ERC Consolidator Grant 2020
Part B2

Section a. State-of-the-art and objectives

This project has three high-level objectives: first, to determine how new computational technologies, integrated as innovative music score systems, can lead to the communication of innovative music ideas, new music experiences, novel compositional approaches, new performance opportunities and music-making engagements, and broader accessibility for musicians of traditional and non-traditional backgrounds (e.g. improvising, self-taught, indigenous traditions etc.). Second, to develop a transdisciplinary theoretical framework that situates digital scores within the wider fields of human-computer interaction, digital humanities and media studies, in order to understand the deep creative experiences of musicking (the act of music-making (Small 1989)) with digital scores built around *artificial intelligence, machine learning, internet networking, robotics, virtual and augmented reality, gaming* and *physical computing*. Third, to discover how digital scores stimulate new relationships between musicians and how these profoundly influence the nature of the digital musician. "Digital Scores" is the first large-scale, integrated project to address these challenges.

- *State of the Art: the music score as a communications interface*

In most music cultures around the world there is a music score system of some sort that operates as a communication interface between musicians (Apel 1961, Bagley 2004, Elsley 2002). Scores have been around since about 1400 BC (West 1994) and have been of great benefit to the practitioners that adopt them (ibid.). Their resilience, reliability and continued use (Williams 1903) are of such that they can be considered 'facts of musical life' (Maconie 1990). Over the course of hundreds of years and as music cultures embraced different code-systems and technologies, musicians utilised the communication potential of scores and notation (Maconie 1990). Creative invention within most of these music cultures has become intrinsically linked with its score system (Gnanadesikan 2009); for example, the physical act of writing notes and rhythms on staves (Western notation or *Ome Swarlipi* for classical Indian music), or shapes and numbers relating to finger positions (e.g. Japanese shakuhachi music, or writing Tab notation for guitarists), or drawing graphical representations of music gesture on the page (e.g. Znamenny chants from Russia, or 20th Century experimental music), have all sustained creative invention within these practices. In all cases, musical ideas are communicated from one mind to another, and the processes of score-making are embedded, infused, infected with the feel and shapes of these ideas to such an extent that they are capable of being re-communicated and enacted again and again across different musicians without the need for the primary composer to be present.

These commonly accepted notation/score systems are an efficient, globally recognised way of distributing ideas in music within certain contexts and for certain types of musicians; and they have been around for hundreds of years. The evolution of, say, Western common-notation, has been analogous with the developments in, for example, the complexity of the tonal, harmonic, rhythmic and the textural language of music; experimentations in compositional ideas such as indeterminacy/ aleatoric practice; graphical representation of sound on the page, and microtonal instruments (Bhagwati 2019). Recently, there have been significant developments in professional and project score writing technologies enabling the publishing of page-based scores direct from the computer, such as *Sibelius* or *Finale* for Western common-notation, *GuitarPro* for tablature, and *Shakuhachi* for Japanese flute. These software environments are exceptional at supporting the type-setting of a music score, enabling files to be downloaded, and distributed digitally.

There are four principal limitations to paper-based traditional music scores (including the digitised platforms): first, if a musician does not normally work with paper-based notation during performance because they are, say, techno/ dance music creators; indigenous musicians from the Asian tradition; improvising musicians, visually impaired, or untrained in any conservatoire discipline, then they are excluded from a significant range of score-based music-making activities and unsupported in sharing and distributing their own creative ideas.

Second, if a compositional idea is not about a sequence of sonic events, then common-notation and traditional scores become limiting. For example, if ideas are dealing with more emergent creative energy within the inter-relationships between sound, space, instruments and musicking in, say, a semi-improvised composition using live electronics networked across an ensemble of four, then a dynamic scoring system that encourages emergent creativity in the here-and-now needs to be invented (Magnusson 2018). Or, if the music idea is of such temporal complexity that it cannot be communicated using blunt symbols, vaguely anchored onto a piece of paper then a real-time computer-based system will be required.

Third, the context for digital scores is rapidly emerging and this is a global concern. Writing in 2018, Hugill signalled the need to completely rethink our definition of musicians that work with, or are 'profoundly influenced by, digital technologies' (Hugill 2018). These 'digital musicians' are a 'new kind of musician: one who originates *and* performs, who creates *and* produces, and who harness the potential of technology in new and exciting ways' (ibid). Furthermore, we are in an 'age of access' where the 'cultural diversity and integration' of the world's musics are leading to a 'world of stylistic plurality and blending' (Chapman 2012). This is due to rapid and open international communications; access to broad alternative musical cultures and ideas; and an acceptance that different kinds of music are of equal merit (ibid.).

Fourth, computation is a platform that supports the contemporary musician's curiosity towards experimentation and adaptation of contemporary technologies and cultures in their music-making. They are also a reflection on contemporary culture and the predominance of digital technology, and digital communications in contemporary life.

- *The emerging features of digital scores* (taken from *The Digital Score* (Vear 2019))

A digital score is not a singular, identifiable creation, nor is there an exemplar for what one might be. Nor are they dominated by the single sense of sight (symbols on a page). In fact, computation and digital media facilitate the communication of ideas across a range of senses. These could be embedded as visual, acoustic, tactile, robotic, or sonic and involve an equally wide range of materials such as text, movement, sound, code, image, haptic objects, as well as the sense of time, presence, and co-operation.

Digital scores communicate contemporary ideas between musicians that would be difficult (if not impossible) to achieve using existing score-systems. They do this by enabling such ideas to be contained and packaged in a combination of hardware and software and re-presented for live realization in performance. A defining feature is they benefit from the usability and functionality of dynamic technological environments at some level, and are responsive, evolving as the performance progresses and operating on a level of interactivity more in common with gaming and immersive new-media art. Crucially, their language of communication is not bound up with traditional training and constructs (although it could be), making them an ideal cross-/ multi-media platform for inclusive music-making.

Digital scores are as much about the creative potential of the medium as the technological solution and what these combined can deliver in no other way. Therefore, when a musician is interested in something that the technology is capable of creating through and with the technology - without which it couldn't have happened - then we can call that a digital score. For example, a composer writing a composition in scoring software as they might have done if it was on paper, is not creating a digital score. This is a traditional score produced using digital technology. However, if the composer was to employ some of the functionality of the software, such as advanced technological features or use a plug-in that can distort or transform the notation, then suddenly this starts to become a digital score.

Digital scores can facilitate journeys of sound across time and space that can be structured in advance or actively in performance. This results in musical narratives that can respond to the forms and functions of media and technology and go beyond those that can be presented in traditional scores. There is a growing interest for scoring systems to be dynamic and to contain functions that move in real-time with the flow of music. Digital scores support interactivity and live responses to such an extent that the composer, or the machine can be felt to be present in the performance as a co-operative entity. Digital scores enhance the connections between musicians and machines by constructing relationships between interfaces, control parameters, interpretive data, sequencing and decision-making processes across the technology of the score. They can prioritise the creativity of the performer by placing them at the centre of the decision-making process in performance regardless of formal training. Interpretation becomes a key skill in the performance practices of musicians engaging with these digital scores. Digital scores are a product of the digital musicians who wish to speak to other musicians through their digitized culture and mindset, regardless of "traditional" training and limiting/ fixed language systems (Bhagwati 2019, Magnusson 2019).

