SwimTunes: A gamified music performance system for co-creating with a novice audience

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ABSTRACT

This paper presents *SwimTunes*, a prototype game system designed for novice multi-user music-making in live performance settings. The system features a digital game and a public web app that allows audience members to participate using their mobile devices. After connecting via QR code, participants create and pilot virtual fish that generate music as they bump into one another. The performer then enters the game as a shark, using camera-based hand tracking to chase and consume the participants' fish. The result is a performance dynamic that evolves from playful co-creation to one of gameful contest between the performer and audience. *SwimTunes* explores how this shifting interaction context can shape the instantiation of a set of musical parameters, and further how performers can harness gameplay metaphors to conduct live audiences in shared acts of musical expression. The paper details the design considerations and conceptual motivations that informed *SwimTunes* before describing its implementation via Node.js, Open Sound Control, Unreal Engine 5, and MetaSounds. It discusses technical challenges and opportunities unearthed during development and outlines future directions for the project and gamified music performance at large.

Author Keywords

Music game, gamified performance, audience participation, Unreal Engine 5, MetaSounds

1. INTRODUCTION

Games are now well established as a versatile platform for musical performance, composition, and interaction. Following precedents in 18th century dice music [17] and the game pieces of Iannis Xenakis [33] and John Zorn [8], several modern performance and composition systems have adopted elements of game design. Examples range from sonifications of familiar games such as chess [24, 30], peg solitaire [22] or lawn bowls [7] to bespoke systems which establish their own rulesets for organizing musical interaction [10, 12, 16, 20, 27, 28]. Advancements in digital and mobile computing have also enabled the repurposing of game tools and technologies in musical contexts. For instance, the growing democratization of game engines has supported wide exploration of their potential for composition [14], performance [28], instrument design [31], and integration with musical programming languages such as ChucK [38].

Many of the musical works that adopt game metaphors or technologies are motivated by a desire to engage novice audiences. The intent is to reduce inhibitions about participating in music-making by leveraging both the intuitive emotional appeal of games [3, 9] and their cultural perception as being more approachable than the specialized domains of performance or composition [39]. To this end, many designs also constrain the musical controls and outputs available to participants to minimize barriers to usability and learnability [5]. These strategies are well exemplified by the rich lineage of 'sound toys' [15], which can be traced through early game software like *Otocky* (1987), the music tables of the 2000s [4, 21], and iOS apps such as *Biophilia* (2011) and *Chiptune Runner* (2013). Despite their growing entanglement with the psychology and technology of games, however, novice-oriented designs rarely seek to invite elements of conventional game *contest* into their music-making experiences [15, 35]. In particular, the potential for playful competition to inform new performer-audience relationships remains underexplored in the context of participatory music performance [23].

This paper introduces *SwimTunes*, a prototype music system for engaging a novice audience in a gamified, multi-user performance. The implementation is lightweight and adaptable, requiring only the performer's laptop to run a central digital game which participants interact with via mobile web browsers. The novelty of this prototype is that performances are designed to shift from a state of open musical play amongst audience members to one of game-like contest between the audience and performer. This allows for a real-time exploration of how changes in the interaction dynamic can shape the expression of the system's musical affordances. *SwimTunes* also functions as a shared musical instrument, demonstrating how competitive gameplay metaphors can be harnessed by a performer to conduct an entangled audience [36]. After reviewing related works in game- and mobile-based participatory performance, I detail the design and technical implementation of the music and game systems via Node.js, Open Sound Control, Unreal Engine 5 and MetaSounds. I conclude with a discussion on the challenges and opportunities presented by the design approach and its future implications. All project files for *SwimTunes* are made available for use under CC BY 4.0 license (see Appendix). A video demonstration is also available as a supplementary material.

