Improvising a Live Score to an Interactive Brain-Controlled Film

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ABSTRACT

We report on the design and deployment of systems for the performance of live score accompaniment to an interactive movie by a Networked Musical Ensemble. In this case, the audio-visual content of the movie is selected in real time based on user input to a Brain-Computer Interface (BCI). Our system supports musical improvisation between human performers and automated systems responding to the BCI. We explore the performers' roles during two performances when these socio-technical systems were implemented, in terms of coordination, problem-solving, managing uncertainty and musical responses to system constraints. This allows us to consider how features of these systems and practices might be incorporated into a general tool, aimed at any musician, which could scale for use in different performance settings involving interactive media.

Author Keywords

Live score, BCI, Film, Improvisation, Max/MSP/Jitter

CCS Concepts

•**Applied computing** → **Sound and music computing;** Performing arts; •**Information systems** → *Music retrieval;*

1. INTRODUCTION

The research reported in this paper brings together two topics: interactive digital music performance and live musical accompaniment of movies. The idea of playing live music to accompany movies first appeared during the early days of silent cinema. In the absence of dialogue, voice-over and diegetic sounds, musicians–typically pianists–provided a soundtrack that supported visual storytelling. Although it disappeared with the advent of the 'talkies', this musical practice has been making something of a resurgence recently, as part of a growing interest in more experiential forms of cinema [3].

NIME'19, June 3-6, 2019, Federal University of Rio Grande do Sul, Porto Alegre, Brazil.

Live score movie screenings take multiple forms, including improvisatory accompaniment to silent movies in the mode of early cinema [8, 27]. A popular new format is for orchestral or ensemble live performances of composed scores to accompany special screenings at prestigious performance venues[1]. This phenomenon has also extended to the performance of video game scores. In many cases this involves a concert, accompanied by video clips of gameplay displayed on screens, a format established over more than a decade [20]. Occasionally live gameplay is accompanied by performance of the score, e.g. [22].

As part of the evolution of live score formats, there are opportunities for designing interfaces that support performers when accompanying unpredictable interactive media, including seamlessly delivered branching narratives like Netflix's high-profile release Bandersnatch[2]. Our specific research deals with live performers' interactions with an emergent technology, in this case a movie that has a multitude of narrative arcs, which impact upon the way that the film is perceived by the audience and performers. Our understandings of these sorts of emerging technologies are key to their innovation in terms of their development, as live musical performance and digital interactivity share an immediacy which seems to recommend this combination of modalities.

2. BACKGROUND

2.1 NMEs for Collaborative Improvisation

Within the NIME community there has been a longstanding interest in designing Digital Musical Instruments (DMIs) and networked systems that support collaborative music improvisation. This can be observed through advancements in Networked Musical Ensembles (NMEs), which range from connecting DMIs to share musical data over the Internet and local area networks [18, 25], to understanding the organisational structures that emerge within such ensembles (i.e. their performing roles and internal politics [17]), and developing systems that facilitate performance and improvisation by means of shared timelines, countdowns, visual cues and synchronization mechanisms [23, 24].

Likewise, the effects that constraints imposed by hidden rules within a system have on the way that experienced musicians improvise collaboratively have been assessed by Tez and Bryan-Kinns [25]. This is also an evident issue when improvising along with 'computer performers' (i.e. auto-

[1]http://royalalberthall.com/tickets/series/films-in-concert
[2]https://www.imdb.com/title/tt9495224/

mated musical agents), which require human performers to cope with the unpredictability of such systems [4, 9, 16, 18]. François et al [9] created a visual interface that provides a timeline of the system's state, which is proposed to support performers' awareness of the musical context so they may improvise more easily along with the machine-generated music. Similarly, in Climb! [16] (a multi-threaded game-like musical composition) the performer is presented with a dynamic score that displays the incoming stream of note events, as well as choices for musical phrases, that when performed trigger different actions (and choose different paths along the composition), with some of those paths leading to sections where the system can play 'against' the performer.