Digital scores are utilising computational creativity, creative computing and the implementation of artificial intelligence. This enables them to be endowed with algorithmic aesthetics where the co-operative code collaborates with the musician. It is possible for musicians to engage with interactive scores in new and engaging ways that has more in common with game play. Some digital scores are also utilising networking technologies enabling musicians to be co-located across high definition video streaming synchronised with CD quality live audio and bound together in a collective virtual space. High volume data communications are providing new opportunities to connect multiple performers, musicians, dancers, and actors from across the globe in a single theatrical event. It is possible for artists based in different physical locations to meet and perform collaboratively in the same music-space, even shared virtual spaces.

- *Existing Corpus (practice and theory)*

A key aspect of the research context for the digital score is that it is mostly driven by creative practice. This is partly because of the pace of technological change, partly because the form itself attracts creative researchers who can see therein considerable experimental possibilities, and partly because of a relative lack of theoretical attention to the field (Hope 2017).

What is emerging is a global body of practice that explores the potential of digital technology as a creative space for score-making. On the one hand there is a broad wealth of innovation offered to musicians through digital scores as they explore the same technology: for example, animated graphic scores and projected images, to mixed-media environments; from co-located telematics with distributed code to artificial intelligence, gaming, virtual reality, thinking machines, robotics and hacked-bodies. On the other-hand, they reflect the cultural interests of their community, making digital scores created by a Korean artist aesthetically and conceptually different from those created in, say, New York. Digital scores not only go beyond traditional practice but also become part of future practice, just as previous new scoring techniques have entered music practice over the centuries, not only in the West but in music traditions globally (Magnusson 2019, Hope 2017).

The corpus of digital scores is still very much in formation, and as a creative phenomenon, has only really been adopted in the past decade (discussed below). In this period, however, it is clear that digital technology is transforming musicians' experience, creativity and practices of the score. Crucially, digital technology changes the nature of relationships in the concept of a score. The primary reason for this is that the digital technology operates as more than simply a tool in the creative process. Digital scores can be an active participant in the creation of the musical work as it offers a conversation with the musician regardless of background. In doing so, it can define, arrange, outline, express, coordinate, collaborate and circumscribe ideas. But it can limit, confine, reduce, restrict and deform musical ideas too. This conversation is a core part of the creative process as the technology reaches into the creative ideas and edits, orders, demarcates, proposes possibilities and limitations about what can and can't be represented in a specific format, technology or within an individual medium (Vear 2019).

A basic classification of the existing corpus of digital scores, based on step-changes in how the combination of computation, digital media and their behaviour affect the nature of relationships and meaning in human musicians can sub-divide digital scores into three main classes (Vear 2019):

1. The Referential Screen. This class of digital score include types that range from the *Augmented Page*, which uses screen-based technology to display images of the printed page; *Technological Conductor* that are created from fixed media (sound files and visual image) and are structured in a linear sequence, and anchored to pre-defined timelines, and *The Collaborating Score* that augments these previous types by introducing the manipulation of live and pre-recorded sound elements in real-time. An example of the latter is *Islands* (2016) by Scott L Miller (US), which is a sound-based digital score and improvisation environment mapping fixed processes in a linear sequence.

2. Interactive Systems. This class includes three distinct types: *Animated Score* is a visual-based scoring system in which the design and notation are dynamic and shifting in time on a screen (e.g. Ryan Ross Smith's *Study No. 41* http://ryanrosssmith.com/study14_1.html); the *System-As-Score* employs hardware systems and electronic components to construct tactile musicking environments (e.g. *Cobra* (2016) by Amit Patel (UK), is a tactile physical object score using knobs and tilt sensors embedded on a beer-mat); and *Creative Systems* which are composite constructions of pre-defined audio and visual material working together with real-time sound processing. This class of digital score is dynamic in the real-time of musicking and are spontaneous as they react and interact to the live situation.

3. Co-operative Code. The nature of this group is that they are felt to be co-operative in musicking. As such, these digital scores evoke a sense of creative autonomy in the flow and are mutually involved in working towards the creation of the music. This means that the musicians and the digital score have clearly defined tasks in a shared enterprise of musicking and the scores are self-directed, intelligent even, in their operation of their tasks. This class comprises four main types: *Performative Code and Hacked Bodies* that is defined by the interactivity between the physical movements of a musician, the data streams from tracking technology and the machine's response (e.g. *Gravity Pleasures* (2017) by Franziska Baumann (SUI)). *Gesamtkomposition* uses multiple computers to synchorinsie multiple streams of media, musicians and data in to a cohesive work (e.g. *Ling Yin* (2016) by Chi Wang (China) for modified Gametrak controller, generative sound-processing system and solo performer). *Networked Ensembles – Connected Score* that binds co-located performers in a network through a distributed and shared scoring system; and the *Living Score* type that is characterized by the use of intelligent computation systems as a co-creational *other* inside the flow of musicking (e.g. *Zamyatin* (2010-2019) by Ollie Bown (AUS) that embeds dynamic algorithmic behaviour in the digital score).

The PI's own work has contributed to this emerging corpus, through works such as: *Three Last Letters* (2011) which was commissioned by Glamorgan International Music Festival and uses a hive network of laptops generating a realtime visual and soundscape score for six improvising musicians. *Black Cats and Blues* (2014-18) released on Metier records by the eminent US-cellist Craig Hultgren, combines generative visual elements with mixed-media soundscapes and projections for the performer to use as scoring elements. *On Junitaki Falls* (2017-18) is for solo oboe and two artificial intelligence performers conjoined through a dynamic graphic score generated by the AI. Recent experiments have centred on robotics and the role of embodied movement as digital scores (e.g. https://patabots.bandcamp.com/releases).

- *Shortfalls of the Existing Corpus (practice and theory)*

There have so far been relatively few theoretical examinations of digital scores. A number of recent studies have discussed notational technology in interactive systems (e.g. Hugill 2018, Hope 2017, Magnusson 2019) but have yet to fully address the digital score as described in this proposal. Studies of electroacoustic and computer music, on the other hand, seem to regard the digital score as peripheral (e.g. Rhodes 2015). Some texts do discuss the effect of multimedia upon musicianship (e.g. Brown 2012) but fail to apply these to the concept of a digital score; while music-oriented studies of digital culture, gaming and new media (e.g. Collins 2008) do not concern themselves with the music score at all.

It therefore falls to practitioner/researchers to provide most of the current theory of digital scores (albeit not always using that term). Many different musicians across the planet are exploring digital scores as a new field of music expression; and their practices are being transformed as a result (Magnusson 2019, Vear 2019, Hope 2017, Smith 2018). A significant research network and associated conference for this field is TENOR (Technologies for Music Notation and Representation). TENOR has a 'strong focus on computer tools and application' and on how 'notation, representation and/or visualisation of the music and sound' can contribute to a more 'durable medium' of representation (ibid.). However, its remit is to bring together researchers and institutions working in this field for networking, comparison, analysis and archiving, and has yet to develop a cohesive theory for digital scores or study digital musicianship in the depth that the "Digital Score" project proposes (see project partner below).