2. RELATED WORK

My work takes place at the intersection of three key research areas: the design of collaborative musical experiences for novices [5], the use of personal devices as a platform for audience participation, and the use of game structures and technologies to organize musical performance. In each of these contexts, the ubiquity of personal mobile devices offers great convenience for performers and participants alike, reducing material and organizational costs while also lowering perceived barriers to entry due to hardware familiarity [29]. This has fueled a diversity of mobile-based participatory performances, many of which also harness game-like elements in their structure or interaction design.

In *Sound Games 1* and *2* [16], players earn points for performing simple mobile-based instruments in sync with one another and additionally compete to acquire more valuable 'leading' instruments by moving around the performance space. In *echobo* [26], participants improvise short phrases and broadcast them to fellow players in a viral collaborative interaction. Both works require participants to download an app, presenting challenges for cross-platform support and introducing a small measure of friction into the user experience [1]. Works such as *TweetDreams* [11] circumvent this problem by repurposing existing social apps. Following improvements in the performance and standardization of web technologies, however, delivering web-based interfaces directly to the audience's mobile browsers has proven a more robust solution.

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Efforts to establish frameworks for web-based, multi-user mobile participation have included *massMobile* [40], *SWARMED* [18], and *NEXUS* [2]. The vision of distributed performance advanced by these initiatives opened the way for new participatory works to gamify web-based designs. *Crowd in C[loud]* [25], for instance, adopts a gamified dating app metaphor. Participants compose five-note motifs as a personal 'profile', audition the profiles of others, and award 'likes' to their favorite tunes which are tracked on a live leaderboard. In *Mesh Garden* [10], players can steal notes from one another by aligning their mobile devices, invoking a casual competition that recalls the final 'knock out' stage of *SoundBounce* [12]. These gamified strategies give rise to a novel blend of cooperative and competitive social interactions that both motivates audience participation and organizes their creative contributions into a cohesive musical outcome. Such dynamics are of primary interest to this paper and a significant point of inspiration for *SwimTunes*.

Each of the works highlighted thus far are collaborative musical experiences for multiple novice participants [5]. They also share some conceptual overlap with notions of multi-player or entangled instruments [19, 36], even if not always an explicit design aim. However, there are several other gamified performance systems that have informed *SwimTunes* despite operating beyond the paradigms of collaboration, audience participation, or mobile-based interaction. Among these are Christof Ressi's *game_over_1.0.0*, developed under the Gamified Audiovisual Performance and Performance Practice project [27], and the game pieces *Pathfinder* and *Icarus* designed for an augmented drumkit [28]. Although these works do not invite direct participation or collaboration with audiences, they are notable for demonstrating the latent potentials of applying game engine technologies and a competitive game framework to audiovisual performance more broadly.

Cello Fortress [37] stands apart from the other works surveyed here as a rare case of explicit competition between the performer and a cooperating audience. The performer improvises on a cello to operate the defenses of a virtual fortress displayed in the performance space. Players then collaborate to assault the fortress, using commercial game controllers to pilot small virtual tanks and overcome the performer's defenses. In this design, participants are afforded only indirect control over the musical output by prompting improvised responses from the performer. *SwimTunes* seeks to invert this relationship: the live musical output is predominantly shaped by user input and the performer's role is instead to direct the audience's musical response. It also aims to build upon the speculative work of Koszolko and Studley [23] by exploring a practical implementation of a 'performer versus audience' relationship within the context of mobile-based music-making for novices.

3. DESIGN

SwimTunes is a gamified music performance where audience members create and pilot their own virtual fish within a shared 2D environment (Figure 1). It begins as an empty underwater scene scored by a gentle swelling of diatonic chords and an ambient aquatic soundscape. Participants are invited to scan a QR code that leads them to a web application serving as the mobile interface for all user input. They first use the web app to select a shape and color for their fish and spawn it into the virtual scene. Participants can then begin to pilot their fish around the environment by tapping coordinates on a two-dimensional plane (Figure 2c). Providing shape and color customization aids participants in identifying their fish on the shared game display, though it also enables rudimentary forms of social and visual 'expression' [3] as found in games that allow for personalizing 'avatars' [9].

