Mixed Reality Approach to Serious Games in Developing Musical Intelligence: A Systematic Mapping Study

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Abstract. *This study presents a systematic review investigating the effectiveness of Mixed Reality (MR)-based serious games in fostering musical intelligence, particularly in the domains of rhythm and melody recognition. By applying the SEGRESS methodology, the authors reviewed 466 articles, ultimately selecting 23 primary studies that met stringent inclusion criteria. The review synthesizes findings across several dimensions, including targeted musical skills, user demographics, technological platforms, assessment methods, and measurable outcomes. Results indicate that most MR serious games emphasize receptive and reproductive musical skills, particularly pitch and melody recognition, with rhythm training comparatively underrepresented. Target audiences predominantly consist of beginners and children, and mobile-based Augmented Reality (AR) emerges as a preferred platform for accessibility. Although studies employed diverse evaluation techniques—ranging from pre/post-tests to user feedback—the majority reported positive impacts on musical learning and engagement. However, gaps persist in research involving intermediate and advanced learners, standardized assessments of musical intelligence, and long-term pedagogical outcomes. This review contributes a foundational synthesis of current evidence and outlines future directions for enhancing the integration of immersive technology in music education.*

Keywords: mixed reality; augmented reality; serious games; music education; musical intelligence; rhythm recognition; melody recognition; educational technology.

1. Introduction

The concept of Mixed Reality (MR) has brought the opportunity, through human-computer interaction, to immerse oneself in subjects via an exciting, engaging, and innovative way [1]. The trend in the foreseeable future is towards a focus on exploiting augmented and virtual reality (AR and VR) to promote involvement, bringing the user closer to the concept they need to learn and comprehend. It uses dimension, style, perspective, and color as impactful forms to evoke emotion through visual stimuli [2].

From the same perspective of creating engaging and interactive experiences, serious games bring the element of fun and entertainment, an inherent characteristic of games in general, as a complement to their main intent, be it to convey a message or educate on a certain discipline [3, 4].

For Gardner [5], of all the gifts with which individuals may be endowed, none emerges earlier than musical talent. A fundamental intelligence that is usually perceived as being relevant only to music-related activities, but in Gardner's theory of multiple intelligences, musical intelligence not only explores another side of human communication that goes beyond common language, but also extends to other forms of intelligence and the success in developing these abilities early is related to the environment you are exposed to at an early age [5].

The context of Brazil is particularly relevant, as the non-compulsory status of musical education in schools potentially contributes to a diminished musical perception among children, which in turn affects their daily lives [6]. MR Serious Games offers a form of accompanied education that can be undertaken at a user's own pace, allowing them to see progress that goes beyond common education [1].

In sum, this review seeks to evaluate the extent to which mixed reality serious games support the development of receptive (recognition) and reproductive (performance/creation) musical skills in formal and informal learning environments based on exposure to musical elements and the interaction with those same elements.

To achieve it, this article is sectioned as follows. Section 2 provides the background and rationale behind mixed reality, serious games, and musical intelligence. Section 3 opens up to related works. Section 4 structures the planning and execution of a systematic mapping of the literature (SML). The results are presented in Section 5. Section 6 concludes this review with final remarks and future directions for the academy.

2. Backgrounds

2.1. Mixed Reality Serious Games

Mixed reality could be defined as a live, direct or indirect, view of a physical, real-world environment whose elements are augmented by computer-generated sensory input, and this includes interactions that go beyond what is commonly known as Augmented Reality, like projections on a construction site for machinery guidance [7]. As long as there's an overlap between information in the real world and virtual, Mixed Reality can be conceptualized as a spectrum that encompasses the real environment, then augmented reality, to virtual reality, and then virtual environment at the other end of the spectrum [8].

Now, when it comes to serious games, we can define them as games that have a well-planned educational purpose and are not intended to be played primarily for entertainment and fun. This does not mean that serious games are not supposed to be made with amusement in mind [3]. A game's ludic nature is a compelling trait that is essential to the serious game concept and cannot be ignored. When allied with mixed reality technology, the ideal scenario is a fun, engaging, and highly immersive experience that can help the absorption of knowledge, which is evaluated in real time by the system, helping with satisfaction and giving users a sense of accomplishment [1].

