Diving Deep with *Nautilus*: An Analysis of Musicking with a Digital Score

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Abstract

In this article, we discuss the analytical findings from a qualitative investigation of musicking (Small, 1998) with a digital score. The main focus of this article is our methodology and the outline of our methods. The composition at the centre of this study is *Nautilus* – a digital score created using the Unity game engine. We discuss in detail the construction of a novel quantitative dataset, which has been designed as a standard structure for the analysis of different digital score case studies. Following this we present our analytical findings from the qualitative study and outline the themes that were created as part of a thematic analysis. As a conclusion, we assess the relevance of our findings against the core aims of the project, critically reflect on the methodology, and finally present some design considerations that emerged through this case study for those wishing to explore game engines as a platform for creative music-making.

Keywords: digital score, digital musicianship, Unity game engine, qualitative investigation, quantitative data set, methodology

1 Introduction and Context

This article discusses a methodology (system of methods) for analysing digital score musicking (Small, 1998). This methodology is part of an ERC-funded project entitled *The Digital Score: Technological Transformations of the Music Score (DigiScore)*.[1] The core aims of this project are to: (1) determine scientific knowledge of how digital scores stimulate new creative opportunities and experiences within a range of music practices; (2) develop a theoretical framework for digital scores as an important transdisciplinary area of research; and (3) build a scientific study of inclusive digital musicianship through the transformative potential of the digital score.[2] A digital score is defined by the project as a *communications interface of musical ideas between musicians utilising the creative potential of digital technology*. The meaning of this in practice is being investigated through a series of practice-based case studies that place the experts at the centre of their practice. The purpose of this is to offer the musicians experiences with which to report back to the researchers of *DigiScore* by contributing to a comprehensive dataset, who in turn synthesise the results into a developing theory (the dataset and theory are discussed below). *Nautilus* (2022) is the first of these case studies and, as such, a parallel aim was to challenge and evaluate the methodology and the provisional theoretical framework.

[1] https://cordis.europa.eu/project/id/101002086.

[2] Taken from original ERC application, which can be downloaded here: https://digiscore.github.io/pages/aboutus/.

A central theoretical construct in studying digital score music-making is that of Christopher Small's notion of *Musicking* (Small, 1998).[3] In this book, he states that "to music is to take part, and that taking part can happen in any capacity, in a musical performance, whether by performing, by listening, by rehearsing or practicing, by providing material for performance (what we call composing)" (Small, 1998, p. 9). Critically, Small stresses that "the act of musicking establishes in the place where it is happening a set of relationships, and it is in those relationships that the meaning of the act lies" (Small, 1998, p. 13). Simon Emmerson clarified Small's principle of "meaning" to infer the "what you mean to me" (Emmerson, 2017, p. 29). This subtle shift circumvents the significant issues of value and who is doing the evaluation of meaning. Therefore, meaning, or the "what you mean to me" (Emmerson, 2017, p. 29), is to be found in the relationships formed between the new creative acts of musicking and the technologies and media of the communications interface: the digital score.

The context for digital scores encompasses a broad range of practices and technological novelty. They build upon contemporary practices that emerged out of the experimental period of contemporary music (late 1960s onwards) and adopt approaches such as improvisation, indeterminacy, comprovisation,[4] sound painting, mixed-media composition and acousmatic production. While not a separate paradigm to the traditional paper-based platform of traditional/conventional scores, they are the next logical step in the development of the music score by advancing the creative potential of the medium that carries communicative properties of notational language (however broad). A critical feature of digital scores is the application of extra notational elements of rich media, animated shapes, interactive and haptic controllers, and even the embodied movement of robots to convey the specific language of the music idea.

Although a relatively young subject of study as a community concern, there is emerging a substantial body of discourse. Proceedings from the International Conference on Technologies for Music Notation and Representation,[5] highlight the diverse range of studies in this field. These study the musicological, technological, creative, musicianship, and artistic practice perspectives of study, with subjects such as Mutable gestures: A new animated notation system for conductor and chamber ensemble (Frame et al., 2022), Using gesture data to generate real-time graphic notation (Dori, 2020), Symbolising space: From notation to movement interaction (Raheb et al., 2020), Drawsocket: A browser based system for networked score display (Gottfried and Hajdu, 2019), Digitization of historical music archives: Preserving the past, embracing the future (Haus and Ludovico, 2017), A web interface for the analysis and performance of aleatory music notation (Baratè and Ludovico, 2017), and An architectural approach to 3D spatial drum notation (Ham, 2017) highlighting the diversity of interests.

Recent books on the subject such as Craig Vear's *The digital score* (Vear, 2019), and *Sonic writing* by Thor Magnusson (Magnusson, 2019), and *The digital musician* by Andrew Hugill (Hugill, 2018) contribute to the theoretical strength of the field. There are significant advances in notational and score-based technologies that are being adapted by musicians in, and out, of this community. For example, MaxScore[6] "provides music notation in Max and Ableton Live"; *Ossia* "is a sequencer for audio-visual artists, designed to enable the creation of interactive shows, museum installations, intermedia digital artworks, interactive music and more in an intuitive user interface"; *Neoscore*,[7] "a Python programming library for creating scores without limits"; and *Decibel Player*,[8] developed by the Decibel Ensemble, is an iPad application designed to coordinate the reading of scores featuring predominantly graphic notation in rehearsal and performance.

Alongside the theoretical discourse and technological innovation there is a substantial corpus of artistic practice and practice-based researchers investigating the field through composition and performance.

[3] Interestingly, this concept can be traced back to a 1977 article by Benjamin Boretz in which he describes it as "musikierung, music-making, the activity of composing, or perceiving, or performing, or theorizing, or analyzing" (Boretz, 1977, p. 127).

[4] Comprovisation is a musical portmanteau combining the meaning of "composition" and "improvisation", attributed to Butch Morris, but is widely used by modern composers such as Sandeep Bhagwati. Comprovisation brings a new formulation of tasks and allocation of roles of the participants to the idea of collaborative work that is consistent in the process of rehearsal for staged performance (Bhagwati, 2021). With it, one comes close to the realisation of the basic idea of "making music together" (Small, 1998, p. 41).

[5] https://www.tenor-conference.org/proceedings.html (accessed 18th October 2023).

[6] http://www.computermusicnotation.com/ (accessed 18th October 2023).

[7] https://neoscore.org/ (accessed 18th October 2023).

[8] https://decibelnewmusic.com/decibel-scoreplayer/ (accessed 18th October 2023).

Musicians such as Ryan Ross Smith, David Kim-Boyle, Cat Hope, Sandeep Bhagwati, Gudmundur Steinn Gunnerson, Georg Hadju, Nick Collins, Amanda Stuart, Erin Vargas, and ensembles such as Decibel (AUS), LoadBang (US), Heart Chamber Orchestra(US), and Ligeti Quartet (UK), regularly commission and perform digital scores.[9]

2 Methodology

The methodology for this study was designed in such a way that it was repeatable across many digital score case studies. Central to this process was the design of a dataset (Section 2.4) and an overarching theoretical proposition (Section 3.2). The individual components of the dataset required specific methods (tools and processes (Candy et al., 2021)) which ensure consistency of data throughout the whole *DigiScore* project lifespan.