Figure 1. Primary game display for *SwimTunes*.

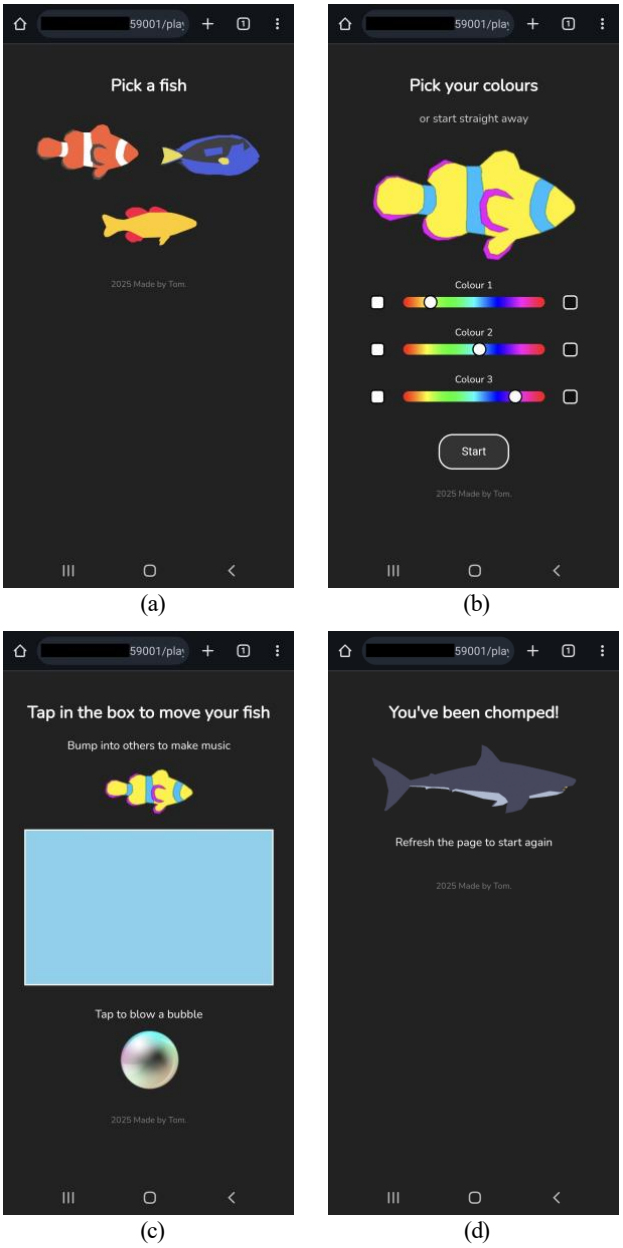

Figure 2. Mobile web application used by participants. (a) fish shape selection, (b) fish color selection, (c) fish controller, (d) notification of being eaten.

Participants are afforded only two means of musical control: 'bubbles' and 'bumps.' For the former, participants simply tap a button in their browser to make their fish 'blow a bubble' (Figure 2c). Each bubble produces one note from a small diatonic set with a short metallic timbre. Pitch is determined by the fish's vertical coordinates and stereo panning is determined by the horizontal coordinates (Figure 3). As for 'bumps', a note is produced each time two fish collide within the virtual environment. These notes draw from a wider diatonic set and use a softer timbre, but otherwise employ the same coordinate-based mapping for pitch and panning. Where 'bubbles' offer an immediate and self-contained musical response that doesn't rely on others, 'bumps' encourage a form of musical and social interaction between participants. The individual decisions made by each participant give rise to emergent musical behaviors as they form a collective 'school' of fish. For instance, the audience might flock together through the scene, resulting in a focused cluster of musical output that rotates around the parameter space. They might instead scatter, distributing notes across the pitch and stereo field, or oscillate dynamically between any number of such configurations as they explore musical outputs together. At this point in the performance, all interaction takes place exclusively between audience members in an atmosphere of open and playful collaboration.