Previous work has examined notions around control, 'looseness' and autonomy when performing along with such musical systems [5, 13, 6]. Our focus here is to bring these understandings to bear upon on the design and use of an interface to support live, improvised musical accompaniment to interactive movie screenings. In this paper we present our approach to designing a visual interface that supports a group of performers in a networked setting playing and improvising live music along to an interactive and multi-threaded brain-controlled movie called *The MOMENT*[3], a sci-fi dystopian thriller that has been touring international film festivals since 2018.

2.2 Brain-Controlled Movie

The MOMENT consists of three narrative threads within a single story. The movie's interactivity is controlled by one audience member who wears a NeuroSky MindWave headset, which uses electroencephalographic (EEG) biosensors to sense electrical activity in their brain. Changes in the controller's brain activity data, interpreted by the inbuilt NeuroSky algorithm, trigger edit points between two of the three narrative threads. The frequency of these cuts and the duration spent on each narrative thread effects the next scene's thread combination. The making of *The MOMENT* and design of its Brain-Computer Interface (BCI) have been reported in detail by Ramchurn et al [2].

Unlike previous Brain-Computer Musical Interfaces, which create audio-visual biofeedback [28, 26], DMIs [14, 21, 15, 19], adaptive musical interactions [7, 12, 29] or narratives [10, 11], *The MOMENT* does not generate sound directly from brain signals, but instead uses those signals to select audio to be played as part of an interactive narrative. At every screening the interactive movie is constructed in real time, and the soundtrack adapts in response to user input to the BCI and multiplies the possible variation in audio-visual content presented. Each narrative thread has seventeen scenes, each with two audio compositions: a primary composition which contains prominent musical themes and elements; and a secondary composition which contains atmospheric, ambient music and Foley sound effects. Each primary composition has been created to be played with either of the other two secondary compositions and vice versa. Taken together, the film has 17 billion different combinations of shots, music and sounds.

The musical score for the movie emphasises and creatively exploits the variety of the content. Two composers, employing different musical styles, collaborated to produce the movie's score: one employed an electronic, noise-based approach; the other utilised traditional, acoustic instrumentation. The former composed music to accompany the narrative thread of an artificial intelligence, while the latter composed music to accompany the narrative thread of a human character who resists networked technologies. Both musicians collaboratively composed the music for the third character, who moves between digital assimilation and resistance. The composers' creative process to produce the soundtrack for an interactive brain-controlled movie has been reported in detail by Ramchurn et al. [1].

Having developed a close collaboration while making and sharing music for the movie's score, the two composers, who are based in different countries, began discussing the possibility of meeting in person to play together. From this discussion emerged the idea of performing the movie music as a live score accompaniment to the real time construction of the interactive movie. This paper reports on continued collaboration between the composers and film director after the production and release of *The MOMENT*, in order to facilitate live, improvised performance of the score alongside screenings of the BCI-driven interactive narrative. We present the design of socio-technical systems for performing a live score, then describe how these systems were practically implemented on two different occasions, before pulling out wider lessons about the design of improvisation interfaces to support live musical performance alongside interactive media content.

3. DESIGN AND IMPLEMENTATION

In this section we describe in detail the complex socio-technical system that was developed by the film director and the two composers through co-design sessions and rehearsals in order to deliver a performance that combined interactive film content with live musical performance of an accompanying score. The improvisational ensemble consisted of two performers, an intermediary composer and the system, including the audience member wearing the BCI headset. As the system constructed the visual montage of the film, it automated the corresponding volume levels of Foley and sent matching MIDI messages to raise and lower the volume levels of the musician playing the current secondary composition. The musicians hence were able to concentrate on performing to the current scene, taking inspiration from the current montage created by the controller, the ongoing scene-by-scene film construction, the other musicians' performance, their pre-existing knowledge of the full narrative and anticipation of upcoming narrative events. These last two points were led by the implicit familiarity the performers had with the film from the process of working with the director when composing the music.

3.1 The Live-Score Performance System

Figure 1 shows the entire BCI-based Live Score Performance System. We now describe the different components of the system as well as the flow of information and interactions between system, audience and performers.