2.1 Design considerations of *Nautilus* as a Case Study

Each case study in *DigiScore* has specific design considerations to avoid replication and to maximize the qualitative findings from this frontier research project. In *Nautilus* these are:

- *Unique research proposition*: the main participant (Carla Rees) is an expert in low flutes and experimental music. Developing a digital score around a gaming environment and artificial intelligence was new to her. It is therefore possible to see insights into how these technical elements and the iterative devising process shift her musicianship and offer potential transformations for her creativity.
- *Digital Score* type:[10] *Gesamtkomposition.* This type of digital score "uses computers to synchronise multiple streams of media into a cohesive work with live performers (human or machine). It coordinates these through a central software environment that is embedded with autonomous or generative behaviour. This actively composes the work in real-time and evokes the presence of the composer in the flow of musicking" (Vear, 2019, p. 128).
- *Technical infrastructure*:[11] *Nautilus* was created using artificial intelligence, machine learning, and the Unity gaming engine.
- *Creation mode*: this involved iterative and agile design processes that engaged all creative practitioners through the process.
- *Performance mode*: the realisation of this digital score relies on improvised practices and involves experimental music language.
- *Accessibility/inclusivity*: this is an important consideration of the *DigiScore* project, and *Nautilus* was developed in such a way that it is accessible and friendly to the low flutes community, most of whom have no, or very little, engagement with the above design considerations.

2.2 About *Nautilus* (2022)

Nautilus (2022) is an intermedial composition that brought together three practitioners to explore and contribute to the project from different perspectives: (1) composer, digital score researcher and project PI Craig Vear; (2) bass flute player Carla Rees; and (3) Unity programmer Adam Stephenson. Each brought their own unique experience and creative practice to the piece, driving both the aesthetic, technical and practical considerations of the work. They shared a core goal: "to create a digital score that supported and enhanced Rees's sense of musicking to a point that felt like it was operating with her in the making of the music" (Vear, 2022). In a partner article to this one (Vear et al., 2023), they describe *Nautilus* as:

> inspired by an imaginary deep-sea journey of a nautilus mollusc, as it navigates deep water trenches across the oceans. The music describes this journey with the

[9] A comprehensive list can be found at http://animatednotation.com/ (accessed 18th October 2023).

[10] The 10 types of digital scores are defined in Vear (2019, Chapter 4).

[11] The *DigiScore* project is focusing on seven technical themes: Artificial Intelligence, Machine Learning, Gaming, Robotics, VR/AR/XR, Networks and Physical Computing.

bass flute and generative sound-design highlighting the topography of the oceans and vast openness of the depths.

On a technical level, *Nautilus* used a Unity game engine as the main platform for the visual and sonic elements of the digital score (this game engine was the "communications interface of musical ideas between musicians utilising the creative potential of digital technology" (Vear, 2019, p. 19). Visually this includes sea-bed imagery and sinking notes written on staves tied to flashing blue anchors (Fig. 1). The compositional process started with an improvisation by Rees. This then became the source material for machine learning processes and the sound design. For the machine learning, a neural network was trained using TensorFlow methods and a dataset of transcribed jazz improvisations. At the start of each iteration of the piece, random notes from Rees's original transcribed improvisation are passed through this neural net that outputs a tone row for that version of the piece. Notes from this tone row are selected at random and displayed as the sinking notes in the score. Another element of the digital score is the generative sound design. This uses extracts from Rees's original improvisation, again randomly selected, and triggered by the amplitude of Rees's live playing. These sounds are manipulated in different ways depending on which section of the piece is currently playing (e.g., in the first part, the audio is slowed down four times). An additional element of interactivity was added with the camera movement linked to the live sound of (1) the live flute (moving the camera left); and (2) the live sound design (moving the camera right). When both sound sources were playing, the camera moved forward through the seascape. These behaviours were packaged together in a Unity game environment which creates an immersive world for the audience and musician, and offers stimulations and possibilities about what to play by inviting an interpretation through sound.

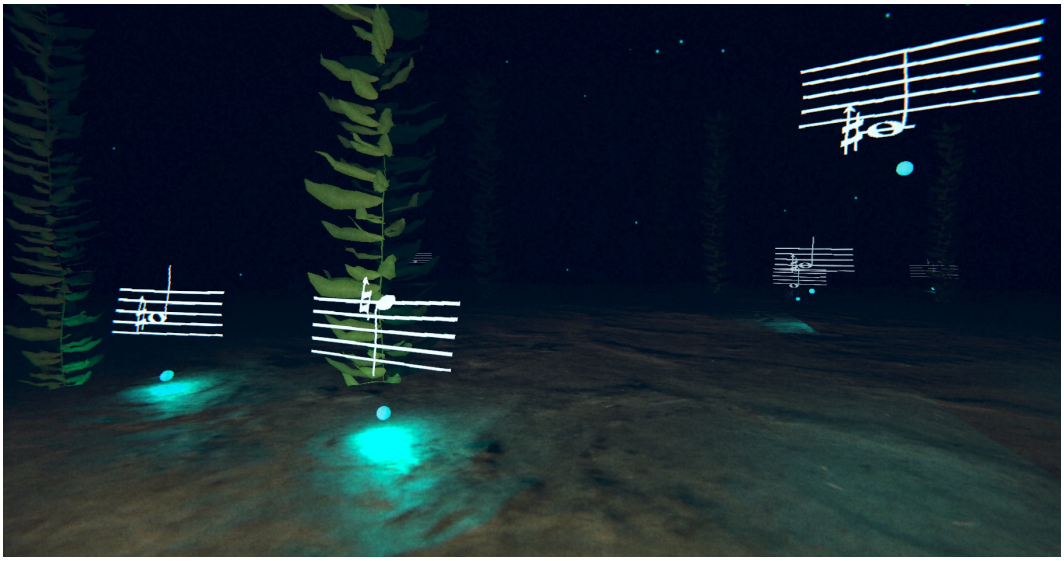

Figure 1: Screenshot of the Visual Part of the Digital Score for *Nautilus*.

2.3 Introducing the Theoretical Framework

A theoretical framework was developed to guide the questioning process which underpinned all the methods in the dataset (see Section 2.5), thereby providing common features for analysis of the dataset. This was an expansion of the theoretical framework presented in Vear (2019). This forms the structure of the analysis below, so we do not discuss it in depth here. However, the basic format is:

1. Connections with the digital score – for example, the relationships to the materials that form the parts of the digital score (sounds, images, game-worlds). Also, how the musicians formed relationships with the active materials such as pre-recorded melodies, machine intelligence, creative media, evoked music-worlds, or the other musicians.
2. The flow in the moment of performing – for example, what journeys the musicians were taken on, how involved in the music they became.

3. Digital musicianship – what skills, knowledge, and approaches the musicians used to facilitate a creative engagement with the piece.
4. Transformative experiences and impact – for example, did the score communicate innovative music ideas, new music experiences, novel compositional approaches, new performance opportunities, music-making engagements, or broader accessibility/inclusivity for musicians? Has this experience changed their outlook on music-making in general? Will the impact of this experience carry over to other future projects?