The tone shifts dramatically once the performer enters. As they raise an open palm to face a hand-tracking web camera, a shark suddenly appears amidst the fish. The performer pilots the shark by moving their open hand in the camera's field of view and can eat nearby fish by closing their hand in a 'chomping' motion (Figure 4). The threat quickly becomes apparent to the audience and a game of evading the performer's shark ensues. For the performer, successfully eating a fish produces a melodic tone based on the same coordinate mapping outlined prior (Figure 3), though this is neither their primary nor most interesting means of musical expression. Rather, it is the power to manipulate audience behavior within the game and thus shape the music generated by their actions. The performer can try to herd the fish toward certain coordinates (and thus musical parameters), block access to certain coordinates, keep fish separated from one another, or simply swim about harmlessly to observe how players react.

Audiences too can adopt varied in-game responses. Players might deprioritize musical interactions to focus purely on the new objective of evading the shark, as one study into competitive musical games suggests [35]. Others might resort to musically 'taunting' the performer by repeatedly blowing bubbles to attract their attention, whether as a personal challenge or in a noble effort to protect other fish. Exploring the audience's social and musical responses in this way is a key motivation for the work and the basis for implementing the shift from playful collaboration toward a 'performer versus audience' contest. This design also enables real-time exploration of how a common set of musical parameters instantiates under contrasting interaction conditions and performer-audience relationships. In service to these goals, my preference is to keep the shark a surprise during performances. This allows audiences to engage authentically with what they first perceive as a collaborative musical sandbox before offering their raw social and musical reactions to the reveal of the performer's antagonistic role.

Several design decisions in *SwimTunes* were inspired by aiding the non-verbal and non-textual communication of the performer-audience relationship. Most immediate was the early choice to represent the audience as fish and the performer as a shark to clarify their dynamic via conceptual association. This also informed the use of hand tracking as the performer's means of piloting the shark. Hand tracking renders visible the performer's responsibility over the shark's actions, enables the 'chomping' motion to serve as an intuitive metaphor for the threat posed to participants, and is more visually engaging than operating a laptop or smartphone interface. In the current prototype, no end condition is programmed into the game or performance. Players cannot defeat the shark, but are also free to rejoin the game as new fish if eaten, allowing both performer and audience to continue experimenting with new game and musical strategies. Alternative possibilities for this design and their implications are discussed further in.

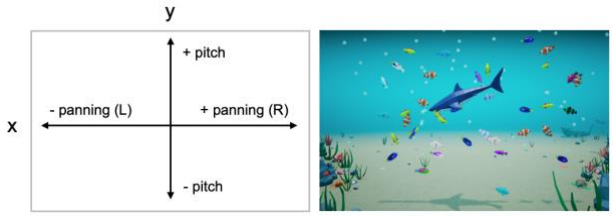

Figure 3. Musical mapping based on screen coordinates of user interactions.

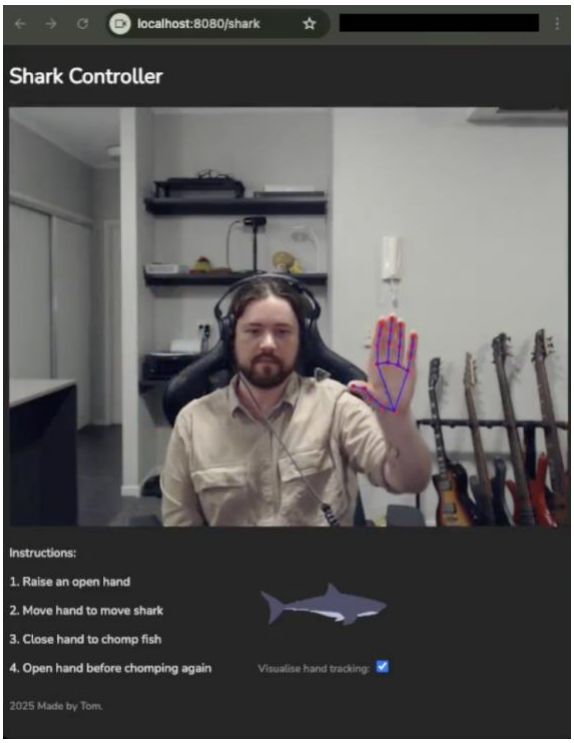

Figure 4. Hand-tracking interface used by performer.