2.2. Musical Intelligence

According to Gardner, like language, music is a separate intellectual competence. One that is also not dependent on physical objects in the world. Musical intelligence is tied to an individual's ability to perform, sing, review musical work, teach someone to play a musical instrument, and identify the emotional mood in music. We can split musical intelligence into two main core aspects of pitch and rhythm, the former being sounds emitted at a frequency you can hear, and the latter being how sounds are grouped following a system, usually in repeated time to give it a sense of motion and pattern [5].

There's more to any musical action when it comes to evaluating Musical Intelligence, something as simple as whistling a tune you like means you remembered the sequence of notes you need to play, when you need to play them, and how to match the sound and then have to control your own body to replicate it [9]. So it's empirical to analyze the elements of music that are involved in a certain experience, if it expects you to recognize those elements (receptive), emotionally react (affective), or perform rhythm or melody through motor movement (reproductive).

3. Related Work

Due to the nature of this systematic review, it was difficult to find any work involving the same themes, but it was possible to identify studies such as Lee et al. [10], and Zhang et al. [2], that provide a perspective on different aspects of our research. While neither focuses on music specifically, both highlight core frameworks such as sensory engagement, emotional immersion, and spatial interaction that directly inform the pedagogical potential of Mixed Reality (MR) in music education.

Zhang et al. [2] emphasize how the multimediatic stimuli (visual, auditory, and haptic) enhance immersion and influence behavioral change in sustainability-focused games. Their review reveals that elements like sound design, spatial visuals, and touch interfaces can trigger emotional resonance, attention, and motivation. Factors essential in developing musical intelligence. Although their work is rooted in pro-environmental behavior, the underlying mechanisms of immersive experience and multisensory design are highly applicable to music-based serious games.

Conversely, Lee et al. [2] provide a broader analysis of serious games across Virtual, Augmented, and Mixed Reality settings. Their systematic review shows VR's dominance but calls for further research into MR applications, particularly in underrepresented domains like music. They also highlight future standards such as personalization, multisensory interaction, and real-time feedback.

We seek with this paper to point out areas that might benefit from those findings in the realm of music, which is underexplored in the context of serious games, and how MR immersion factors in towards skills like recognizing musical elements (pitch, rhythm, melody) and reproducing those elements, be it by memory or following instructions.

4. Methodology

As the main objective of this study, we conduct a systematic review of the literature following SEGRESS (Software Engineering Guidelines for REporting Secondary Studies) guidelines made by Kitchenham et al. [11, 12]. Following their structure, the methodology was structured into two phases: first, planning the review protocol, and second, executing the selection and analysis of articles to draw conclusions from the gathered data.

4.1. Planning

First, we defined our main question based on our main objective: "How effective can the use of MR serious games-based musical education be for musical skill development?". We then followed it with the secondary questions:

SQ1 - What type of musical ability does the game aim to develop?
SQ2 - Who is the target audience or the learner group for the game?
SQ3 - What technological platform is used by the game? (e.g., AR, Mixed Reality, VR)
SQ4 - What was the participants' musical knowledge before using the game?
SQ5 - What are the stated objectives or expected learning outcomes of the game?
SQ6 - How was musical learning or skill development measured and evaluated in the study?
SQ7 - How much improvement in musical intelligence (e.g., rhythm or melody skills) was observed after using the game?

For selection, it is also necessary to define our criteria for inclusion (IC) and exclusion (EC) of the articles, to filter what we gather to analyze, following Table 1. A pre-selection stage was performed to remove any research that does not mention words in our research string in their title, abstract, or keyword list. Once the pre-selection process ends, a quick analysis of the titles and abstracts following our selection criteria is conducted to select or reject papers, and these selected papers go through a full text reading to be accepted if they do not meet any of the exclusion criteria.

Table 1: Selection papers criteria.

Criteria Type	Code	Description
Inclusion (IC)	IC1	Papers that answer at least one of the research questions.
Exclusion (EC)	EC1	Duplicate papers.
	EC2	Papers that are forewords, books, book chapters, abstracts, posters, panels, lectures, keynotes, tutorials, editorials, or demonstrations.
	EC3	Papers that cannot be accessed in full.
	EC4	Papers that are not in English or Portuguese.
	EC5	Papers in which the search string is not mentioned in the title, abstract, or keywords.
	EC6	Papers that are not primary (reject systematic reviews or mappings).
	EC7	Papers that do not answer at least one of the research questions or do not meet any of the inclusion criteria.