- *Problem Definition*

All the factors discussed in the *state-of-the-art* are transforming the digital score into something more than merely a screen displaying images of paper scores; as such it is proving to be a more flexible and malleable concept for communicating ideas in music across a broad range of musicians, abilities and backgrounds. Although there is a great range of practices encompassing this field of exploration (outlined above), there is no single body of discourse that brings these together into a specific and cohesive whole. This is understandable as the field is fresh and exciting with no agreed borders. Yet, these approaches transform practices and languages, and meanings for musicians at every stage of creation with the digital score. These in turn stimulate new relationships between musicians and opens up the possibilities of new creative experiences, and are transforming A) innovation (e.g. animated scoring systems); B) composition methods (e.g. working with artificial intelligence); C) performance environments (e.g. integrated cross-disciplinary performance); D) music-making engagement (e.g. telematics performance linked through distributed scores); and E) accessibility (e.g. communicating ideas between untrained, improvising, or indigenous musicians).

The lacuna in the theoretical and practical understanding of the meaning of digital scores is due to that fact that any studies have so far focused on using the signatures of traditional musicology as the benchmark for understanding the digital score. Any new study of digital scores needs to understand how the digital score presents a different set of propositions and signatures to the notion of a music score due to its core involvement with computation and digital media, and therefore is to considered as a new type of music communications interface and practice worthy of its own tradition of inquiry (Agamben 2009), with its own theoretical benchmarking.

- *Problem Solution*

The central challenge that this project will investigate is **how digital scores stimulate new relationships between musicians and open up the possibilities of novel creative experiences; and how these profoundly influence the nature of digital musicianship.** The solution therefore, needs to look beyond what a score is (technical construction) and study what it does to these digital musicians inside the flow of the creative acts of music-making: composing, performing, making, designing and coding. Given the computational and digital media nature of these digital scores, this is naturally a trans-disciplinary challenge and needs to draw on theories from music, philosophy, performance, media studies, gaming and software engineering, to name but a few.

A core principle adopted by the "Digital Scores" project is Christopher Small's notion of *musicking* (Small 1998), and to approach the challenges as practice-based (discussed below) and from the perspective

that 'to music is to take part'. Small writes that this 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)'. He goes on to stress 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' (ibid.). Simon Emmerson clarified Small's principle of 'meaning' to infer the 'what you mean to me' (Emmerson 2007), (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*) is to be found in the relationships formed between the new creative acts of musicking and the technologies and media of a digital score; and these are different from the relationships stimulated with traditional music scores. Meaning, in this perspective, goes beyond simply colouring a musical idea through aesthetic choice, although this is part of the process. Meaning is to be found in the inter-relationships and inter-connections between *musician – technologies – media – music.* This means examining the relationships within, across, through and emergent of the creative acts of musicking and the materials of these acts, e.g. people, sound, space, computation, media, interactivity, virtual presence and time.

The core team, led by the PI, will use the insights gained through musicking to develop a concept of *digital musicianship* for understanding the shifting nature of musicianship with digital scores. Digital musicianship will expand on current thinking about the craft of musicianship in the contemporary context. To this end musicianship is understood as 'a person's ability to perceive, understand and create sonic experiences' (Brown 2012). Digital musicianship will need to express how digital musicians are aware of musical features with digital scores, their facility to articulate and interpret their features and their affects, and the musician's capacity to demonstrate understanding through active analysis and the generation of music. A starting point for this project is the five dimensions posited briefly by Brown (2012) of: *aural awareness, embodiment, imagination, representation* and *interaction* (ibid.); and crucially how these 'provide opportunities for reflection, creation and sharing' (ibid.)

- *Preparatory Research*

In 2019 the PI published the findings from over a decade's worth of practice-based experimentation in this field in his Routledge publication of *The Digital Score – Musicianship, Creativity and Innovation* (Vear 2019). This monograph featured contributions from over 50 significant musicians from 4 continents with the intention to 'initiate a conversation about how the music score is being transformed by digital technology' (ibid.). The theoretical framework underpinning this research was based on the argument that musicians working with digital scores are implicitly aware of the inter-relationships of *musician – technologies – media – music* and its inter-connections from a two-way phenomenology of ***Taking-in****:* how the perceived affect of the technology and media of a digital score reaching out, suggesting, offering and shifting through the tendrils of affordance and experience make connections with the musician(s) through notions of a) *Liveness*, b) *Presence*, and c) *Interaction*. ***Taken-into***: how the digital score can establish a world of creative possibilities through embodiment and the flow of the domains of a) *Play*, b) *Time*, and c) *Sensation*).

Within this publication Vear identified and defined *seven modalities of the digital score* that can 'offer ways of describing, analysing and evaluating digital score composition and performance, and as a model for practical exploration of the digital score' (Vear 2019). The seven-modalities framework incorporates philosophies and theories from a transdisciplinary perspective and integrates ideas about relationships to the technology, (e.g. Heim 1994), sociological understandings of technology's role in being (e.g. Deuze 2012), notions of Code/space (e.g. Kitchen & Dodge 2011), performativity and liveness of media (e.g. Kitchen & Dodge 2011), creativity of the coder and the philosophy of software (e.g. Berry 2008, 2012), affectual and phenomenological affordance of technology (e.g. Norman; Gibson c1988; Gelernter 1994), embodied relationships between musician and the media (e.g. Ihde 1976), embodied relationships between the machine and musician (e.g. Ihde 2010), music world relationships (e.g. Small 1998), the Human→ (Machine-world) relationship (e.g. Ihde 1975), and the process of fusing these together (e.g. Murch in Chion 1994). This research and the book set out the groundwork for the "Digital Scores" project.

- *Scientific and Cultural Importance*

The "Digital Scores" project represents a significant step change that will have the potential to reposition digital scores from the margins of music experimentation for a few, to the centre of practice and meaningful engagement for many. It can lead to new forms of practice and musical expression, and support creative inclusive music-making in the digital realm. It will present solutions for the publication and distribution of innovative new music and the communication of novel musical ideas in the digital age. It will do this by creating the necessary scientific understanding of both its theory and practice. It will focus on new ways of understanding digital musicianship and the creative affordance of delivering next-stage developments in notions of the music score. It will generally overlook the page-on-the-screen tradition of

common-notation migrated to tablets, or the backing-track-with-live-soloist format except where the digital aesthetics of such are relevant to the research. Instead it will focus principally on emerging and new technologies which challenge familiar patterns of music-score production and digital musicianship and support innovation, creativity and inclusivity.

The benefits of this research will extend beyond music studies, performance and publishing. It will impact upon computing by establishing new sets of user requirements and providing new models for software development. It will have a direct impact on certain emerging technologies by providing creative input. It will lead to new understanding of creative processes, performance practice and audience engagement. It will provide a resource for composers, performers and other artists working in the wider media arts through establishing a system that maps a range of artistic practices and reframing the contexts in which they work. This will enable innovation and further practice-based research not just around digital scores but across the media arts. It will also be relevant to those working within cultural production and the creative industries, by providing new models for digital publishing. Finally, academic researchers will find great use for the critical outputs of the project, which will define an emerging corpus of digital scores and provide a critical framework for its analysis.