4. TECHNICAL IMPLEMENTATION

SwimTunes is designed to be lightweight and adaptable, requiring only a performer with a laptop and a willing audience with mobile devices. It is suited to any context where participants can see a central game display and hear stereo sound output. Given the role of social interaction in the performance, it is best served by spaces with a large display or projection surface that can be comfortably seen by twenty or more participants. I assume this context when describing the system architecture (Figure 5).

4.1 Game and Music Systems

At the center of the work is the digital game that tracks and displays the virtual environment, fish, and shark to the audience. This was developed in Unreal Engine 5 (version 5.5.1) using a small collection of creative commons assets (listed in Appendix). The game application also drives all sound generation for the performance, including both a synthesis-based music system and a small number of file-based sound effects. Both were designed using MetaSounds, a node-based procedural audio system native to Unreal Engine 5 that supports close integration with its gameplay systems. MetaSounds features configurable oscillators, noise generators and a simple suite of built-in DSP tools such as filters, delay, and reverb, but does not yet offer a ready-made solution for polyphonic synthesis. I built a monophonic synthesizer for each unique musical event (e.g., one for

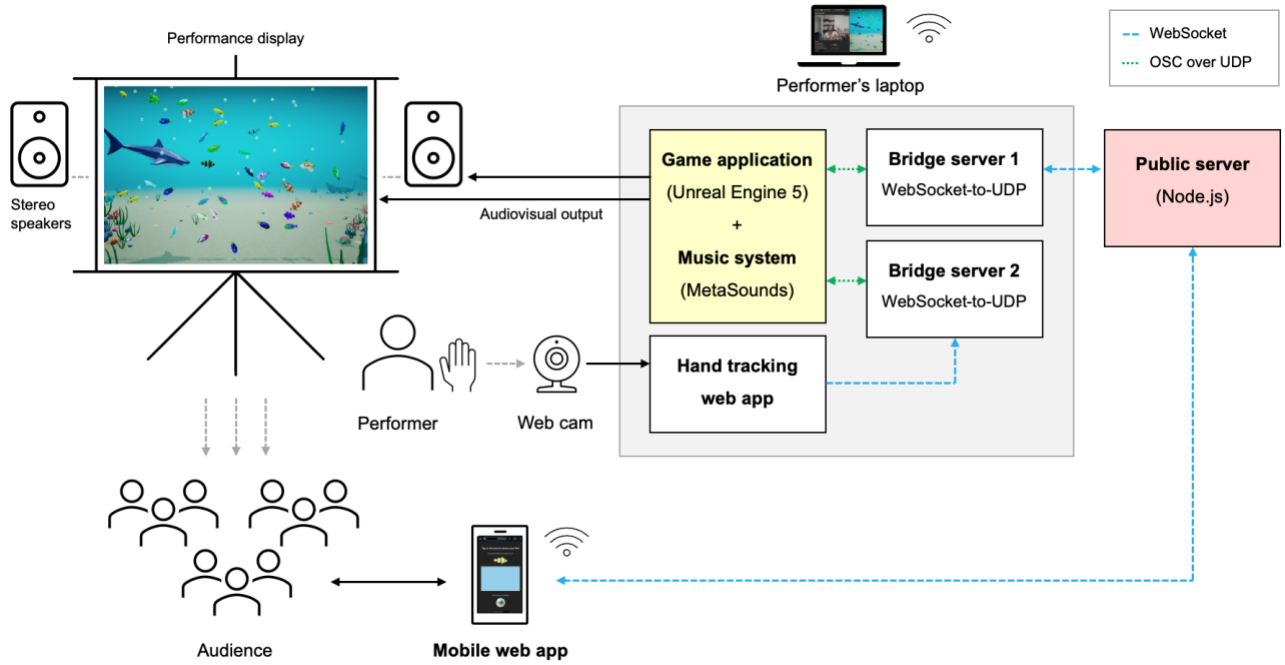

Figure 5. Overview of *SwimTunes* system design.