It is important to stress that the purpose of this framework was to elicit responses to the themes defined by the framework. Additionally, it was important that both the capture and analytical process did not narrow this data-gathering process by over-reliance on the framework. As such, through the data-gathering process, we were mindful to adhere to the following principles:

- Allow the musicians to express themselves in whichever way they needed to in order to reflect on their experiences.
- Encourage them to prioritise and find importance in areas that were not included in this ongoing framework.
- Seek out additional themes which enhanced, augmented and expanded our questioning strategy. This, in turn, offered us an opportunity to use reflexive thematic analysis to draw insights from the responses (discussed in Section 3.4).

2.4 Dataset Design and Concept

The data collected from every digital score case study conforms to a dataset designed to capture musicians' experiences in, with, or through musicking. It has been designed to capture two discreet phases of each digital score project:

1. Intention phase (also called creation or encoding).
2. Reception phase (also called decoding or realisation) (see Fig. 2).

The methods/tools applied for each of these phases were chosen to capture experiences from two different perspectives:

1. In-vivo (articulating experiences inside the creative acts).
2. In-vitro (reflecting on inside experiences from outside the creative acts).

——INTENTION——				——RECEPTION——					
Proposal	**Reflective Journal**	**Intention Statement**	**Performance/ Artefact**	**SRM (Stimulated Recall Method)**	**SSI (Semi-Structured Interview)**	**Audience Survey**	**SSI (Semi-Structured Interview) with creator**	**Performer(s) Questionnaire**	**Creator(s) Questionnaire**
In-vitro: Artistic Proposal from the creator(s)	In-vivo: Reflection during the creation process	In-vitro: Reflection questionnaire from all creators	Digital score and its materials, documentation of performance media files, instructions, etc.	In-vivo: Stimulated Recall Interview with performers taken directly following the performance	In-vitro: Semi-Structured Interviews with performers one hour following the performance	In-vitro: Audience Surveys gathered after the performance	In-vitro: Semi-Structured Interview with composer gathered a week after the performance	In-vitro: Legacy Questionnaire from performer taken 4 weeks after performance	In-vitro: Legacy Questionnaire from creator(s) taken 4 weeks after performance

Figure 2: The Dataset Design of *Nautilus* Case Study showing Two Distinct Phases of Digital Score Creativity and Musicianship: Intention and Reception.

At key points in the creative process a "sounding" was constructed that captured key data about a perspective and phase at that point. For example, the "Intention Statement" online questionnaire from the "Intention" phase is a key document that captures the composer's intention to embed or encode, relationships into the digital score with which – it is hoped – that the realising musician

will find meaning. This was an in-vitro reflection. The "Simulated Recall Method" recording was designed to capture the performer's immediate reception of the digital score with in-vivo responses to the process of performing the digital score. This involved their looking back at the video recording of the performance, which also visualised their Electro-Dermal Activity measurement to expose any sub-conscious events in their arousal. Similarly, the "Semi-Structured Interview" with the performer immediately after the performance of the digital score aimed to extract in-vitro data and insights from inside music-making about where that musician found meaning.

2.5 The *Nautilus* Dataset Contents

Over the life-cycle of the *Nautilus* case study, we captured data using the methodology introduced above. Data from the "Intention" phase was captured from both Vear and Stephenson as the main creator team, and data from the "Reception" phase was captured from the performers Rees (April 7, 2022), and Franziska Baumann (April 29, 2022). Rees is an established professional musician specialising in low flutes. She has been active in various styles of music-making for many years and has commissioned works for low flutes that explore technology, experimental notation, contemporary practice and intermedia performance. Baumann is a leading performer in technically mediated vocal performance. She has innovated the use of live electronics in the real-time manipulation of her own voice and has worked with many composers, developing novel compositions that exploit the creative potential of such technology.

The data collection starts with the initial project proposal/artistic intent statement by the composer/creative director Craig Vear and ends with questionnaires on the legacy of the experience with the digital score. The *Nautilus* dataset includes:

Intention Phase

- Artistic proposal from the composer: this was designed to outline the aesthetic and technical design intention of the project. It was acknowledged that this might change through the process of creativity, but is an important document to capture in order to book-end the creative process (in-vitro).
- Reflective journal/digital blog: designed to capture ongoing thoughts and reflection on the creative process. In this instance, this took the form of blog-like exchanges on the process between the composer and the first performer of *Nautilus* (in-vivo).
- Intention Statement questionnaires from all creators: designed to articulate the intended connections and relationships embedded into the digital score as they relate to the theoretical framework (in-vitro).

The Artefact

- The digital score, and its materials, documentation, code, instructions, media file etc., packaged as apps that would work on both Microsoft Windows™ and Mac OS™ platforms.

Reception Phase

- Video documentation of the performances: from the first and second performer of *Nautilus*.
- Electro-dermal activity (arousal) skin response measurements: two sets from each performer.
- Stimulated recall interviews: from both performers immediately following their performance.
- Semi-structured interviews from both performers: conducted within an hour of their performance.
- Six audience surveys from the first performance: gathered immediately following the performance.
- Semi-structured interview from the composer: conducted within a week following the performance focusing on Vear's reception of the realisation of the digital score.
- Legacy questionnaires from performers: gathered after four weeks from the performance and focusing on the lasting legacy of the experience of the performance and the digital score: one from each performer.

- Legacy questionnaires from the creators: gathered after four weeks from the performance and focusing on the lasting legacy of the experience for the creators with the digital score.

3 Data Analysis

In this section, we discuss the methodology we used to analyse the collected data, as well as detailing the theoretical framework that guides this analysis.

3.1 Methods of Data Analysis

The raw data that we used for data analysis were the questionnaires, semi-structured interviews, stimulated recall transcripts and blog data from the dataset (see Section 2.5). This data can be accessed on Figshare (Vear, 2022). To analyse the data, we used the Codebook approach (Braun and Clarke, 2021; King and Brooks, 2018; Ritchie and Spencer, 2002), a type of thematic analysis that integrates the qualitative research principles of reflexive thematic analysis with a structured approach to coding. The Codebook approach is well suited to our research because it allowed us to develop themes early because of working with a concept-driven theoretical framework (Braun and Clarke, 2021; King and Brooks, 2018; Ritchie and Spencer, 2002).

Overall, this analysis process involved four main steps: (1) reading all the raw data so as to prepare the ground for the analysis process and to become familiar with the raw data material; (2) coding the raw data according to the themes from the theoretical framework; (3) refining codes and subthemes by comparing them to raw data using reflexive thematic analysis; and (4) interpretation of the findings into a provisional narrative.

In our methodology, we have a theoretical framework that guides our thematic analysis (top-down approach e.g., Braun and Clarke, 2012), from which we deduce codes as evidence of our themes. We also use reflexive thematic analysis to identify any new themes and patterns in our data which may offer a new perspective on the theoretical framework throughout the lifecycle of the research project (Braun and Clarke, 2019). With the Codebook approach, we could use both coding dependability and reflexive analysis to chart a developing analysis of the overall data. Another advantage of the Codebook approach is that both researchers involved could contribute coding ideas and insights on the developments of themes and subthemes (Braun and Clarke, 2021).