- *High Risk, High Gain*

As the 'state of the art' survey given above has shown, practice-based research is the major mode for digital score research. However, the under-theorisation of the field and the lack of any kind of analysis of this form of digital musicianship makes these strands a key piece of added value to the project. The high gain is therefore a transdisciplinary critical understanding of the digital score from within and without, leading to a fundamental reconceptualization of the music score in a digitized world.

The high risk resides principally in the generation of new knowledge through the creation of artefacts. There is a longstanding and active debate about the methodologies for such knowledge creation (Borgdorff 2006; Coessens et al 2009; Biggs & Karlsson 2010, Shneiderman 2016, Edmonds & Candy 2018); the PI is at the forefront of this debate and has been contracted as editor-in-chief for The Routledge Handbook of Practice-Based Research (due for publication 2021). This debate outlines the challenge for other more established scientific communities when trying to evaluate practice-based research, and for researchers who are trying to develop their scientific abilities while maintaining the credibility of their practice. The key challenge is the transformation of the 'unfinished thinking' (Borgdorff 2006) generated by the practitioner-researcher in, with, and through their practice, into new insights and new knowledge that benefit the field. In short, practice, and the artefacts of such practice do not speak-for-themselves and do not constitute new knowledge. It does, however, generate new insights that are 'enclosed in aesthetic experiences, enacted in creative practices and embodied in artistic products' (Borgdorff 2011). Formal knowledge emanating from such practice is then determined through a rigorous process of evaluation and reflection from the experience of the practice. As such knowledge is usually set in a specific context, examined through scientific processes, against theoretical frameworks and must reach beyond the particular cases in order to contribute to knowledge in the round.

The practice-based research strand of this project will adopt the artistic research model (Borgdorff 2011) which supports a scientific enquiry into a form of knowledge production enmeshed in the reflexive praxis of doing. Artistic practice research provides a 'specific articulation of the pre-reflective, non-conceptual content of art' (Borgdorff 2011) in this case the 'thinking in, through and with' digital score creativity. As the "Digital Scores" project aims to examine musicianship and transformation inside the creative acts of music it is logical that a representative portion of study should concentrate on the experience inside musicking, specifically facilitating professional musicians to become embodied in real-world digital score environments (making and performing). This artistic-research practice will enable the team to gather evidence of the operational significance (meaning) of musicking with digital scores. The purpose of this approach is to move away from an observational-enquiry style of conventional musicology towards a shared-enquiry aimed at unearthing tacit and epiphenomenological knowledge through doing. Interrogating the tacit dimension (Polanyi 1966) of praxis across the range of themed case studies will help to distinguish between propositional knowledge (facts), procedural knowledge (processes), and the tacit knowledge of 'knowing more than we can tell' (Polanyi 1966). This process will bring a clear picture of musicians' experience within the music creation, that, once decoded using the theoretical framework, will offer exceptional insights to the understanding of this field.

The results of the "Digital Scores" project will not just be papers but (like in engineering) new technologies, novel processes and artistic artefacts that advance current knowledge in a profound and original way. These will take the form of experimental Case Studies (roughly 50), interwoven with a body of critical and reflective writing and debate. This linking of creative practice with epistemological development has been identified as embodying transdisciplinary or 'mode 2' knowledge production (Gibbons et al. 1994)

and is a vital process in breaking free from 'traditional thinking, discipline boundaries, and narrow aspirations' (Shneiderman 2016). "Digital Scores" sit at the very intersection of applied and basic research of art and technology and so blurs the boundaries between "science" and "art". This project is therefore real "frontier research" which will create a theoretically informed platform for further digital score research.

Section b. Methodology

The main aims of the "Digital Score" project are to: 1) conduct an ambitious programme of practice-based research investigating the transformation of the music score through new computational technologies. 2) develop an innovative theoretical framework which, in drawing upon digital humanities, software studies, computer science, media arts, musicology, post-humanism and performance studies, seeks to establish a transdisciplinary approach to a critical understanding of digital scores. 3) build a scientific study of inclusive digital musicianship through the transformative potential of the digital score.

To achieve these aims the research programme will be conducted through three complementary and interwoven strands:

1) *Theoretical Studies*, the PI and the team will bring together a transdisciplinary panel of experts from the digital humanities, software studies, computer science, media arts theory, musicology, and performance studies, to establish and develop a transdisciplinary approach to critical understanding of new forms of music score creativity in the digital age.

2) *Creative Experiments*, comprising the design, development, realisation and dissemination of a series of practice-based case-studies (roughly 50) across different geographic locations and socio-cultural backgrounds and sub-cultures, that examine different emerging technologies as the basis for digital scores. These will be conducted by the PI and other team-members under his supervision, and engage composers, professional and community musicians, and creative technologists in a ground-breaking analysis of their experiences in the flow of music-making with digital scores in real-world audience-facing scenarios.

3) *Digital Musicianship*, will synthesise the findings from the other two strands and develop an analytical framework for understanding the shifting nature of musicianship with digital scores. This will include a comprehensive programme of interviews with digital score creators and theorists, and engage a range of musicians in practice-based workshops with the emerging corpus of digital score practice.

- *Feasibility & Implementation*

The PI has significant experience in research leadership activities, these are highlighted in the part B1 and his C.V. It is important to stress his experience as a professional musician for over three decades in which he performed internationally, and at the highest levels of the profession in many fields of music that are aligned to the challenges of this project, specifically, music technology, improvisatory, and experimental music. His compositions incorporate AI and co-operative machine collaboration, and many of these have been commissioned and published by significant contemporary music organisations. This makes him ideally placed to be leading the creative and artistic strands of this project. Furthermore, his book *The Digital Score* (2019) established the theoretical groundwork and method for this project. Overall these attributes uniquely position him in the whole field to lead the cross-discipline research team with a high-risk and high-gain imperative.

The PI will lead each aspect of this project, the core research team, and oversee/drive the development of the practical, analytical, and theoretical research processes. He will take full responsibility for the leadership of each work package (WP) throughout this project. He will lead the intellectual development of this research, will conduct the European series of case studies, and lead the experimental studies as part of the Digital Scores Experimental Lab (discussed below). The project team comprises 2 Post-Doctoral Research Fellows (detailed below), and a project manager who will administer the financial and logistical demands of this project, provide social media support and maintain the Content Management System for the project website.

- *The research team*

Given the broad range of aesthetic and artistic approaches to the digital score, and the pluralistic/ blending nature of the 'age of access' (discussed above) it is important that this research is conducted not by a single individual but a team of senior researchers from a variety of music cultures and geographic locations (listed below). To this end this project will adopt a *hub-and-node* network approach to organising the investigative team and to maximise the potential of research insights. A *hub-and-node* network connects every location through a single intermediary location called a *hub*. *Hub-and-node*, as a network structure, allows for a greater flexibility within the project eco-system through a concentration of knowledge and information flows.