For the search strategy, we obtain the elements in Table 2 using the PICOC strategy to separate the terms into Population, Intervention, Comparison, Outcome, and Context. We did not use the comparison because this article aims to explore the literature without making direct comparisons to specific interventions. Due to one of our research questions regarding who can be of interest as a subject to an immersive game intervention for musical education purposes, no terms are defined for the population.

Table 2: Defined PICOC strategy search criteria.

PICOC term	Word
Population	Game
Intervention	Mixed reality
Comparison	-
Outcome	Learning
Context	Musical Education

Thus, we organized our search string considering those main PICOC terms and their variations and synonymous terms, as follows:

(”game” OR ”games”)
AND
(”augmented reality” OR ”virtual reality” OR ”extended reality” OR ”artificial reality” OR ”mixed reality” OR ”cyberspace”)
AND
(”learn” OR ”learning” OR ”education” OR ”educate” OR ”training” OR ”train” OR ”tech” OR ”teaching”)
AND
(”music” OR ”musical”)

The research databases chosen for this review were ACM Digital Library, El Compendex, IEEE Digital Library, ISI Web of Science, SBC Open Library, Science@Direct, Scopus, and Wiley.

For the execution of the SML, we planned three stages: 1) **Search** (stage 1): we performed searches in scientific databases, collected results, and removed duplicate studies; 2) **Selection** (stage 2): we reviewed the titles, abstracts, and keywords of each study, applying the selection criteria; and 3) **Acceptance** (stage 3): we performed a full text reading of the selected studies, reapplied the selection criteria, and extracted data to address the research questions.

Finally, to support the implementation of the SML protocol, we used the *Parsif.al* system for organizing references. We then utilized *Google Sheets* to assist with the selection process and data summarization.

4.2. Execution

After the planning process was completed, we executed this in the research databases for available studies, collecting every article for the search step, then we reviewed titles, abstracts, and keywords during the selection step and applied our criteria for acceptance of those papers. In total, the search step returned 466 studies(Table 3 - search) from which 160 studies (34%) were removed because they were duplicates, and 305 remained (66%). For the selection step (step 2 - Table 3 - selection), after applying the selection criteria, 259 studies (56%) were rejected, leaving 55 studies (12%) for the next step. Lastly, in the acceptance step (step 3 - Table 3 - acceptance), 37 studies (7%) were excluded. Therefore, the 23 studies selected for analysis represent a 5% subset of the initial 466 articles identified by the search.

Table 3: Papers per selection steps.

Research Base	Search	Duplicated		Selection		Acceptance	
		Rejected	Remnants	Rejected	Remnants	Rejected	Accepted
ACM Digital Library	17	7	10	8	1	0	0
El Compendex	30	21	9	8	1	1	0
IEEE Digital Library	0	0	0	0	0	0	0
ISI Web of Science	138	57	81	66	24	12	12
SBC Open Library	0	0	0	0	0	0	0
Science@Direct	62	4	58	58	0	0	0
Scopus	217	69	148	119	29	18	11
Wiley	2	2	0	0	0	0	0
Total	**466**	**160**	**306**	**259**	**55**	**31**	**23**

Consequently, Table 4 presents the studies acquired after each step was performed, showing the publication year, the title of the article, and a code to refer to different studies in this systematic review.

5. Results

Presented in this section are the results of our SRL, including a summary of the demographic data as a preliminary analysis, followed by each research question being addressed.

5.1. Preliminary Data

Analyzing the countries from which each accepted publication originates (Figure 2), we observe that Brazil has the most articles (5 - 21%), followed by Poland and South Korea (2 studies - 9%), and then Canada, China, Germany, Greece, Indonesia, Italy, New Zealand, Slovenia, Spain, Switzerland, Taiwan, Turkey, Ukraine, United States, all contributing with one study (4%). Research from Brazil demonstrates a trend of focusing on themes of accessibility for people with special needs (deaf and learning disabilities) and teaching children. Poland and South Korea provide both pilot studies and a sequel study, explaining the existence of two studies in the data. It is important to note that even though the SBC Open Library, a Brazilian research base, did not return any results, we still have 5 of the accepted studies originating from Brazil, showing that MR serious games for music education are already peaking interest in interdisciplinary subjects and have not been explored in the context of computing as an area of study.

From the temporal distribution of the articles over the years (Figure 1), we can assume an observable increase in the number of studies starting in 2006, with

Table 4: Accepted primary studies.