3.1.1 Playback System

The Playback System (2) is a Max/MSP/Jitter patch which generates a unique film from the data sent from the NeuroSky headset worn by the Controller (1). The playback system receives data from the BCI (a), sends video to the projector and performers' video monitor (4), and sends dialogue audio to the mixer. Data about the ongoing film (b) is also sent to the Live Score Conducting System (3). Specifically, the scene number, time remaining on scene, and the current and next primary and secondary threads.

3.1.2 Live Score Conducting System

The Live Score Conducting System (3) was created especially for the live performance of the film's score. It is built on top of the existing Playback System (2) and receives data

[3]https://www.imdb.com/title/tt7853742/

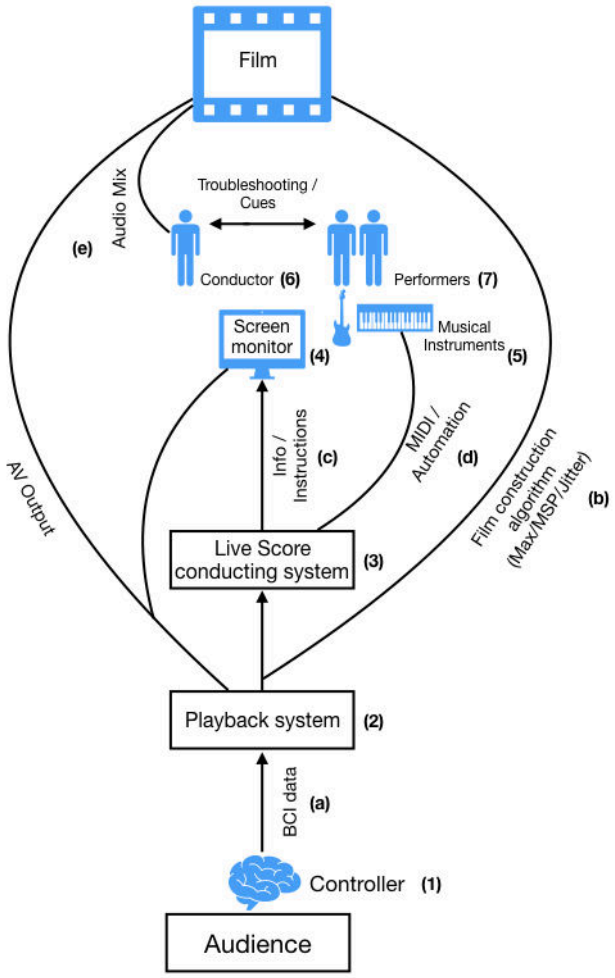

Figure 1: Diagram of the Live Score Performance System developed by the film director and score composers during co-design sessions and rehearsals.

from real-time algorithms in Max (b). It displays information (c) to the Intermediary Conductor (6) and the Performers (7) about the current and future state of the film. It also sends automation volume control data via MIDI (d) to Performers' Instruments/Tools (5) as the Playback System (2) decides when to cut based on live BCI data from the Controller (1). The user interface of the Live Score Conducting System (3), which displays information and instructions (d) for the Conductor (6) and the Performers (7) during performance, can be seen in Figure 2.

3.1.3 *Performers' Instruments/Tools*

The performers' setups each included a laptop running Ableton Live and their own modules, pedals and instruments. Audio was sent out to the Intermediary Conductor (6) to mix (e). Both performers' Ableton projects were linked to the Live Score Conducting System (3) via MIDI, which controlled the volume of secondary musical tracks according to cuts triggered by the Controller (1) via the Playback System (2).