The senior research team are world leaders in the field of digital scores and technological representations of notation in music, and are cultural and academic leaders not only in their territory (Asia, US, Canada and Australia) but also across the world. Critically, they are recognised as world leaders in the practice of digital scores and will bring this practice into their research in this project. They will manage the

research activities of their *node* territory with the PI operating as the *hub*. The *node* co-investigators will conduct a programme of research under the leadership of the PI, contribute to the intellectual development of this research and conduct their own Digital Scores Experimental Lab research (discussed below).

The senior research team are: ***Australia*** – Prof. Dr. Cat Hope is a musician and Head of Music at the Sir Zelman Cowen School of Music - Monash University. She is a leading expert on animated notation, mixed-media opera and experimental electronic music performance. She has written extensively on musicianship and animated graphic scores. ***Canada*** – Prof. Dr. Sandeep Bhagwati is a multiple award-winning composer, theatre director, media artist and Canada Research Chair for Inter-X Art at Concordia University. He currently directs *matralab*, a research/creation centre for performance arts, and directs the TENOR Network. His current work focusses on how new technologies can be useful and foster musical change for musicians who normally do not work with paper notation during performance (e.g. from techno to indigenous musicians, from improvisers to Asian traditions). ***USA*** – Prof. Dr. Kenneth Fields is Professor in Multimedia Arts and Technology at the University of California at Santa Barbara, USA and Professor of Computer and Networked Music at the Central Conservatory of Music, China. He is a world leader in telematic and network music performance and score distribution. ***Asia*** – Prof. Dr. Li Xiaobing is director of the electronic music laboratory at the Central Conservatory of Music, Beijing, China. He has composed digital scores for multi-media, Chinese opera and small ensembles and has written on the cultural history of digital music in China.

- *Project Partner*

The TENOR-Network (Technologies of Notation and Representation) https://tenor-network.org will be the official network partner for the "Digital Scores" research project. TENOR brings together researchers and institutions around the Technologies of Notation and Representation theme through yearly international conferences and events. The senior research team will disseminate research insights throughout the project at TENOR events and capitalise on the critical mass of delegates that regularly attend. This includes a broad range of artistic practices and research interests from across the planet. The purpose of this partnership is to disseminate early findings from the project and present these to a critical community appropriate to the research field. The responses from this community will form part of the ongoing evaluation of the project's findings and theoretical development.

- *Justification of Post-Doctoral Research Fellows (PDRF)*

PDRF-1 (Music Perception and Cognition). The first PDRF will have expertise in music perception and cognition analysis of musicians. Their responsibility is to design, implement and refine the processes of analysing the perceptual and cognitive processes of musicians working with innovative digital score environments, under the leadership of the PI. Specifically, they will implement and refine the analytical tools developed across the project, and manage and evaluate the qualitative data that emerges. They will work with the PI and the senior research team to synthesise this data into the ongoing development of the theoretical studies and contribute to defining the nature of digital musicianship. This is a crucial role in this project and requires a dedicated researcher to assess and evaluate the ongoing insights from across the various practice-based activities in WP2. They will work throughout the lifespan of this project (years 1-5).

PDRF-2 (creative AI software engineer). The second PDRF will have expertise in AI software engineering, machine learning, and computational creative systems. Their responsibility is the design and implementation of the digital score systems that are defined in the *hub* Digital Score Experimental Lab under the leadership of the PI. Specifically, they will concentrate on the implementation of the integrated human-computer interaction technology, software development and oversee hardware design. This is an important role in the high-gain nature of this project, and requires the persistent presence of this PDRF to critically reflect on the creative aspects of this work and to contribute to the development of the theoretical understanding of this project. They will work on WP2 only (years 2-4).

- *Timeline*

The "Digital Scores" project will unfold in three phases: Preparation Phase (1 year); Experimental Phase (3 years); and Summary Phase (1 year). Fig. 1 shows the overall plan by half years:

	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
WP1: Preparation Phase										
Task 1: Theoretical study										
Task 2: Interviews and survey of practice										
Task 3: Case Studies Preparations										
Task 4: Project website										
WP2: Experimental Phase										
Case Study 1 (defined by each centre)										
Case Study 2 (defined by each centre)										

Case Study 3 (defined by each centre)										
Case Study 4 (defined by each centre)										
Case Study 5 (defined by each centre)										
Task 1: Digital Score Experimental Labs (all centres)										
Task 2: Road show										
WP3: Summary Phase										
Task 1: Artistic outcomes										
Task 2: Academic conference including final concerts										
Task 3: Academic outcomes		TENOR Network								

WP1: Preparation Phase

This phase will aim to establish the theoretical and organisational bases for the experimental work in the next work-package.

- *Task 1: Theoretical study*

The theoretical study will aim to define and situate digital scores within the wider and already substantially theorised fields of digital humanities and media theory. It will be inherently transdisciplinary, drawing upon experts from software studies, computer science, media arts, creative technology, electroacoustic music, gaming and performance studies. It will critically examine current practices in digital score creation from existing examples across the world and also reach out to other disciplines (such as computer arts) to identify works that can inspire digital score studies. It will also address the philosophical questions of embodiment, agency, narrative, liveness, presence, artificial intelligence, and post-humanism, in order to identify the issues raised by the specificity of creativity in this project.

There will be ten fully documented colloquia, which will take place at monthly intervals during the first year and held online as a virtual symposium featuring a series of invited experts (provisional list below) alongside provocations from the project team. These will address the *Taking-In/ Taken-Into* framework (discussed above) from Vear (2019) and the five dimensions of *Aural awareness*, *Embodiment, Representation, Imagination* and *Interaction* posited by Brown (2012) as:

Colloquium 1. Aural awareness (Brown). This is defined as the ability to listen carefully and critically to the soundworld of a digital score, and to inform this ability with knowledge about how such sounds and media are produced – both naturally (acoustics), technologically (via musical instruments and other tools) and intelligently (via autonomous agency and intelligent behaviour from the software of a digital score). Specific questions will include: what are the new models for developing aural awareness in digital scores? To what extent do we need to consider a broader range of sensorial awareness with mixed-media scores? Is there such a thing as a core repertoire for digital scores education? How do students and musicians internalise this music through kinaesthetic activities? What models of analysis do we need to develop in order to understand how the intermediality of digital scores begin associative phases of cognition?

Colloquium 2. Embodiment (Brown & Vear). Embodiment is the phenomenological experience of musicking that involves sensation, gesture, and movement, along with all the associated motor and coordination skills. Specific questions will include: how does the musician's experience of their own body and environment inside musicking with digital scores affect concepts of personal-interpersonal subjectivity and agency? What spaces and dimensions are established inside the musicking of digital scores? And how do we examine these? What kind of experiences are being created by autonomous and intelligent digital scores?

Colloquium 3. Sensation and Affect (Vear). Sensation is an aesthetic awareness in the experience of an environment (music-world) as felt through their senses, and affect describes the experience of feeling or emotion through such senses. Specific questions include what role does the senses play in the flow of musicking and how can they be evoked through our relationships with digital scores? Can affect bind emotions to our actions and those of others inside digital scores? In what way does the other senses influence digital score musical responses? How does affect colour aesthetic choices? And how can we understand the flow of digital score music and the relationships we assign meaning to through the senses?

