citizens. During this period, hackers discovered methods to breach telephone networks and make free calls—even to high-profile figures such as government officials.

Players assume the role of a young talented hacker during this age of technological innovation, earning money by making illegal phone calls using proprietary equipment. The gameplay mechanic requires players to apply their listening skills: to complete a phone call, players must dial a number and then identify the sound motif that follows. Correct identification of specific timbral characteristics allows the call to connect successfully.

D. Example Exercise Implementation

A typical exercise proceeds as follows: The player receives a job request from a virtual client requiring a phone call to a specific number. Upon dialing, the game presents an audio sample—for instance, a musical excerpt with a boosted frequency band. The player must identify which frequency range has been modified (e.g., "500 Hz" or "4 kHz"). In Training mode, incorrect answers prompt helpful feedback indicating the correct response; in Jobs mode, errors result in failed calls and reduced earnings; in Testing mode, no feedback is provided until completion.

This integration of exercises within the narrative framework transforms repetitive ear training into goal-oriented gameplay. Players are motivated not merely by skill development but by narrative progression and in-game rewards, addressing the engagement challenges inherent in traditional ear training approaches.

V. Evaluation and User Feedback

Surveys were conducted with users to systematically collect data on the reception of Sound Jobs. Respondents included students of the Music in Multimedia program at the University of Silesia as well as professional sound directors and composers. The questionnaire addressed multiple dimensions: overall impression of the game, appreciation of specific elements, areas requiring improvement, interest level, storyline engagement, sound quality, interface usability, game mechanics, and specific features such as the tutorial system.

Key survey findings indicated overall positive reception of the gamification approach to timbre solfege. Respondents appreciated the integration of listening exercises within an engaging narrative context, reporting that the game format increased their motivation to practice compared to standalone training software. The progressive difficulty system received favorable evaluation, with users noting appropriate challenge scaling across the three modes.

Areas identified for improvement included the absence of game save functionality (addressed in version 2), requests for expanded sound material variety, and suggestions for interface refinements. Professional audio engineers provided particularly valuable feedback regarding parameter ranges and exercise authenticity relative to real-world production scenarios.

Based on survey results, the second version incorporated: persistent game state saving, refined graphical interface elements, reorganized modal structure (three modes replacing the original two), and expanded exercise content. Ongoing classroom evaluation at the University of Silesia continues to inform iterative development.

VI. Conclusion

The completed first version of Sound Jobs is currently employed in timbre solfege instruction for students of the Music in Multimedia program at the University of Silesia. The tool has been positively received and effectively fulfills its pedagogical objectives, introducing gamification elements into the educational process. The second version, incorporating user feedback, is presently under development and evaluation through the Unity engine on instructor workstations.

The project demonstrates the viability of integrating professional-grade ear training exercises within an engaging game framework. Listening exercises aimed at developing timbre solfege competencies have been successfully embedded within the narrative structure of Sound Jobs (Fig. 7). Players develop analytical listening skills by accurately identifying changes in audio signal timbre to complete phone call tasks assigned by virtual clients.

Future development plans include: expanding the library of musical excerpts to include rock and metal genres; developing additional exercise types addressing stereo field manipulation and more advanced spatial audio concepts; conducting formal comparative studies between game-based and traditional ear training approaches; and establishing a public repository or demonstration version to enable verification, broader use, and community contribution to the project.

Code and demo availability: Plans are underway to release a demonstration version of Sound Jobs and establish a code repository. Interested parties may contact the corresponding author for information regarding access to the current version for educational or research purposes.

Fig. 7. Game Logo

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