3.1.4 *Performers*

The Performers (7)–who are also the composers of the film score–had a video monitor (4) showing the film as it played. Here they could see the cuts happening between narrative threads in real time. As mentioned previously, the audio of the secondary musical layers was faded automatically with

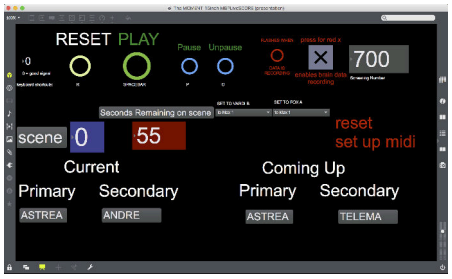

Figure 2: Conducting System User interface

these cuts. They could also see the user interface (Figure 2) for the Live Score Conducting System (3), which they used to situate their performance within the version of the film being created. This display played a countdown of how many seconds were left in the current scene. On zero, the "Current" combination of primary and secondary musical layers was replaced with the "Coming Up" layers and the scene number would increment. An onscreen flash was used to indicate a change in the "Coming Up" combination, which could fluctuate right up to the point of scene transition in response to the BCI data (a). They both had a monitor speaker with their mix and could see the Conductor (6).

3.1.5 *Intermediary Conductor*

The Intermediary Conductor (6)–also the film director and Max programmer–had two main jobs. The first was to produce the final mix of the audio (e); the main concern was to make the dialogue audible. As the film recombines differently each time, dialogue can change from performance to performance and so a responsive mix was needed to balance dialogue and music. The second job was to monitor the scene countdown and bring it to the performers' attention if there were any last second changes to the primary or secondary musical layers. The Intermediary Conductor would hold his hand out at ten seconds before a scene change and count down from 5 seconds. He was also on hand if there were any live issues involving the equipment and could direct the performers how to compensate in those circumstances and adjust the audio mix accordingly.

3.1.6 *Controller and Audience*

The Controller (1) sat at the front of the auditorium in the front row of the Audience. They were fitted with the NeuroSky headset by the Conductor (6), who introduced the performance and checked the sensor performance. The Controller's data was broadcast live to the Playback System (2) for the duration of the film. On the film's completion the headset was swapped to a different Controller for the second of the back-to-back film screenings. Thus, the Audience received two versions of the film, allowing them to appreciate the variations in the narrative, montage, and performances of the score.

4. PERFORMANCE

The MOMENT live score was rehearsed and performed first in a cinema as part of the Reykjavík International Film Festival (RIFF) in October 2018, where a viola da gamba (medieval string instrument) player joined the two composers. A second performance was staged in the theatre at Nottingham's Lakeside Arts the following month[4]. Figure 3 illustrates rehearsal, technical and performance setups. Audience members were offered raffle tickets, two of which were

[4]https://vimeo.com/327719289

Figure 3: Left: The Intermediary Conductor's station. Top right: Rehearsals in Reykjavík. Bottom right: Performance at Lakeside Arts, Nottingham.

then chosen to select individuals to wear the BCI headset and control the interactive film for back-to-back screenings. This double bill format not only produced 48 minutes of film content for the performers to accompany, it was also intended to embed comparison within the experience, encouraging the audience to identify differences between the screenings and appreciate the musical variety.

4.1 Performing with the system

We report on the practical considerations of implementing the Live Score Performance System at RIFF and Lakeside Arts on the basis of interview data. Interviews with performers were conducted over three days of system co-design sessions and rehearsals in Iceland, and immediately after the RIFF event had ended. At Lakeside Arts interviews were conducted directly before and after the performance on the evening of the event.

Some elements of the system had to be automated out of necessity, specifically matching the second-by-second cutting of the film caused by the controller's brain data, as *"there's no way we could be watching volume faders, like, using our fingers to pull them up and down physically"*. Nevertheless the live setting provided interesting opportunities for the musicians to respond in the moment to the interactive media content, with the unpredictability being described as *"what's quite exciting I think"*. The electronic musician actively sought to intensify the uniqueness of the live experience with *"a massive sound bank of sounds loaded up"* from which to make *"random choice"* from *"100s of different sounds for it and the same with all the different cuts"*.

When a performer had a primary thread to play, they were free to lead the musical response to the scene. This is exemplified by a moment when the electronic musician had the primary thread and concentrated on *"watching the cuts of the film"* rather than *"the fader going up and down"* in order to match the rhythm of the BCI-driven montage with that of the beats he was selecting live. In this case he was improvising with the interactions produced by the controller's patterns of brain activity.