Colloquium 4. Liveness (Vear). Liveness describes the sensation that the digital score is co-operating in the real-time making of the music, and this meaningful engagement feels 'alive'. Crucially, liveness in a digital score has less to do with corporeality (the living fleshy-ness of human form) or the virtuality of subjective impression (the sound of a pre-recorded image of a human performer). Questions include: how does mediated and recorded media evoke a sense of liveness in the here-and-now of digital score musicking? How do these relationships effect the creative choices that are made with digital scores? What does it feel

like to be co-creating with a mediated realtime digital score agent? How do "alive" computerised digital score agents become embedded into the compositional process?

Colloquium 5. Presence (Vear). Presence is an experience that some*thing* is there in the flow, or I am there inside some music-world. Presence implies something more than simply a sound is there, or human agency is there, rather we should consider our 'experience of it' as the primary connection in defining the relationship to this presence. In this sense, the context of presence can be defined as the meaningful engagement in which the 'perceiving body' is 'part of that environment and not a detached observer' (Emmerson 2014). Questions will deal with issues of how a digital score evokes a sense of an autonomous other in the flow? How is this perceived/ rationalised as a collaborating performer and what relationships does this create? To what extent can decision-making process have presence inside digital score musicking? How should mediated digital score musical agents behave?

Colloquium 6. Representation (Brown). This colloquium will set-out to understand questions of representation and mediated notation in digital scores. This involves examining how digital scores are notated or recorded in some external form which may be symbolic, visual, electronic, digital, haptic, or as intelligent presence. It will also address how musicians understand and represent themselves and those of others inside the flow of musicking. Indicative questions include: to what extend can non-textual symbols be notation for a digital score? How can computational digital score technologies communicate symbolic information between musicians? How can musicians negotiate representations of self and mediated others inside digital score musicking? What is the material affect of live and present media in a digital score? How do musicians perceive meaning and information in the collaboration of live digital score media? What are the post-human experiences of musicking with "living" intelligence inside a digital score?

Colloquium 7. Imagination (Brown). This colloquium will examine imagination in digital score musicking. This involves the intellectual experience of musicking, including perception, judgement, meaning and invention. Specific questions include: what creative processes are digital score composers wishing to effect in the minds of the performers and the audience? How do musicians perceive the role of imagination in digital score musicking? What role does imagination play in the meaning-making with digital scores? How can artificial intelligence and co-creative digital systems be embedded with their own sense of imagination? How do we make sense of what we experience with digital scores, if the real and the unreal, sensation and imagination blend and cannot be separated?

Colloquium 8. Play (Vear). Huizinga (1949) argues play in music-making operates within a realm he calls a 'play sphere', within which are embedded the 'necessities and subordination' of each composition. Play is inextricability part of their musicking: the performer plays their instrument, the composer plays with ideas, the software developer plays with code and algorithms, and the improviser plays with materials. Indicative questions include: how does idea and musicking become immutably fused within a mediated world of digital score? How do human musicians play with digital score mediated presences? And what models/ rules/ attitudes do they invent to remain in the play-sphere with these new play-mates?

Colloquium 9. Time (Vear). The perception of time inside musicking plays a central role to the experience of the musician. For the performer, time is always in a state of emergence (*my creativity is marking the passage of time with sounding events*). The composer is involved in a process of speculation about the future perception of time by the performer and audience by embedding these into a digital score, even if it uses generative and real-time computation to realise the work in realtime. For the audience, the very nature of a live performance means that it always exists in the now, and, at that same moment, it is disappearing into the past of experience. An overarching question is what strategies, concepts, priorities and imperatives are required to deal with time and temporal dramaturgy in these new digital scores?

Colloquium 10. Interaction (Vear & Brown). This colloquium aims to understand interactivity in digital scores. This involves examining the musical interaction with technologies, mediated presence, the liveness of computational intelligence, co-presence of 'others' (real or generated), and the social and cultural phenomenon of the digital score as it, and its data interacts with humans. This interplay has much in common with game play immersion and human-computer interaction as each rely on playfulness in the flow. It is the relationship within such interplay through the pleasures of playfulness that affect the musician as it reaches out and offers meaning inside the flow.

Invited experts will include: Prof. Dr. Atau Tanaka (Director of Embodied AudioVisual Interaction, Goldsmiths College, University of London); Prof. Dr. Jon McCormack, (Director of SensiLab, Monash University, Australia); Prof Dr. Andrew Johnston (Interactivity University of Technology Sydney); Dr. Ulla Kallenbach (Independent Imagination Researcher, Denmark); Prof. Dr. Ernest Edmonds (Creativity and Cognition Studio, UTS Sydney/ De Montfort University, expert in computational art); Prof. Dr. Andrew R. Brown (Griffith University, Australia); Dr. Saskia Jaarsveld (University of Kaiserslautern, Germany; director of Creative Cognitive Abilities)*;* Prof. Dr. Marc Leman (University of Ghent; director of Embodied Music

Cognition Lab); Prof. Dr. Riccardo Manzotti (IULM University Milan, Italy; expert in artificial consciousness); Prof. Dr. Sarah Bay-Cheng (York University, Toronto; expert in digital performance and virtual reality); Prof. Dr. Stephen McAdams (McGill University, Canada, Director of Music Perception and Cognition Laboratory); Prof. Dr. Thor Magnusson (Professor of Future Music, Sussex University); Prof. Dr. James Saunders (Composer, Bath Spa University); Jennifer Walshe (Independent composer); Prof. Dr. Jonathon Impett (Orpheus Institute, Ghent); Prof. Dr. Gordon Calleja (director of Digital Games Institute, University of Malta). Prof. Christopher Redgate (professional musician, Royal Academy of Music).

- *Task 2: Interviews and survey of practice*

Alongside the theoretical study of digital scores in Task 1, the PI and PDRF-1 (Music Perception and Cognition) will conduct a series of interviews with practitioners of digital scores and media/ computer artists whose works can be seen as influential to this field. The questions will expand the subjective and objective propositions emergent from Task 1 and will be augmented by theories of musical representation of self and others in joint action (e.g. Keller et al 2016), social cognition of interaction through music performance (e.g. D'Ausilio et al 2015), Empathetic Involvement (e.g. Carr et al (2004)), Embodied Music Cognition (e.g. Leman 2008), and Player Involvement (e.g. Calleja (2011)); implemented successfully in Vear 2019. These will be conducted via Skype using the questions in a semi-structured way to enable a greater flow of dialogue and reflection. Each interview will be video and audio recorded and stored on the project website. Speech to text software will transcribe the interview, from which PDRF-1 (Music Perception and Cognition) will copy edit. The aim is to conduct 100 interviews over the course of this task.

- *Task 3: Case Studies Preparations*

The objective of this task will be to plan the experimental phase in conjunction with the *node* centres. All relevant working arrangements will be prepared during this phase and the distribution of case studies themes will be agreed. Since it is impossible to be precise about each case study before the research project as a whole has started, it is only during this task that such definitions may be prepared. The level of such support will be a matter of negotiation, but will reflect the requirements of each case study and may include sourcing technology experts from the host institution to assist on a case study, identify professional and community musicians, conducting interviews, contributing to team Think Tanks and organising formal sharings of work-in-progress with an audience. In the second half of this task the first case study commissions will be advertised across academic and artistic networks and a transparent evaluation process implemented.