3.2 Theoretical Framework Themes

The theoretical framework guides the questioning process and the analysis of the dataset while aligning with the core aims of the scientific investigation. The purpose of the theoretical framework is to draw out new insights into the relationships formed with digital score musicking. They are catagorised according to three different themes:

1. Musicians' connectivity to the materials of the digital score; and the experience of their flow in the moment of interpretation (encompassing stages 1 and 2 of the framework; Section 2.3).
2. The digital skills needed and acquired from making and interacting with the digital score (stage 3 of the framework).
3. The transformative experiences musicians had with the digital scores that might have an impact on their future creativity and music-making experiences (stage 4 of the framework).

Each of the three themes created a focus area for drawing out new insights from the musicians on the relationships formed with the digital scores, and can be regarded as a top-down approach. The Codebook approach (King and Brooks, 2018; Ritchie and Spencer, 2002) allowed us to structure our data according to the themes implied through the theoretical framework, and to develop bespoke "codes" in the NVivo software to reveal insights from the raw data. A "code" is a thematic category, or a word-string, chosen by the researchers to search in NVivo through the raw data. In doing so we highlight paragraphs or phrases that match the thematic category and that can therefore be considered as critical findings.

In the following sections we present our findings of the analysis of the raw data based on these three top-down themes. We discuss each theme in turn and highlight critical sub-themes that were identified. As an overview, these are:

1. Relationships

A. Connectivity

- Agents
  - AI Agents
  - Performer Choices
    - Performer Prescription
  - Sound Material
  - Visual Elements
- Balance/Intermediality/Space
- Immersive Environments
  - Atmosphere
  - Immersive Experience
  - Immersive Game Environment
- Interaction
- Overview/Memory

B. Flow

- Challenge vs Flow
- Collaboration
- Emergent Behaviour
- Extended Through Sound
- Form/Structure/Narrative
- Journey
  - Navigation Strategy
  - Worlds/Environment

2. Digital Musicianship

- Control
- Creativity
- Educational Perspective
- Future Developments
- Interdisciplinary Approach
- Performers' Agency
- Skills
- Video Game Influences

3. Transformations

- Accessibility
- Composer/Performer Relationships
- Impact
- Innovative Experiences
- New Performance Opportunities

3.2.1 Quantitative Appraisal of Themes and Subthemes

Table 1: Quantitative Appraisal of Themes and Subthemes coded in the NVivo software.

Themes	Subthemes	Coding References
Relationships		**351**
	Connectivity	239
	Flow	112
Digital Musicianship		**104**
	Control	7
	Creativity	17
	Educational Perspective	7
	Future Developments	4
	Interdisciplinary Approach	8
	Performers' Agency	33
	Skills	12
	Video Games Influences	16
Transformations		**68**
	Accessibility	16
	Composer/Performer Relationships	10
	Impact	6
	Innovative Experiences	26
	New Performance Opportunities	9

3.3 Thematic Analysis Results

3.3.1 Relationships

Using NVivo software for thematic analysis, relationships were sub-grouped into two main classes of *connectivity* and *flow* to reflect the main properties of this theme. Each of the subsequent subthemes (e.g., *AI Agents, performer choices,* etc.) was chosen to add detail and nuance to the types of relationships musicians form through musicking with the digital scores.

Connectivity

The critical findings deriving from codes defined in the "connectivity" theme generally pointed to the materials and actions that the musicians used to form relationships with the digital score. From our list of codes for "connectivity", "agents" gathered over 100 references from both creators and performers. Examples included the mention of the note glyphs, the sounds, and the visual imagery as generating connections. This, we believe, is because they were the main vehicle through which the compositional material was presented as part of the communications interface. We found that the creators highlighted how they used these elements to encode musical information into the digital score. As such, their purpose was to communicate a connection of musical material to the performers, with the aim of forming meaningful interactions.

The main subthemes of "agents" were "visual elements" and "sound materials" as well as "performers' choices" in assigning actions to these agents. For example, Vear described the gaming world of *Nautilus* as "foremost visual" (Vear, 2022), populated by different objects such as the underwater kelp, water bubbles and underwater creatures. Kelp was often referred to as "cactus" by Rees and note-like objects were referred to as "glyphs" (Rees, 2022). For her, she found connections in these "kinds of sinking glyphs which have predefined notes on them. They randomly sink down". Stephenson mentions blue lights and notation as "visual elements" (Stephenson, 2022) that were encoded into the digital score. He highlighted how "bright blue lights float from above, lighting the environment

around them and contrasting against the dark background. The blue lights have random notations attached for the performer to play if they desire".

All the visual elements of the score were treated as objects that the performers could choose to interpret and assign different sounds to. Rees mentioned that:

> There are specific objects within the score, which I kind of assigned different sounds to and I think that's an interesting thing because, of course, a different performer would assign different sounds to those things, but for me, it's about creating a sense of almost a sense of drama. (Rees, 2022)

The second performer of *Nautilus*, Baumann, reflected in her stimulated recall interview on her relationship to the kelp object as "this plant coming closer to me, which gave me a feeling of more intensity" (Baumann, 2022). Rees prescribed a specific sound to it: "I began by assigning sounds to visual cues – so for example a sound for crashing into the cactus" (Rees, 2022).

The sound material of *Nautilus* was formed from the pre-generated parts of Rees' improvisations on the bass flute. We found that this backing track provided a feeling of comfort, immersion and support to the performers. It was also an element that the performers could connect to. Baumann mentioned that the generative sound design:

> Makes it very easy… so it's inviting. Yeah, it's very inviting and that would be interesting to have another precomposed track for this game and that would give another kind of meaning to what we see. (Baumann, 2022)

Rees referred to the sound materials of the soundscape as defining an atmosphere which was also supporting her harmonically:

> Without the soundscape there, it feels like something completely different and completely alien. And I think it's quite comforting to have it there, and I think it gives creative freedom in interesting ways. (Rees, 2022)

From the intention phase perspective, the important aspect of all the visual and sonic elements of the digital score was that they should balance with each other to work intermedially and create a unified whole. In his semi-structured interview following the performance, Vear stated that:

> The sound design shouldn't try to do all of it, the whole composition, because it's trying too hard and it's not making room for the visuals. If the visuals try to do everything in the underwater scene, it would just be wrong. Similarly, the behaviours of the Unity engine had to be enough not to entice the performer or Rees into a video game, but just to be enough that it brought her in and the audience into this world. (Vear, 2022)

Overall, our findings highlighted the kinds of choices performers had to make in order to create meaningful relationships with the digital score and the elements of the digital score that formed connections with them. Our evaluation of these critical insights is that the creative considerations in encoding visual and audio agents were discerned by the performers. We found that these could also be traced back to the intention statement of the composer, and the balance of these elements ensured that the performers stayed in the flow of the performance in *Nautilus*, which we discuss below.

Flow

In the category of "flow" we found that "journey" attracted over 50 references from the creators and the performers and was considered to be synonymous with flow. It was an aspect referred to by the performers in the semi-structured interviews and the stimulated recall interviews taken directly after their performance. For example, in her stimulated recall interview, Rees talked us through her process of interpreting the digital score in real time while watching the video of her performance. During this she describes her journey through the digital score in one particular moment as follows. This extract highlights the shifts in focus for her meaning-making while in the journey of her musicking:

> Slower moving at different pace …. And then we got the surface, to kind of interpret the surface as being a different kind of sound, because it's something else

> that we haven't seen before … So there's a bit of multiphonicky stuff going on in there … And then I got really fixated on this D that was floating across the stage, an amazing thing going really slowly (Rees, 2022).