ID	Year	Title
S01	2021	Training Using a Commercial Immersive Virtual Reality System on Hand-Eye Coordination and Reaction Time in Young Musicians: A Pilot Study [13]
S02	2024	Enhancing music rhythmic perception and performance with a VR game [14]
S03	2024	Training using a commercial immersive virtual reality system on hand-eye coordination and reaction time in students: a randomized controlled trial [15]
S04	2021	Toc-Tum mini-games: An educational game accessible for deaf culture based on virtual reality [16]
S05	2020	Salsa dance learning evaluation and motion analysis in gamified virtual reality environment [17]
S06	2023	A Comparison of Interfaces for Learning How to Play a Mixed Reality Handpan [18]
S07	2020	Developing Music Harmony Awareness in Young Students through an Augmented Reality Approach [19]
S08	2014	Teaching Children Musical Perception with MUSIC-AR [6]
S09	2020	A Pitch Perception Training Game in VR Environment for Enhancing Music Learning Motivation [20]
S10	2022	ChordAR: An Educational AR Game Design for Children's Music Theory Learning [21]
S11	2007	GenVirtual: An augmented reality musical game for cognitive and motor rehabilitation [22]
S12	2024	Presence and Flow in Virtual and Mixed Realities for Music-Related Educational Settings [23]
S13	2008	Prospective design of interactive emotional sound edutainment system: MESIG [24]
S14	2009	Design of interactive emotional sound edutainment system [25]
S15	2013	Music education using augmented reality with a head mounted display [26]
S16	2019	Augmented reality and QR codes for teaching music to preschoolers and kindergarteners: Educational intervention and evaluation [27]
S17	2014	E-cecilia: Implementation of a music game [28]
S18	2017	Interactive musical game with a gesture-controlled virtual puppet [29]
S19	2018	Creating an interactive musical experience for a concert hall [30]
S20	2017	Music everywhere – augmented reality piano improvisation learning system [31]
S21	2014	Music-AR: Augmented reality in teaching the concept of sound loudness to children in pre-school [32]
S22	2021	EasyARPiano: Piano Teaching Mobile App with Augmented Reality [33]
S23	2023	A Multiplayer Virtual Reality Game for Playing Gamelan Music in a Virtual Orchestra Mode [34]