- *Task 4: Project website*

The website is a core element of the project, providing not only a storage location and public-facing showcase, but also being the locus for all the theoretical and practical activity. As such, it will be flexible virtual space with server-side programming, an available open searchable framework, real-time streaming, a managed virtual environment and 10TB storage for the multimedia archive. There will be a scalable architecture with high bandwidth for streaming to large numbers of users. Software will include Windows data centre, VMWare 6.0, MySQL and Linux (RedHat) as a basic provision, but since the “Digital Scores” project will be building software of its own as part of each case study, this list will expand over time. The website will be housed at De Montfort University and will include a multimedia archive of all materials relating to the project and to the wider corpus of digital score and related theoretical literature. There will be a managed virtual environment for research exchange and public engagement, with a bespoke front-end designed for impact.

WP2: Experimental Phase

This phase will comprise a series of practice-based case studies (roughly 50 in total) consisting of the creation and analysis of a range of digital score prototypes. As discussed in the *state-of-the-art*, there is a broad wealth of approaches, technological innovation and cultural/ aesthetic diversity across the planet to digital score practice; and a process of blending/ plurality due to the ‘age of access’. It is therefore crucial that this work package 'spans the space' and examines as broad a range of case studies from a variety of music cultures. But, it must prioritise and support sustained and creative practices so that the reflective, analytical, and theoretical processes are built on meaningful engagement of all musicians involved. Anything less will bring forth weak, insubstantial or misleading evidence. This is why nominal 6-month durations for each case study are important, aiming for a total count of 25 case studies by commissioned musicians, and a further 5 (25 in total) by each of the senior research team as part of their centre’s Digital Score Experimental Lab (discussed below).

Each centre in the *hub-and-node* organisation will host a series of practice-based case studies involving professional, freelance, improvisatory, indigenous, self-taught, outsider, student and community musicians and composers. There will be 5 case studies conducted in each centre (UK/Europe, US, Canada, Australia and Asia) each lasting 6 months. The theme for each of these will be different across the network and will be determined in advance by the team to ensure equal coverage of the themes and cross-synthesis of

insights. The themes are: *artificial intelligence, machine learning, internet networking, robotics, virtual and augmented reality, gaming* and *physical computing* (detailed below).

Each centre will commission a different professional composer for each of their case studies. The commissioned composers will work with musicians from a range of backgrounds (to ensure an engagement with the inclusivity imperative of this project) and appropriate technology experts from the host institution to realise a working prototype. Through an iterative loop process of *{design, development, testing, refining}* with musicians, the working prototype will be performed in front of a live audience, alongside the other compositions created at the other centres.

The theoretical research that began in WP1will continue through the practice-based experimentation of WP2. The artistic-practice will follow the iterative loop process and the critical reflection process will support a feedback loop between the practical invention and theoretical development. This will involve each *hub-and-node* centre interviewing the participants of their case studies using the interview structure defined in Task 2 of WP1. These insights will be collected frequently and at regular intervals in order to critically inform the development of each case study. The case studies will not result in fully finished commercial compositions: these are to be experimental prototypes that are designed to investigate key research questions. However, they will be performed across the network as part of the critical reflection process and then published during WP3.

A typical workflow for each case study will be: month minus-1: pre case-study preparations, advertising competitive application for a commission based on the defined theme. Selection and recruitment of appropriate musicians and a needs analysis of each selected prototype. Months 1-6: progressive iterations of prototype using RIPA prototyping process: R: *Rapid Generation* = quick gain, small steps, user experience first; I: *Iterative* = unpick experience, rebuild with inductive/ deductive solution, alpha test ready for musicians; P: *Performative* = authentic environment for performance, alternating between lab test and real-world performance scenarios such as live streaming, informal lunchtime concert, formal evening concert; A: *Agile* = "quick and dirty" approaches prioritising the results from critical reflection and user-experience as indicators for next stage development (for more information see http://agilemanifesto.org).

A crucial factor of this RIPA process is that once a month the prototype composition will be tested with real-world musicians in front of an audience inside each centre (which could be a lunchtime concert or to a body of students). Following this the musicians (performer, coders, composer etc) will be interviewed. The critical reflections from this will then be folded into the development of the next month's iteration. At the end of the month the *hub-and-node* team as a whole will meet online for a Think Tank (collaborative creative problem-solving session (Hilliges et al 2007)) to discuss and challenge the on-going theoretical development of the project. These online Think Tanks will facilitate a cross-fertilisation of ideas and insights across the centres and avoid silo-thinking within the team members. The Think Tank will also deduce pattern-making across the ongoing case studies, and induce theoretical frames to be taken into proceeding iterations and case studies. The Think Tanks will also assess and evaluate the research methodology. Above all, it aims to maximise new insights from within the research process by providing external perspective through fresh thinking (Fink et al 2010).

- *Case study themes and research questions*

Each case study will examine a different emerging technology as a research theme for the creative practice and a ground-breaking analysis of musicianship through such practice. These seven themes (below) have been carefully chosen as they represent both a range of exciting and emerging opportunities for the innovation of the music score, and different immersive communicative qualities for a range of musicians. The analysis process will closely follow the theoretical development in WP1 and will use the *Taking-In/ Taken-Into* framework from Vear (2019) and the five dimensions proposed by Brown (2012) as the core basis of the analysis. This will be augmented by theories of musical representation of self and others in joint action (e.g. Keller et al 2016), social cognition of interaction through music performance (e.g. D'Ausilio et al 2015), Empathetic Involvement (e.g. Carr et al (2004)), Embodied Music Cognition (e.g. Leman 2008), and Player Involvement (e.g. Calleja (2011)) as developed in WP1 Task 2. The themes are:

1. Artificial intelligence - Digital scores employing artificial intelligence (AI) can be characterised by the use of intelligent systems that are co-creational inside the flow of musicking. However, there are many different approaches to the implementation of computational intelligence within the digital score with each potentially offering differing degrees of felt co-operation, creative presence and autonomy. How does, say, AI involving machine listening respond to input in creative ways within the concept of a digital score? How does it change human musicianship when AI driven digital scores are perceived to be co-operating in a creative and inspiring ways within the shared flow of musicking? What does it mean to co-operate within an embodied AI relationship through a digital score? And what are the implications of concepts such as artificial/ machine consciousness on the digital score?

2. Machine learning - Machine learning (ML) is a form of AI where a computer algorithm analyses and stores data over time, then uses this data to make decisions and predict future outcome. Deep learning is the next evolution of this: instead of requiring human 'supervision', algorithms can autonomously use 'neural networks' analogous to the human brain. This raises several questions such as how does it feel to perform with an AI trained digital score that has learnt the performance practices of an individual human musician? What musicianship skills are required to deal with this situation? And what might the AI learn from the score archive of dead composers?