Similarly, Baumann mentioned that "I had this feeling of being under the water [...] to get a breath of excitement". She also highlighted how through her journey she felt a connection to the seafloor and how that guided, or "connected", her to the video game journey (Baumann, 2022).

"Journey" was also an aspect that was consciously built into the immersive video game experience by the creators of *Nautilus*, as remarked by Stephenson: "*Nautilus* is based on the journey of a deep sea mollusc" and Vear: "The flow is meant to be one of continuous depth and journeying through this underwater world". On this idea, Baumann summarised her experience of flow in *Nautilus* with the challenges she experienced:

> I think the flow of music making has several aspects. It needs a certain challenge or risk taking or freedom but not too much risks, or too much difficulties; if it would ask too much mental decisions, I would go out of the flow of music. Some mental decisions are good challenges for me.

She continued:

> I also need a challenge or need something which gives me something that's like when I improvise with a musician. If the musician is too easy it's getting boring because then I have to make the music great, and here I felt like it asks me to make clear decisions, but also it offers me a lot. (Baumann, 2022)

From this statement, we can deduce that the balance of surprising and novel elements for Baumann versus her ability to be in the flow of the performance was well calibrated. The correlations between the intentions of the creators and reception of the performers is also observed in the "flow" category. The creators purposefully built into *Nautilus* a feeling of journeying through this underwater sea environment in order for the performers to maximise their connection to the digital score and experience of flow.

3.3.2 Digital Musicianship

In this section, we discuss our findings through the analytical lens of "digital musicianship". These we define as the skills musicians bring into the project from their background and experience from working with technology. As a result of interacting with the digital score, musicians may acquire new skills that contribute to their creativity, knowledge and perception, which could provide future opportunities for development.

One of our key findings was that although the case study demanded very little prior training or knowledge of new digital skills from the performers, it offered other creative possibilities for their development. Because *Nautilus* focused on the video game immersion of the performer, it was interesting to observe how making and interacting in this environment brought on new possibilities for development for the creators and the performers. For example, Vear mentioned that using Unity was a "great opportunity to evaluate how a Unity engine might be used as a platform for a music score and to work in a team that got this, supported this, and progressed this". Furthermore, he observed that:

> It was interesting to feel how my role became more about being a creative director than a composer. In fact, the term 'composer' was too reductive considering the roles and conversations that I needed to take on in order to drive the vision of this project forward. (Vear, 2022)

As far as an expansion of digital skills, working on *Nautilus* also provided stimulating experiences for game developer Stephenson. He mentioned that "[t]his was also my first proper foray into audio in the Unity game engine, more than just sound effects for a game". With further development of these skills, he acknowledged that "I've already begun to use the audio skills I've learned in other projects, as well as implementing effective architecture principles into my system designs" (Stephenson, 2022).

It could be concluded that the creators of the project acquired new digital skills as a result of working in the interdisciplinary setting of *Nautilus*, where music performance meets video game environment.

On the other hand, the focus on performers' agency created challenges for the performers that stimulated their creativity in interpretation. Rees observed that:

> So, it's a kind of interesting thing to look at when you're in that environment. You've got certain elements that are given to you in the score like the pitches for example, anyone playing those pitches would be playing the same notes, but would they play them the same way? I find it quite interesting and just sort of thinking through those kinds of things, and what I can do from a performer perspective. What are the choices that are open to me? And actually just the analytical part of it, [I] find that really interesting, and kind of different from how it would be if you were just playing with it. (Rees, 2022)

Baumann also had some valuable observations on how immersion and deepening in the process of interpreting *Nautilus*, stimulated her as a musician: "I think it's an ongoing deepening in all these aspects of immersion, music making, flow, decision making in the moment". Additionally, she said: "I'm sure it will always be different depending on who is playing the score because it offers that you can bring your own personal experience into the piece" (Baumann, 2022).

3.3.3 Transformations

Through the analytical process, we found that the musicians had several transformative experiences with this particular digital score that might have an influence on their future creativity and musical experience. Given the novelty of the video game environment both for the creators and for the performers of *Nautilus*, the code "innovative experiences" gathered most references from the data. From the artistic proposal of *Nautilus,* we learn that the composer's original intention was to create a unique musicking space:

> To have the score itself on a journey with you is a very different experience; for it to be interactive, and for it to elicit behaviours, and for it to invite you into its world, and for it to be responding to you, and for it to let you create, and giving you the opportunities to make something new. At that moment, trusting that the score has 'got your back' I think makes it a very special place. (Vear, 2022)

The interdisciplinary environment of video game coding and music provided a new creative experience for the video game developer as well:

> My perspective was more technical and after seeing the visual presentation hundreds of times during development I'd grown somewhat insensitive to it. However, when the performer tested it, I was completely mesmerised and forgot about the hours spent tweaking code and creating the environment. (Stephenson, 2022)

The experience of working on *Nautilus* also had transformative effects on the performers. For example, Rees mentioned: "It's given me an interesting framework for future work, both intellectually and artistically", and "the fact that doing something like this actually makes you think about stuff in a way that maybe just performing a piece wouldn't" (Rees, 2022).

From the audience surveys, we also learned how the immersive video game environment of *Nautilus* was received. One audience member stated, "Definitely learned that musical scores can be created in many various and unexpected ways". Another wrote: "Music can communicate with the environment created by Unity, a new experience and performance I have never seen before".

In addition, there are experiences that the creators and the performers said would carry over into their other creative projects as well as further developments of *Nautilus*. For example, Vear stated that *Nautilus* "opens out the possibilities of meeting others in this world, either as NPCs [non-player characters] or remote performers. There always exists the possibility of this occurring" (Vear, 2022). The legacy of this experience had a clear impact on the performers' experience; for example: "I've found it a fascinating way of bringing together many different facets of my practice and my musicianship" (Rees, 2022); and "I take this observation with me to other projects and also make sure to keep the flow and excitement high in digital environments" (Baumann, 2022).

The transformative experiences intended for the performers by the composer/creative director of *Nautilus* were well received by the performers and it could be said that they had an impact on their creativity and music-making which they hope to take to future projects.

In addition, one audience member remarked that: "It was interesting to see how a digital music score can be created for the musician to encode themselves and interpret in their own way, creating a unique piece of music each time".

3.4 Reflexive Thematic Analysis: New Themes Identified

During the analytical phase employing the established theoretical framework, we concurrently undertook a reflexive thematic analysis. This parallel process involved a comprehensive examination of codes and subcodes in direct comparison with the raw data. The primary objective was to unearth novel themes and critical insights that extended beyond the confines of the framework's predefined structure (Braun and Clarke, 2019). This was an evaluatory process insofar as we cross-correlated the critical moments using common codes that were identified from the in-vivo and in-vitro perspectives. In this section we will highlight and discuss the main categories of the new themes discovered through this process:

- Immersive environments
- Performers' agency
- Accessibility

Interestingly, each of these new categories aligned with the thematic categories of the framework, i.e., immersive environments in relationships, performers' agency in digital musicianship, and accessibility in transformations. The recurring frequency of the codes associated with the new categories throughout the analysis suggests that they could be regarded as major themes within this case study. These may be taken on to expand our theoretical framework for future digital score case study analysis. We will now discuss each in turn.