'bubbles', 'bumps', 'chomps') and configured the game engine to create new instances of these synthesizers whenever the respective event is triggered. The synthesizer then plays a single note determined by the event's coordinate-pitch mapping (Figure 3) before being deactivated by the game engine as a means of voice management.

4.2 Web-based User Input

Communication between the audience and game engine relies on a remote public server and a local 'bridging' server. Both were built using Node.js. The public server delivers the web application to the participant's mobile browser (Figure 2) and receives user input—such as new fish coordinates or 'bubble' presses—over a persistent WebSocket connection. The local server then acts as a bridge between the public server and game engine. It receives user input as JSON data, processes this into OSC messages, and transmits them to Unreal Engine 5 as UDP datagrams. This is enabled by the osc-js library for Node.js[1] and the Open Sound Control plugin packaged natively with Unreal Engine 5. Communication is bi-directional throughout, allowing the game application to notify specific participants that their fish has been eaten via their browser client (Figure 2d). The web application itself is written in basic HTML, CSS, and JavaScript.

4.3 Hand-tracking the Performer

The final component of *SwimTunes* is the camera-based hand-tracking system for controlling the shark. It consists of a local web application as a user interface (Figure 4) and a second local bridging sever for processing user input into OSC messages for Unreal Engine 5. Hand tracking is powered by MediaPipe's Hand Landmarker,[2] a machine learning computer vision model that can track twenty-one separate hand and finger features in a real-time camera feed. The shark moves persistently toward the transposed XY coordinates of the center of the performer's hand. A 'chomp' is registered whenever the performer's thumb tip is brought sufficiently close to their fingertips, prompting the game engine to destroy any fish immediately in front of the shark's mouth. This action cannot be triggered again until the performer reopens their hand. When combined with the need to react quickly to live fish movement, this restriction encourages the performer to enact enthusiastic 'hand chomping' motions as a vivid and potentially amusing visual metaphor for the audience.

4.4 Project Files

All project files are made available for use under CC BY 4.0 license via the Appendix. The compartmentalized architecture is well-suited to flexible repurposing. Both the fish control system and hand-tracking system can be used to route OSC messages to any other compatible app on the local network. Likewise, any other OSC-capable application can serve as a control input for the game engine and music system.

5. DISCUSSION

As an early prototype, *SwimTunes* has yet to be submitted to a formal evaluation. The system has been informally tested by approximately 120 undergraduate students with limited to no musical experience, in groups of 30 participants per performance. These were technical stress tests only: no research data was collected, and students were not expected nor prompted to provide feedback. What follows are my preliminary reflections on the opportunities and limitations uncovered during the development and testing of *SwimTunes* as they relate to my chosen conceptual approach and technical implementation.

5.1 Usability

One concern for the participant experience is the need to pilot fish using a mobile device while also watching a separate central display for visual feedback. The students participating in informal testing did not demonstrate any difficulty with this, though it may present a challenge for less dexterous users. The game visuals could instead be displayed directly in each participant's browser, though this was avoided to prevent audiences from looking exclusively at their phones and preserve the social dynamics of the performance. Retaining a central display also enables a non-participating audience to experience

[1]https://www.npmjs.com/package/osc-js
[2]https://ai.google.dev/edge/mediapipe/solutions/vision/hand_landmarker

the performance as passive bystanders. Future iterations will explore gesture-based control as an alternative input, which several works have shown to be an engaging means of smartphone-based musical interaction [6, 10, 12]. For instance, participants could hold their phones in landscape orientation as a physical analog for their fish and 'swim' it through the air to control the position or momentum of its virtual counterpart. Beyond minimizing the need to glance at a secondary screen, this would also help to unify the interaction metaphors between audience and performer (i.e., both would be 'swimming' using similar hand movements) as a potential means of heightening engagement and social connection.