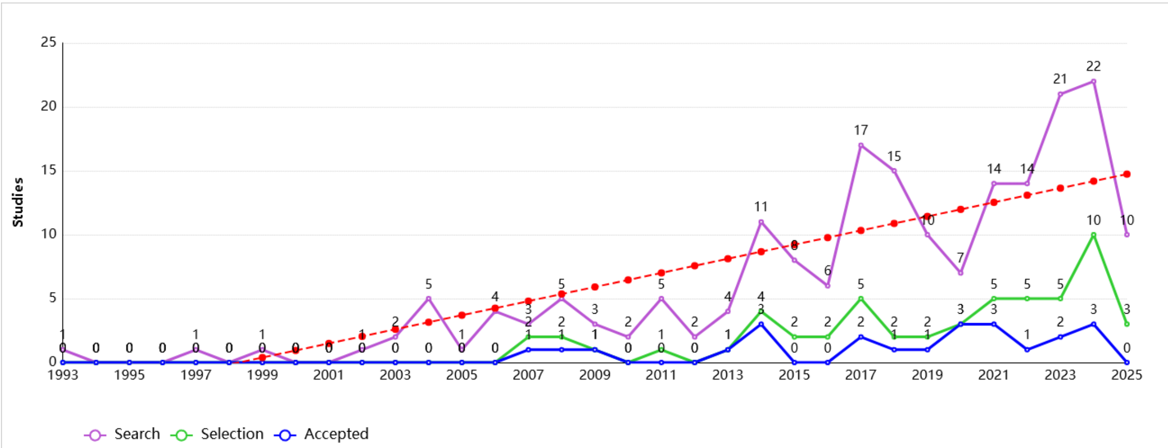

Figure 1: Number of studies by publication year

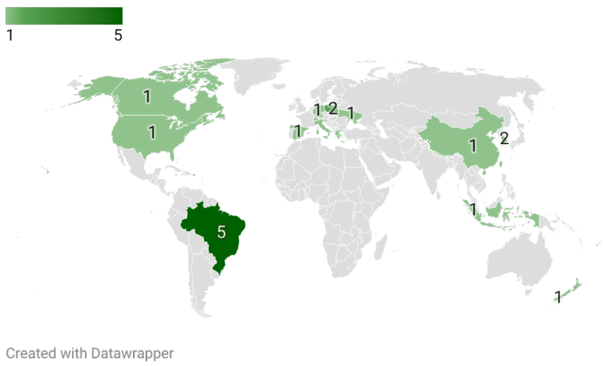

Figure 2: Studies per country

peaks of selected and accepted studies in 2014, 2017, and 2024. These peaks may correlate to a trend of growing interest in Mixed Reality technologies, in 2014 with the first announcements of VR headsets being in production and expected to be sold for public consumption, around 2017, where the first boom of this technology occurred, as VR products became more popular and produced by more companies, and it only grows as a subject of study in the years after. The steady increase shown by the trend line of searched studies (Figure 1 - red dashed line) suggests that this growth in research interest is likely to continue.

Finally, considering authorship (Figure 3), we identified recurring names, including Kyujung Kim (South Korea), Letícia Gomez (Brazil), Myunjin Park (South Korea), Valéria Farinazzo Martins (Brazil) and Sebastian Rutkowski (Poland), which may represent their interest in research on immersive technologies for musical education and become references in future reviews.

5.2. Research Questions

5.2.1. SQ1 - What type of musical ability does the game aim to develop?

The first question, though seemingly subjective, was answered by separating the activity that immersive experience proposes and tying it to musical elements that develop or engage aptitudes involving musical intelligence, as highlighted in Figure 4. In this way, we could gain a better understanding of what subjects are being studied and what may need more academic focus.

Figure 3: Main authors

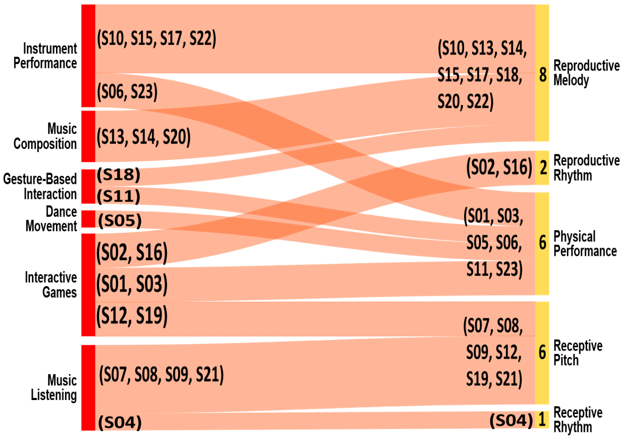

Figure 4: Music abilities developed.

The graph gives insight into which activities done to promote musical education are popular and which abilities they mainly develop. Admittedly, any exercise in musical intelligence may develop more than one musical ability [5], but we are concerned with focusing on their main ability to distinguish patterns and gaps in the literature. Through the analysis of each study, we identified that the articles tend to involve the ability to recognize and reproduce pitch or melody, while rhythm, both receptive and reproductive, has significantly less representation. Meanwhile, six studies mainly involve movement and musical performance in a physical world to be detected in the virtual environment, while the others involve interacting with a virtual object for performance.

5.2.2. SQ2 - Who is the target audience or the learner group for the game?

This question has the objective of identifying to which population MR serious games have been most commonly introduced in research for musical education purposes. Children and novice learners were the predominant target groups (children: [6, 27, 32, 21, 29, 14, 19, 13, 24, 25]; novice learners: [18, 26, 33]), individuals with disabilities (S04 - deaf [16]) or those undergoing rehabilitation (S11 - learning disabilities [22]) were also addressed. This visualization (Figure 5) shows the breakdown of the learner categories.

The term ”students” as a target audience is diverse, ranging from those in formal music schools to university students in unrelated fields, indicating various applications of music technology in education, as

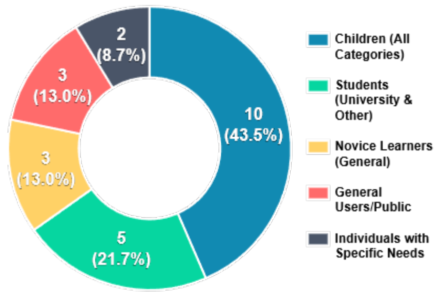

Figure 5: Target population of the studies.

exemplified in studies focusing on music school students [13] physiotherapy university students [15], university students with varied musical sophistication [23], and music students learning music/pitch [20].