3.4.1 Immersive environments

"Immersive environments" was a second major code with 77 references and was evident in the connectivity category from the theoretical framework. It was present in the sub-codes of "atmosphere", "immersive experiences" and "immersive video game experiences". The immersive experiences were commented on extensively in the reception stage of the data collection from performers and the audience. We found that it was discussed in the intention stage data by the creators of *Nautilus*. It is also interesting to note how it gathered many positive responses from the performers and the audience. From the creator's perspective, it was written into the artistic proposal as an experience that the performer could have with *Nautilus* because the score uses "a unity game environment which creates an immersive visual space for the piece" and "the environment is immersive but if carefully considered, doesn't get in the way of the musical experience" (Vear, 2022). These statements were recorded before the piece was presented to the performer, the first coming from the artistic proposal and the second from the blog-like exchanges between Rees and Vear.

In the semi-structured interview, Vear reinforced the theme of immersion by stating that: "So, it's not the idea to place Rees or a performance into a game but to use the game environment as a material with which for them to construct meaning". Vear continues by stating:

> It's really about creating these environments that will be interacting with each other and the performer and making this whole world kind of comfortable and immersive for the performer, inviting them to be in it. (Vear, 2022)

The intention of this statement was felt and commented on by the first and second performers of the piece:

> Some things like this I actually felt very easy to do, because it was very immersive right from the beginning, and I think there's a sense of communication that comes from the atmosphere which is really powerful. (Rees, 2022)

For Baumann: "because it offers a space, I can immerse, and the space has a certain character of the feeling under the water" (Baumann, 2022). Since Baumann performs with a sensor glove with which she also processes electronics in her setup, the feeling of immersion is also very physical for her:

> If I move, I think for movement, I get immersed almost like this thing being here, being part of it, to create a meaning, or also an intensity and therefore the glove with the gesture system and the movement and the voice. Yeah, it feels immersed, it feels I'm part of it. (Baumann, 2022)

Additionally, statements on immersion appear again in the reflective part of the legacy questionnaires, suggesting it was a significant experience for the performers. For example, Rees mentioned that she "particularly enjoyed how being immersed in the score completely changed my perception of time. That suggests it was a completely immersive experience" (Rees, 2022). On this subject there was a question of balance for the materials of the piece. For the composer, it was essential that "the behaviours of the Unity engine had to be enough not to entice Rees into a video game, but just enough that it brought her in and the audience" (Vear, 2022).

The references gathered for the immersive video game code reflected the immersive effect the digital score had on the performer and the audience. Rees discussed the importance of the presence of the large video display wall had on her and her relationship with the audience:

> It's in front of a massive screen. So, the actual performance is immersive. Yeah, it's not like looking at a piece of paper that's a score. You can't jump into that so the fact that you have to be immersed in that space. I find it really interesting in terms of it removes distractions and of course, in this situation I had to have my back to the audience, because we're all looking at the same screen. (Rees, 2022)

Besides the video screen of the digital score immersing the performer and the audience visually, the soundtrack of the score also helped with the atmosphere of immersion. Again, Rees mentioned that a lot of her sense of immersion "comes from the audio that I'm hearing" (Rees, 2022).

3.4.2 Performers' Agency

Through the analytical process, "Performers' agency" gained 33 references and was evident in the digital musicianship category of the theoretical framework. Our findings showed that performers' agency was built into the score by the creators of *Nautilus*, and this principle was reinforced through the performers' connectivity and immersion with the digital score. It was interesting to find that this effect was felt not only by the performers but also by the audience.

From the intention phase of data gathering, we found that both creators of *Nautilus*, Vear and Stephenson, considered that the performers will make musical decisions as they react and interact with the visual and audio materials in the score. On this matter, Stephenson stated:

> For example, when the camera passes through some kelp, they might react with a loud, sharp sound. They can also make decisions based on desired movement. If the backing track becomes more powerful at a certain time, the performer might fight back against it to continue moving forward or have a rest and let it take over. (Stephenson, 2022)

Vear discussed that:

> The performer can assign meaning to different objects, so while different players might have the same sense of mood and even be using a similar 'box of tricks' appropriate to the instrument and performance techniques, there is an opportunity to take an individual approach. This would mean that different performances could sound quite different but still maintain a form of broad identity as the piece. (Vear, 2022)

The visual and audio design of *Nautilus* provided a framework in which performers felt confident about making decisions while influencing the world in which they were interacting. This principle was established in the compositional phase of the project, and following the performance of the digital score, was recognised by the creators. On this, Vear mentioned:

> There was enough in there to kind of contextualise it, so that the performer was able to make the right decisions and be confident that the decisions that they are making are for the benefit of the music that is produced by the live situation in the score, as it was learned in real time. (Vear, 2022)

Stephenson confirmed this in his reflections on the performance, saying: "The interaction design in *Nautilus* was intended to give the performer a feeling of influence on the world's behaviours, but not a feeling of exact control" (Stephenson, 2022).

The decision to include performers' agency in *Nautilus* gave performers freedom to devise the materials of the digital score as it suited them. Rees mentioned that she "felt extremely calm through the performance, in control and also free to express and to take time and pace however I wanted" (Rees, 2022). She also suggested that the experience of interpreting *Nautilus* would be different for every performer:

> It's a kind of interesting thing to look at like when you're in that environment you've got certain elements that are given to you in the score like the pitches for example; anyone playing those pitches would be playing the same notes, but would they play them the same way?

The sense of agency also gave Rees a feeling of ownership of her own unique performance of the digital score: "it definitely feels like I'm performing it. It's kind of my performance. Somebody else would do something completely different and make different decisions, and approach it in a different way, and I think that's really interesting too" (Rees, 2022).

Baumann had a similar reaction to the agency and performance choices she had to make in the moment:

> So then I have to be in the moment, and that helps me to keep the presence, and there the intention, the decision-making in the moment of how I apply the sounds, or how do I interact, when do I interact, why do I interact? So, the decision-making was still made in the moment, like as an improviser. (Baumann, 2022)

Baumann also reflects on the phenomenon of agency that she felt she shared with the digital score and how it challenged her. For example:

> In that case it was easy to go in, because it has a very good mixture between offering, making it easy for the performer, and at the same time challenging, challenging the performer to also make decisions. So, the agency is on both sides. (Baumann, 2022)

Through the reflexive thematic analysis process, it became clear that the sense of agency is also connected to how immersed a performer feels in the moment of the performance. For example:

> I have the freedom, but I'm connected to something. I'm connected to the suggestions and immersed in the situation. I have the security of a background, pre-recorded track. And all this combination offers me to navigate, and [...] at the same time to take responsibility for what is there. But also, what I contribute. (Baumann, 2022)

The feeling of agency that the performer experienced was also felt by one of the audience members, as stated in the audience survey: "Yes, the visual aspect of the score definitely influenced the performance and allowed the performer to harness their pure reactions to the environment, resulting in a highly expressive performance".

3.4.3 Accessibility

This category helps us understand how performers and the audience might react to the immersive video game environment of *Nautilus*. Our findings were that the accessibility and inclusivity of *Nautilus* opens up new possibilities for the musical scores to be easily available to many different performers, not just those trained in the Western classical music tradition but also those from other backgrounds and levels of musical experience.