In some scene combinations both threads selected had been composed by one performer, and in these cases what emerged is the other performer found they were free to experiment alongside: *"I'm not meant to be doing anything, but that's when I started trying to just do some beats over the top. I'm just trying to improvise over the top. That's all I was doing when it's that case, just your bits and then same with mine"*. The acoustic musician characterised how the nature of this live performance contrasted with other concerts: *"usually it would be just like start, middle, stop. But it's always like start and then you get disturbed and then you do another thing."* During the unpredictable performance journey, the film content served as an anchor point for musical improvisation: *"we know how to make a sound that'll fit the picture, so we can just play off each other's sounds"*.

However, although the performers were familiar with the film content and could respond to it, they did not know exactly what content they would accompany in the course of each screening. The source of sustained uncertainty in this performance situation was the fact that the composition of each upcoming scene was not determined until the very point it started. The display indicating which primary and secondary threads are "Coming Up" was taken from the EEG sensor's decision-making algorithm and changed throughout scenes. Performer awareness of this ongoing process seems to have been key to the live score system: *"it flashes up what the next scene's going to be, how long is left of the current scene, which is vital or there's no way we'd be able to know what was coming up because there's so many combinations."*

If the algorithm is on a boundary it will flip between narrative thread combinations up until the last second of a scene. This effects performers, who recall *"that moment"* where the scene was due to change in five seconds but still continued to jump between thread combinations. In practice, an important function of the Intermediary Conductor was therefore to direct the performers' attention if last second system changes were happening across scene transitions. This could however be challenging, by his own admission: *"I get lost in the film sometimes, or I'd be [to the] right looking at the levels and I'll notice that the time's went past and I've missed a cue to give these guys"*. This communication to ensure shared situational awareness came to define the performance style, described as *"vibing off the cues"*.

Scene transitions were a moment of high tension as neither performer could commit to the next musical theme until the very last second. The acoustic musician talked about how if the primary thread remains unchanged, on the next scene he was *"building something up"* musically. This had the effect of creating continuity, which may not exist in the non-live score screenings, when the score is determined by the BCI-driven playback system. However, the confidence with which a performer could judge the likely threads for the next scene changed depending on algorithm variability and the remaining time left before that scene. For the acoustic musician this posed challenges for shaping his live performance: *"I have to switch to another one [thread] then I have to start playing something else, and I don't want to do the same thing again and again. Sometimes you think it's going to switch and then it remains"*.

In addition to performance challenges posed by the design of the playback system, technical failures during both live score events needed to be worked around by the performers. During the first screening in Iceland the acoustic performer's automation for secondary threads was not being delivered. This meant that his secondary music did not fade in and out with the visual cuts, which he reflected afterwards meant that the performance had felt *"kind of empty a little bit"*. However, the electronic performer pointed out that the version of the film produced on this occasion was more reliant on the electronic primary musical threads meaning that *"people wouldn't have noticed the cuts"* to the secondary accompaniment.

During the second screening in Iceland the electronic musician's laptop crashed mid performance meaning that he

could not perform while it restarted. He alerted the Intermediary Conductor, who communicated with the acoustic musician, telling him to take over on the primary tracks. This had the knock-on effect of pushing that performer's Ableton sync out of time, playing the music from the next scene early. This secondary issue became noticeable to the performers onstage because of a disjunction between the scene content and musical content: *"the first thing we really realised was when it started playing the romantic music"*.

This audio-visual synching situation was negotiated between the musicians and the Intermediary Conductor, who recalled: *"you leaned over to me and said, is it okay? And I was like, yes, actually it's quite interesting what's happening there. But then after that there was some quite heavy stuff happening and it was out of sync and I think we both felt that. We dropped it down and then I think we made a decision there for you to improvise"*. Reflecting on the whole unintended episode afterwards, the electronic musician felt comfortable *"just going off visual cues [...] just going by feel"*. Furthermore, the acoustic musician felt it positively contributed to the performance: *"I really liked the improvised stuff though. It did have a totally different vibe"*.