5.2.3. SQ3 - What technological platform is used by the game?

For possible MR technology applications, this question aims to provide insight into the platforms of choice for serious games within the academic community and the rationales behind these choices.

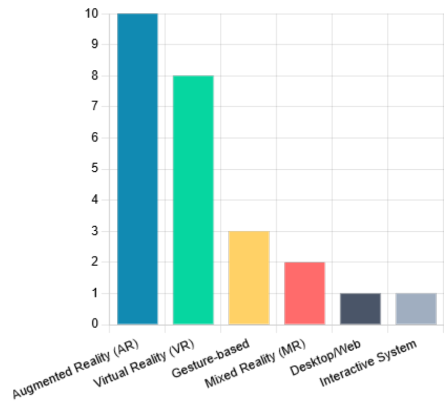

Figure 6: Immersive platforms used.

Immersive technologies (AR and VR) are the most prominent platforms, chosen for their potential to make musical concepts tangible and create engaging practice environments (VR: [16, 13, 15, 14, 17, 20, 34, 23] AR: [6, 22, 32, 21, 27, 19, 26, 33, 31, 23]). Within AR, mobile AR applications are a notable trend that aims to increase accessibility by leveraging common devices like smartphones and tablets. ([19, 21] - multi-platform including mobile, [27, 32, 33]). Gesture control is a significant feature, either as a primary interface [29, 24, 25] or inherent in AR/VR systems ([14] - VR controllers, [17] - VR motion capture), promoting more embodied and kinesthetic learning experiences.

5.2.4. SQ4 - What was the participants' musical knowledge before using the game?

To further understand the target demographic, this question identifies the musical skill level of study participants as a method to imply how MR platforms would be useful to other levels of musical knowledge besides the entry level.

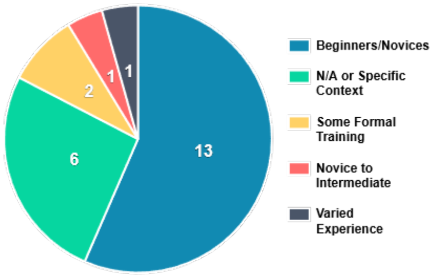

Figure 7: Musical development of subjects in studies.

More than half of the interventions target learners in the beginner or novice stages[6, 32, 21, 27, 19, 26, 18, 20, 33, 24] (57%), aligning with the focus on foundational skills and initial engagement, for example, non-dancers [17] and beginners to playing Gamelan[34]. Studies where the stage is "Not Applicable" (N/A) often involve participants with specific needs[16, 22] or where conventional musical progression is not the primary goal[15]. We generally observed a lack of specificity in defining learner stages in several studies, which can make direct comparisons of outcomes more challenging.

5.2.5. SQ5 - What are the stated objectives or expected learning outcomes of the game?

Being an interdisciplinary subject by nature, serious games vary in intent and can have interesting alternative applications for musical education, having musical intelligence as a path to achieve different objectives and outcomes.

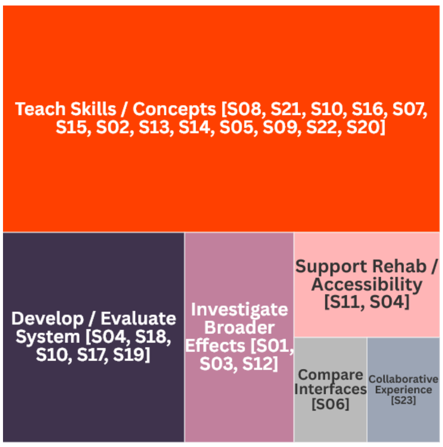

Figure 8: Intended objective of studies.

The most common objective is to teach or develop specific musical skills and concepts, such as pitch, rhythm, harmony, or instrumental performance [6, 32, 21, 27, 19, 26, 14, 24, 25, 17, 20, 33, 31]. A significant portion of the research focuses on the design, development, and initial evaluation (usability, engagement) of new educational games or interactive systems [16, 29, 21, 28, 7]. And then we have studies that aim to investigate broader effects (e.g., cognitive skills, social presence) [13, 15, 23] or address specific needs like accessibility and therapy, extending beyond direct musical instruction [22, 16].