In composing the digital score, Vear was also concerned that it should be accessible to the low-flute community, and he developed the score for that community in mind in collaboration with Rees. However, this did not prevent other performers like Baumann (primarily a vocalist) from engaging with *Nautilus* in a meaningful way. This, we believe, is because the notation was flexible to interpretation and the performer has a lot of agency in interpretation. On this, Stephenson stated: "the performer doesn't have to learn a proprietary notation system to enjoy the experience" (Stephenson, 2022). Furthermore, Rees reflects on the potential for accessibility that digital scores like *Nautilus* could have for the performers:

> There is also potential for this format to increase accessibility, as it could be created in a form that does not require an ability to read complex musical notation. This might make the music approachable for performers from different musical cultures/backgrounds for whom historically European notation systems are not part of their working methods. (Vear, 2022)

An additional consideration was for the accessibility of new music for the audience, by using a Unity engine to enhance their appreciation of contemporary music. On this, Vear said: "having this familiar mediated environment enhancing the music, or you know, kind of evoking the music, can be a nice welcoming place to invite people into contemporary music" (Vear, 2022). Rees confirmed this statement and mentioned that she thought "it's really potentially very powerful, this whole idea of the video game environment that you could actually have from notation that doesn't require any prior knowledge of conventional notation to be able to communicate musical ideas" (Rees, 2022).

The audio component of the score also made the piece easily accessible to Baumann, who was not present in the developing stages of the digital score with Vear, Stephenson and Rees. She mentioned that "this background sound kind of offers some security and kind of makes it also accessible" (Baumann, 2022).

In the semi-structured interview, Rees considered the larger implications of accessibility that the open notation of *Nautilus* allows. Here she said:

> It would be interesting, but it's actually quite profound I think, and also thinking about the potential education, the potential in terms of accessibility, you know, getting away from this kind of notated score that requires this huge amount of previous experience and knowledge, and maybe you can give these scores in this version to a whole lot of different musicians, with different ranges of experience, and they can do something that's meaningful for them. And I think that's really exciting, even if it's not technically very complicated. (Rees, 2022)

3.5 Audience Survey

Because both researchers were implicated in the design of the theoretical framework and methodology of the project, in addition to Vear acting as the creative director of the *Nautilus* case study, this could be seen as one of the weaknesses of the research. Examining the audience survey could help us understand how the *Nautilus* digital score might have had a transformational effect on those outside the creative and research process.

The results of the audience survey gathered both quantitative and qualitative responses such as age, gender and location and three questions to be rated on a 1–5 Likert scale. It should be noted that it was presented at a small sharing event at De Montfort University; six creative technology master students were in attendance. The questionnaire asked respondents to rate how often they attend performances with new media, followed by a similar rating question to compare how the experience of *Nautilus* compared to other performances with digital media that they might have attended before in respect to its novelty and surprising effect. Finally, the survey asked respondents to rate how much the performance contributed to a new outlook on a musical performance for them.

While running a crosstab query in the NVivo software, it was noted that for those who do not attend many performances with digital media, the performance has contributed to a new outlook on digital music performances. This result was confirmed by three out of six participants. However, those who attend many performances involving digital media also found that the event provided a new outlook on musical performance for them (three out of six participants). In addition, most of the audience

members rated the performances as surprising, despite their previous experiences of performances with new media.

4 Discussion

The methodology of the *Nautilus* case study revealed many significant insights into the way musicians form meaningful relationships with the digital score. Here we would like to evaluate our methodology and theoretical framework to demonstrate how it enabled us to draw design considerations for those wishing to engage with the Unity game engine as a creative platform.

A key discovery from our methodology is the correlation between creators' intentions during the design phase and the reception phase experienced by performers and the audience. The creators of *Nautilus* emphasised achieving a balance between visual and audio elements to immerse performers in a realm of intermediality. This intention influenced performers' choices with the digital score, manifesting in statements about immersion and interpretative freedom. This correlation, a by-product of collaborative efforts, underscores the importance of composers actively engaging with musicians throughout the creation process to ensure the realisation aligns with their intentions.

Our reflexive thematic analysis highlighted a high reference yield in performers' agency and accessibility, indicating an open interpretation environment in *Nautilus*. This insight leads us to advocate for a level of trust between musicians and the digital score, fostering a shared agency of creation. This collaborative approach blurred the traditional roles of "composer" and "performer", emphasising a creative team dynamic. Furthermore, using Unity as a creative platform enhanced the collaborative potential of the team. This platform helped turn all participants into co-creators, fostering a cohesive blend of media elements for a balanced intermedial experience. Considering the balance of visual, interactive, and audio materials in the digital score enhances musicians' and audiences' immersion in the platform.

Exploring connectivity in the Unity game environment revealed that non-standard elements gained meaning for musicians in the right context. The game environment became an integral part of the digital score, inseparable from graphic elements and musicians' involvement. This interconnectedness aligns with Don Ihde's (Ihde, 1990) concept of multistability relations in technology. However, it was, in this instance, important to view Unity as a musicking platform rather than a gaming one. In *Nautilus*, the creators reconceptualised traditional gaming using musicking elements and developed this, fostering a trans-disciplinary language. Our recommendation emphasises the need for all media elements to work cohesively to achieve this balance of intermediality.

In analysing the data, three major categories emerged: immersion, performers' agency, and accessibility. These overlapped with the core theoretical framework themes. This overlap enhanced the interpretation of our data and demonstrated how close connectivity and immersion with the digital score contribute to performers' skill acquisition and transformative experiences. As the research project progresses, the flexibility of the theoretical framework is evident in its ability to accommodate new categories and themes through reflexive thematic analysis. This adaptability makes it a dynamic system (Van Der Schyff et al., 2018), ready to absorb new concepts, ensuring its relevance and effectiveness for future case studies.

Acknowledging the study's weakness in its close connection to researchers' perspectives, we find validation in audience surveys supporting the novelty and transformative effects observed. The evolving research project benefits from reflexive thematic analysis, demonstrating the flexibility and adaptability of the theoretical framework to absorb new concepts based on the unique focus of each case study. However, despite the close connection to researchers' perspectives, the audience survey supports our findings, indicating that outside observers also experienced the transformative effects captured in performers' and creators' data.

As a contribution to the discourse and practice of making music scores with game engines, we present the following points which we have derived from the evaluation process of using this methodology:

- It is truly beneficial to the creative product if the "composers" work with the musicians throughout the creation and development phases of the digital score. As evidenced in Section 3.3, the digital score is embedded with a sense of playability that is felt by other performers of the work.

- As an extension of the above, a major consideration is the musicians', and audiences', immersion in the platform and all its media elements. We are naturally attracted to games, and this is not limited to younger generations.
- There is a need to get all the media elements to work as a cohesive whole. An understanding of the balance of intermediality is essential in this aspect and we would recommend that musicians undertake some research on it. We recommend Crossley (2019) as a start.
- Related to the above, non-standard elements inside Unity can take on a musical meaning. For example, even the kelp/"cactus" has meaning and can be interpreted as musicking material.
- Given the openness of interpretation, there should be a degree of trust with the realising musicians, and an invitation by the digital score to share the agency of creation.
- Traditional roles of "composer" and "performer" are blurred. Letting go of these, and operating more like a creative team, was essential in *Nautilus*.
- In the video game environment, the aspects of form can now be considered from the perspective of "journey" and "flow". In *Nautilus*, these were also handled from the perspective of the dramaturgy of experience.
- The Unity engine needs to be considered not as a gaming platform, but as a musicking platform. For example, conversations and understandings about dynamics, notation, pitch, harmony, tempo, involvement, play, narrative, design, assets, glyphs, etc., were given new meanings in the context of *Nautilus*.