5.2 Individual Expression

Another challenge in the current design is discerning an individual's musical contributions once a large number of participants have joined. As Dahl et al. found with *TweetDreams* [11], some participants may invest so deeply in tracking their personal influence over the music that it detracts from their appreciation of the larger system at play. This tradeoff between individual musical expression and the overall participatory experience is a well-known design tension for musical systems targeting novice audiences [5]. However, it presents less of a concern in *SwimTunes* for several reasons. First, the work revolves around high-level relationships between the audience as a collective and the performer, which are upheld so long as the audience's combined influence over the musical output remains discernible. Second, almost all musical output emerges from the persistent input of participants (i.e., pressing the 'bubble' button, swimming into other fish), which in turn produce rather transient sonic results (i.e., single, short notes). As such, each shift in audience activity creates pockets of underutilized textural, pitch, or stereo space that participants can occupy if they desire to stand out. Finally, the presence of extramusical incentives (i.e., escaping the shark) offers an alternative focal point for those attracted to low-level, individualized interaction while still contributing to the shared musical outcome.

5.3 Tensions between Game and Music

User feedback for musical games like *Mesh Garden* [10] demonstrates that players can become deeply engaged with competitive objectives. This is ostensibly desirable for designers hoping to encourage audience participation. However, user studies of other competitive music-making games indicate that some players may deprioritize or even ignore musical interaction when faced with a game-based challenge [34, 35]. These users were no less engaged in the overall experience, but performers should consider whether they are incentivizing interactions that jeopardize the musical intention of their work. For instance, most 'sound toys' avoid competitive game elements to ensure that the experience remains primarily concerned with sound creation and exploration for casual users [15]. *SwimTunes*, on the contrary, is motivated by a desire to explore this tension in a live performance setting. This is the purpose of guiding audiences from a state of playful co-creation to one of contest with the performer: to explore 1) how audience behavior shifts when game elements are introduced during musical performances, and 2) how this shapes the real-time expression of the system's musical parameters.

5.4 Gamifying Musical Entanglement

In the context of multi-user instruments, entanglement describes a decentering of the individual player from the production of music. Player actions become enmeshed within a single mutual collective and any attempt to lead or control others loses meaning [36]. In this respect, *SwimTunes* is not itself a wholly 'entangled instrument' because: 1) players can make self-sufficient musical contributions by blowing 'bubbles' and 2) the performer explicitly aims to coerce player behavior for their own musical purposes. Instead, *SwimTunes* encourages a form of 'partial' entanglement, which it then gamifies as the basis for a novel performer-audience relationship. This is made possible because much of the audience's musical contribution relies on their collective movement to trigger 'bumps', and the performer in turn can only shape the musical output in relation to this collective behavior. In other words, the audience becomes a quasi-entangled musical swarm that the performer can conduct through their shared understanding of the underlying competitive gameplay metaphor (i.e., evading the shark).

This raises new questions about how emerging themes in the design of entangled instruments, such as the balance between autonomy and democracy [36], could be influenced by gamified contexts. For instance, if the 'bubble' feature was removed from *SwimTunes* to further enmesh player action, but the performer's antagonistic role as the shark was retained, could an audience experience entangled intra-action as a mutual collective? Or would the game-based incentive of self-preservation suppress these experiences by reasserting a focus on the individual? These tensions highlight the need for continued consideration of the role that games and competition could play within multi-user instruments and live performance more broadly.