3. Internet networking - The over-riding feature of this type of digital score is that co-located performers are linked together in a network that is operational in binding these musicians to a central score concept. This goes beyond simply connecting co-located musicking through online tele-communication software and technologies (sometimes called network music, telematics or distributed music), but focuses on the solutions for organising, sharing and distributing compositional materials for the enhancement of collective musicking. Questions arising from this include: what does it feel like to perform with digital scores streamed across a network of co-located performers? What are the differences in musicianship when networked digital scores are 1) autonomous, e.g. the digital score is generated at each site and its operation is independent of the others; 2) shared, e.g. each site shares the same score and this might be distributed across the network from a common source; or 3) hive, e.g. each site creates its own interpretation of the digital score and shares its interpretative parameters amongst the network of machines?

4. Robotics - How can robots be used as digital scores within the flow of musicking? How can a (physically) embodied system be endowed with the ability to 'perceive', 'act' and 'learn' and how can this be communicated in a digital score? What does co-operation between the human-musician and the robot-digital score feel like? And how does this shift musicianship? Is the robot-score merely a physical presence, or does it embody something other in the flow?

5. Gaming - Game engine AI is used to generate appropriate responses and intelligent behaviours within elements of the gameplay. This typically relates to non-player characters (those that are not controlled by the player), but are equally employed in the behaviour of the music, sound, temporal narratives, design, macro decision making of the game drama, and many other elements not experienced immediately by the player. When implemented into a digital score how does a musician relate to the presence of these AI characters/ avatars? What motivates game-play for the musician, and how can a digital score utilise this phenomenon? How can Game AI generate a music play-space as a digital score and is there such a phenomenon as 'open-world' digital score? And, what musicianship skills and preparations are required to deal with these new practices?

6. Virtual and augmented reality - Virtual and augmented reality (VR/AR) is a simulated experience that can be similar to or completely different from the real world. It can combine several simulated sensations into a binding experience such as super-imposed computer-generated images within a binaural soundscape. A digital score created using VR/AR might employ spatial imaging of notation upon the real-world for the musician to find and sequence, the binaural sound design landscape might entice the musician to physically move around the performance space. How does an active and dynamic engagement with a VR/AR world shift the musician's understanding of the notion of a score? What techniques of digital representation in the score need to be created to communicate ideas to musicians? How does it feel to be inside a virtual world and a score-based digital score world?

7. Physical computing - This type of digital score is defined by the interactivity between the physical movements of a musician, the data streams from tracking technology and the machine's creative response. These can use the dynamic movements of a body to control, generate or manipulate sound with a computer system that applies a varying degree of co-operation in its response. An example is when a digital score uses gaming technology, such as a Kinect camera, to track the movements of performers, the data stream from which becomes the source material for a translation into sound by an aesthetic algorithm. Questions that arise from such an approach are how can these aesthetic algorithms control elements such as processing parameters, form, and narrative in digital scores? What does it feel like to be plugged-into the data-driven performative elements (sound, image, computation) of a digital score? What are the skills needed to feel performers-as-code in collaboration with the aesthetic algorithms of digital scores? How can humans, their data-streams and digital scores co-create and perform in the shared experience of musicking?

- *Task 1: Digital Score Experimental Labs*

Each centre (UK/Europe, US, Canada, Australia, Asia) will run a Digital Score Experimental Laboratory (D-SEL). The aim of this task is to experiment with the ideas that emerge from the theoretical and artistic practice research of the "Digital Scores" project as a series of practice-based prototypes (nominally five in each, across the life of WP2). These will generally adhere to the project themes, but will also be agile and open to new and emerging technologies that require a different set of skills than the participants of the case

studies can offer, or are specialisms of the senior researcher. Although a broad range of composers and musicians will be commissioned through the case studies, it is generally accepted that they will operate within their known aesthetics and processes (and this is valued as the focus of the analysis will be on the shifts in their musicianship). However, the project needs to explore the full potential of the transformation of the music score being wrought by new computational technologies, and this requires an approach that values innovation, risk and failure beyond the known parameters of an individual's practice. The ethos of D-SEL, is therefore experimental and risky, going beyond the parameters of what might be considered a 'music score' so that the project can explore the boundaries of meaning and the associated transformations of musicianship (composition, performance, coding, designing, making etc). These experimental prototypes will be conducted using the RIPA approach (see above), with a key objective to identify innovation in experience for the musician. The PI has a long-standing reputation of innovation and risky play in music composition and is therefore is well positioned to lead this task across the network.

- *Task 2. Road show*

The PI and PDRF-1 (Music Perception and Cognition) will visit each centre of the *hub-and-node* network over this work-package (years 2-4). The purpose will be to work intensively with the centre co-I's for several days and critically evaluate their ongoing findings, while limiting the CO2 footprint of this project to essential travel only. A parallel aim is to conduct a series of workshops at the host university and other HEI's within each geographic territory (e.g. in Australia the road show will visit the university music departments in Melbourne, Canberra, Sydney and Brisbane, New Zealand and Tasmania, with Singapore and Dubai as stop-overs). The primary objective is to engage undergraduate and post graduate students and their community of local musicians from a range of backgrounds and abilities in the corpus of the digital score, evaluate their musicking, and to examine their wants and needs from digital musicianship education.

WP3: Summary Phase

This phase will see final publication of the creative experiments, academic outputs, and all the documentation.

- *Task 1: artistic outcomes*

This task will concentrate upon the publication via the website of outcomes from the experimental Case Studies. These will comprise live performance (where appropriate), films and other multimedia material, software resources, working blogs, notes, scores and other written material.

- *Task 2: academic conference including final concerts*

The final academic conference will be a two-day event held at De Montfort University. It will be aimed at practitioners, academics, computational technologists and the music publishing industry. Themed sessions will be created around the main research questions that were addressed through the experimental Case Studies. There will also be a special session focusing on the technological and computational contributions of the project, and another on the future of music-score publishing. All project participants will present papers.

- *Task 3: academic outcomes*

The academic outputs will include a co-authored book edited by the PI on the topic of *Digital Musicianship* to be published by Routledge (the PI has a standing contract with Routledge). Each member of the team will contribute a chapter within a themed structure created around the main research questions that were addressed in the experimental Case Studies. The PI will also complete a second edition of his book *The Digital Score* which will update and expand the corpus used to illustrate the book, and add a new section on intelligent digital scores.

Throughout the "Digital Scores" project the PI, PDRF's and the co-I's will seek to disseminate academic papers at appropriate and strategic points in the process, such as in peer-reviewed arts research journals including the *International Journal of Creative Computing*; *Contemporary Music Review; Contemporary Theatre Review; Digital Creativity; Tempo; Leonardo; Computer Music Journal; Organised Sound;* or scientific publication in IEEE computing conferences such as COMPSAC, the International Computer Music Conference and computer vision conferences such as ICCV, CVPR and ECCV; and at special digital score panels at international academic conferences such as TENOR (Technologies of Notation and Representation); ICMC (International Computer Music Conference), CHI (human computer interaction), and ISEA (International Symposium of Electronic Art).

The public-facing website and database of digital scores will provide online tools and resources alongside information and analysis; full documentation of each project, including movies, audio and multimedia content and, where possible, the complete performances. This will amount to roughly 50 new commissioned digital score compositions and associated performances.

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