5 Conclusion

In this paper, we discussed our findings from a qualitative investigation of musicking (Small, 1998) with a digital score called *Nautilus*. This digital score was created using the Unity engine and machine learning techniques. We implemented a methodology based on a dataset design of different qualitative methods through the life cycle of the creative process of the digital score. This life cycle was divided into two distinct phases that surround the central artefact of the digital score: the intention phase, where the score is created; and the reception phase, where the score is realised, performed and experienced.

In our discussion (Section 4), we critically reflect on the strengths and weaknesses of the dataset design and methodology. The purpose of this is to refine the design and methodology so that it can be applied in future case studies with digital scores using a wide range of technologies, such as robotics, AI, internet, networks, etc. The relevance and vitality of this larger roll-out will be critically reflected over time, throughout the larger *DigiScore* project. But at the local level of *Nautilus* we can draw out specific design considerations that we hope are insightful for anyone else wishing to create a digital score using the Unity game engine as the central platform.

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References

Baratè, A., & Ludovico, L. A. (2017). A web interface for the analysis and performance of aleatory music notation. In H. L. Palma, M. Solomon, E. Tucci, & C. Lage (Eds.), *Proceedings of the International Conference on Technologies for Music Notation and Representation – TENOR'17* (pp. 25–31). Universidade da Coruña.

Baumann, F. (2022). Interview with Franziska Baumann as part of Nautilus Musicology Dataset. *Figshare, De Montfort University*. https://doi.org/https://doi.org/10.21253/DMU.20418447.v2

Bhagwati, S. (2021). Notational perspective and comprovisation. In de Assis, P., Brooks W., & Coessens, K. (Eds.), *Sound & score. Essays on sound, score and notation* (pp. 165–177). Routledge.

Boretz, B. (1977). Musical cosmology. *Perspectives of New Music*, *15*(2), 122–132.
Braun, V., & Clarke, V. (2012). *Thematic analysis.* American Psychological Association.
Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*, *11*(4), 589–597.
Braun, V., & Clarke, V. (2021). Can I use TA? Should I use TA? Should I not use TA? Comparing reflexive thematic analysis and other pattern-based qualitative analytic approaches. In *Counselling and psychotherapy research* (pp. 37–47, Vol. 21). Wiley Online Library.
Candy, L., Edmonds, E., & Vear, C. (2021). Method. In C. Vear (Ed.), *The Routledge international handbook of practice-based research* (pp. 305–322). Routledge.
Crossley, M. (2019). *Intermedial theatre: principles and practice*. Bloomsbury Publishing.
Dori, G. (2020). Using gesture data to generate real-time graphic notation: A case study. In R. Gottfried, G. Hajdu, J. Sello, A. Anatrini, & J. MacCallum (Eds.), *Proceedings of the International Conference on Technologies for Music Notation and Representation – TENOR'20/21* (pp. 68–74). Hamburg University for Music & Theater.
Emmerson, S. (2017). *Living electronic music*. Routledge.
Frame, C., Ilsar, A., & Trolland, S. (2022). Mutable gestures: A new animated notation system for conductor and chamber ensemble. In V. Tiffon, J. Bell, & C. de Paiva Santana (Eds.), *Proceedings of the International Conference on Technologies for Music Notation and Representation – TENOR'2022* (pp. 1–7). PRISM Laboratory.
Gottfried, R., & Hajdu, G. (2019). Drawsocket: A browser based system for networked score display. In C. Hope, L. Vickery, & N. Grant (Eds.), *Proceedings of the International Conference on Technologies for Music Notation and Representation – TENOR'19* (pp. 15–25). Monash University.
Ham, J. J. (2017). An architectural approach to 3d spatial drum notation. In H. L. Palma, M. Solomon, E. Tucci, & C. Lage (Eds.), *Proceedings of the International Conference on Technologies for Music Notation and Representation – TENOR'17* (pp. 39–49). Universidade da Coruña.
Haus, G., & Ludovico, L. A. (2017). Digitization of historial music archives: Preserving the past, embracing the future. In H. L. Palma, M. Solomon, E. Tucci, & C. Lage (Eds.), *Proceedings of the International Conference on Technologies for Music Notation and Representation – TENOR'17* (pp. 1–8). Universidade da Coruña.
Hugill, A. (2018). *The digital musician*. Routledge.
Ihde, D. (1990). *Technology and the lifeworld: From garden to earth*. Indiana UP.
King, N., & Brooks, J. (2018). Thematic analysis in organisational research. In Cassel, C., Cunliffe, A.L., & Grandy, G. (Eds.), *The SAGE handbook of qualitative business and management research methods: Methods and challenges* (pp. 219–236, Vol. 2). SAGE Publications Ltd.
Magnusson, T. (2019). *Sonic writing: Technologies of material, symbolic, and signal inscriptions*. Bloomsbury Publishing USA.
Raheb, K. E., Stergiou, M., Katifori, A., & Ioannidis, Y. (2020). Symbolising space: From notation to movement interaction. In R. Gottfried, G. Hajdu, J. Sello, A. Anatrini, & J. MacCallum (Eds.), *Proceedings of the International Conference on Technologies for Music Notation and Representation – TENOR'20/21* (pp. 91–99). Hamburg University for Music & Theater.
Rees, C. (2022). Interview with Carla Rees as part of Nautilus Musicology Dataset. *Figshare, De Montfort University*. https://doi.org/https://doi.org/10.21253/DMU.20418447.v2
Ritchie, J., & Spencer, L. (2002). Qualitative data analysis for applied policy research. In Bryman, A. & Burgess, R. (Eds.), *Analyzing qualitative data* (pp. 173–194). Routledge.
Small, C. (1998). *Musicking: The meanings of performing and listening*. Wesleyan University Press.
Stephenson, A. (2022). Interview with Adam Stephenson as part of Nautilus Musicology Dataset. *Figshare, De Montfort University*. https://doi.org/https://doi.org/10.21253/DMU.20418447.v2
Van Der Schyff, D., Schiavio, A., Walton, A., Velardo, V., & Chemero, A. (2018). Musical creativity and the embodied mind: Exploring the possibilities of 4E cognition and dynamical systems theory. *Music & Science*, *1*. https://doi.org/https://doi.org/10.1177/2059204318792319
Vear, C. (2019). *The digital score: Musicianship, creativity and innovation*. Routledge.
Vear, C. (2022). Interview with Craig Vear as part of Nautilus Musicology Dataset. *Figshare, De Montfort University*. https://doi.org/https://doi.org/10.21253/DMU.20418447.v2
Vear, C., Rees, C., & Stephenson, A. (2023). *Nautilus*: A case study in how a digital score can transform creativity. *Tempo*, *77*(303), 33–42.