5.5 Future Directions

The novel performance dynamic articulated by *SwimTunes* can serve as a robust platform for future experimentation. One area for enquiry is to explore the implications of a more complete game framework with a 'quantifiable outcome' [32]. Applying this to *SwimTunes*: if the audience were given a means of defeating the performer's shark while also being prevented from re-entering the performance once eaten, then one side could be crowned as the 'winner' of the game. This simple change has the potential to cause significant shifts in how audiences make musical decisions and perceive the activity as a whole, least of all by imposing a defined ending for the performance. Whether the resulting experience is desirable for performers or audiences bears further investigation. An alternative but related approach would be to introduce individual game 'elements' [9, 13] such as points or leaderboards. Works such as *Crowd in C[loud]* [25] and *Sound Games 1* and *2* [16] have implemented this effectively, though the strategy remains largely untested within the context of a 'performer versus audience' relationship [23]. Most immediately, I will submit the current prototype of *SwimTunes* to formal performance experiments and user evaluations. These will be designed to capture audience perceptions of such works, the nature of engaging with them, and how this influences the music-making experience. The findings will deepen our understanding of the potential role for games within participatory music performance and continue to chart pathways toward new performer-audience relationships.

6. CONCLUSION

This paper has detailed the design and conceptual motivation for *SwimTunes*, a gamified music performance system for co-creating with a live audience of novice users. The game and music systems were both developed in Unreal Engine 5, demonstrating the increasing democratization of game technologies and their diverse applications for music performance. I have situated *SwimTunes* within the expanding practices of game-based and mobile-based music-making and articulated a point of departure from related works such as *Cello Fortress* [37], *Mesh Garden* [10], and those of the Gamified Audiovisual Performance and Performance Practice project [27]. The paper contributes a practical implementation of the underexplored 'performer versus audience' relationship [23] and a preliminary discussion of its limitations and opportunities. It also contributes the *SwimTunes* project files for use under a CC BY 4.0 license to support further prototyping of game-based music performance systems. Future research will submit *SwimTunes* to formal user evaluations to better understand the audience experience of making music in these novel performance contexts. The findings will inform the development of future game-based music systems and chart new potentials for the performer-audience relationship.

7. ACKNOWLEDGMENTS

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8. ETHICAL STANDARDS

This paper complies with the NIME ethical standards. No human or animal participants were involved in this research.

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A. APPENDIX

A.1 Project Files

A.2 Attributions

The game application for *SwimTunes* made use of the following assets licensed under Creative Commons 4.0 Attribution (CC BY 4.0):
- 'Fish' by rkuhlf. https://skfb.ly/6Sx7N
- 'Sea Weed' by rkuhlf. https://skfb.ly/6SB6Q
- 'Coral' by rkuhlf. https://skfb.ly/6SEIp
- 'Shark' by rkuhlf. https://skfb.ly/6SIUH
- 'Shells' by rkuhlf. https://skfb.ly/6SvyA
- 'Star Fish' by rkuhlf. https://skfb.ly/6SE7r
- 'Crab' by rkuhlf. https://skfb.ly/6SzXz
- 'Rocks' by rkuhlf. https://skfb.ly/6SsPW
- 'Turtle' by rkuhlf. https://skfb.ly/6Swro
- 'shipwreck low poly' by compost the second. https://skfb.ly/6TDpB
- 'Bite' by OllieBacon. https://freesound.org/s/517147/
- 'oceanwavescrushing' by Luftrum. https://freesound.org/s/48412/
- 'Underwater Deep Water Loop' by Department64. https://freesound.org/s/651743/
- 'Thud_3_Dry.wav' by zimbot. https://freesound.org/s/122124/

The game application for *Swim Tunes* also made use of the following public domain assets (CC0 1.0 Universal):
- 'Bite (Cartoon Style)' by Jofae. https://freesound.org/s/353067/
- 'cartoon bite.wav' by Mikes-MultiMedia. https://freesound.org/s/531245/