5.2.6. SQ6 - How was musical learning or skill development measured and evaluated in the study?

Consequently, as part of any training process, it is necessary to measure development through quantitative and qualitative methods; therefore, the objective of this question is to highlight common methods of evaluation.

Table 5: Studies by evaluation of musical learning.

Measurement/Evaluation Category	Study IDs	Count
Pre/Post Tests (Knowledge/Skill-based)	S21, S16, S07, S02, S09	5
User Experience Feedback	S04, S08, S10, S06, S12, S23, S15, S01, S03, S05	10
Metrics (Performance , Task Completion & In-game Analytics)	S04, S06, S10, S12, S02, S05, S22	7
Observation & Tester Evaluation	S08, S18, S23, S16	4
Clinical or Standardized Cognitive-Motor Assessments	S11, S01, S03	3
System Implementation & General Feedback	S13, S14, S17, S19, S20	5

Mixed method evaluations are prevalent, often combining quantitative measures (such as pre/post tests or performance metrics) with qualitative user feedback [14, 18, 19, 21, 27]. There is a strong and consistent emphasis on the evaluation of user experience (UX) and usability, recognizing their importance for the adoption and effectiveness of technology [16, 6, 21, 18, 23, 34, 26, 13, 15, 17, 14, 19]. The rigor and nature of musical learning assessment vary, from standardized tests and detailed analysis in some studies [13, 14, 15, 17, 20, 27, 32] to more observational or feedback-based approaches in others [24, 25, 28, 29, 30, 31, 33], often reflecting the main goal of the study (e.g., system development versus efficacy testing).

5.2.7. SQ7 - How much improvement in musical intelligence was observed after using the game?

Finally, we tried to gather any prior evidence of improvement in skills adjacent to musical intelligence, questioning if the studies provide analysis of the applied results of their experiments.

Table 6: Observed improvement in studies.

Observed Improvement Category	Study ID	Count
Statistically Significant / Clear Improvement in Targeted Skill	S01, S03, S02, S05, S09, S16, S21, S08, S10	9
Positive Results / Observed Improvement (less formally quantified or broader)	S07, S14, S06, S11	4
Focus on other outcomes	S04, S12, S23, S18, S15, S17, S19, S20, S22	9
System Designed For Improvement	S13	1

Many studies that focused on specific skills and used direct assessments reported positive outcomes or statistically significant improvements in those targeted areas. Alternatively, enhanced engagement and motivation are frequently reported as key positive outcomes, even in skill-focused studies, highlighting a major strength of these technological interventions. A "Not Applicable" (N/A) for musical intelligence improvement often means that the study's primary goal was different (e.g., accessibility, user experience, general cognitive skills), not a failure of the technology for its intended purpose.

6. Final Remarks and Future Work

Throughout this study, we presented a systematic review of the literature that examined how MR-based serious games can be effective in providing musical education and, by proxy, developing musical intelligence. (Gardner) Based on the analysis of the accepted studies, a diverse number of methods have been employed to develop musical intelligence and the set of skills necessary for musical recognition, reproduction, and performance, with promising results in the realm of pitch and melody recognition and opportunities for working with rhythm recognition and reproduction with a gap in measurements directly related to musical intelligence.

As valuable strengths of MR-based serious games in music education provided by the selected papers, we noticed the high engagement with AR/VR platforms due to the fun and multisensory stimuli provided by immersive technology. Furthermore, strong references for reviewed studies involve a focus on foundational skill development, increasing accessibility via mobile AR, emphasis on user experience (UX) and usability, especially for those with special needs, and the potential for embodied learning through gestures, possible through real-time motion capture. In analyzing the literature, we also identified several weaknesses, such as a lack of research involving intermediate or advanced musicians, high variability in the rigor of musical learning before assessment, no direct measure of musical intelligence in a pedagogical setting, and a potential for the technological novelty to overshadow pedagogy.

For future work, it is necessary to be mindful of cost and accessibility barriers for some hardware (head-mounted displays). It is also important to try to ensure the pedagogical soundness of tech interventions, managing screen time, especially for younger children, and accepting that, as an emerging technology, rapid technological changes may require constant adaptation. Moreover, we perceived work opportunities that develop more advanced musical skills, conducting longitudinal studies on long-term impact, comparisons of traditional music education methods versus a technological approach, expansion of accessibility and therapeutic applications, and possibly AI integration for learning paths as a future direction.

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