At the Lakeside Arts event the same laptop crashed again during the first screening, although there were no technical failures during the subsequent screening: *"we had a nice run on the second one, where it all worked as it should have, so they [the audience] didn't experience one where it was a double crash and they never had the full flow"*. On this occasion, because of their previous experience, the performers seemed to be untroubled by the crash: *"It was just like, nodded yes it's crashed. And then we just... let's deal with this and get it back on track, improvising"*. Afterwards the acoustic musician reflected on the collaborative nature of the performance as being able to handle problems because *"it divides the responsibility. So it's nice backup to have I think"*.

Across both live score events the tendency of the performers was to view technical failures as part of the interactive unpredictability of the format, rather than as marring its value. They reassured themselves that *"even if everything goes wrong technically, nobody knows what it's supposed to sound like"*. The problems are understood as inherent to the format, *"it wouldn't be live if things didn't go wrong, would it?"*, and even as a virtue, *"happy accidents that's what it's all about"*.

5. DISCUSSION

Given the technical failures and successful coping mechanisms that we observed being employed during these two live score performances of *The MOMENT*, it seems justified to question whether the system devised and employed for this purpose was in fact necessary, and whether the musicians could have freely improvised along to film content without it. The fact that technical failures did not cause an obvious breakdown was, in fact, due to the flexible design of the system, which constructs content in real time. Unpredictability is built into an interactive experience with no predetermined, 'correct' output, making it easier to absorb problems within the socio-technical arrangements.

It is clear from our interviews with performers that the most 'vital' role played by the live score conducting system is the information and instructions it provides about interactive playback. The real time prediction of which narrative threads are "Coming Up" in the next scene influences the musicians' approach to performance, whether they build up a current theme or get ready to switch to another. The confidence with which they prepare for the next part of their performance is completely dependent on the feedback they get from the system regarding BCI input. At the moment of greatest tension–the point of a transition between scenes–the system automatically manages the practicalities of fading between threads.

Automation therefore allows the performers to concentrate on scene transitions as points of musical continuity or contrast, as part of their creative response to the interactive double-bill format, which is all about variation and comparison. This unpredictability seems to inform many elements of the performance approach: the introduction of new instrumentation, sounds and techniques; experimentation with new accompaniment for the content; influencing one another; and responding to the particular selection of content; all of which we argue constitutes improvisation in the context of a live score performance. Likewise the Intermediary Conductor is able to adjust the audio mix to best combine the visuals, Foley and live score. This responsive role extends throughout the performance, as the Intermediary Conductor also oversees shared awareness at points of scene transition and technical failure.

5.1 Implications for System Development

If we are to design a general tool which allows for the scaling up of live score performances without the original composers, we must consider the implicit knowledge generated during the composition process and how that can be unpacked to inform the design of a system that can cue and also give information about the narrative state. Returning to the assigned musical threads of the composers, this information and information like it–character themes, tension, pacing–could be supplied as improvisational guidelines. By displaying more information from within the playback system, like metadata about emotional content of the threads, the live score system could provide additional guidance for musicians less familiar with the movie content. Composers of future films could, as part of their process, create metadata for use in live performances.

Further automation could be designed to load musical scene elements based on the state of the playback system. The role of the Intermediary Conductor could also be further automated; by sensing audio levels of the dialogue the system could automatically 'duck' any other soundtrack elements. In terms of making the system more resilient to technical glitches, sync issues could be resolved by incorporating a playback counter from the playback system to keep any time sensitive content in sync.

Our current system informs the performers of the upcoming scene's narrative thread combination from the real time algorithm, which the musicians must then manually time and switch accordingly. As we have reported, there are implications of tension at the scene transitions. While the system could automatically swap between primary and secondary musicians it would not solve the issue of supporting building and resolving of musical themes. Perhaps giving musicians an indicator of the probability of future combinations may be more supportive of improvisation, and further study to understand how uncertainty can be managed during live score performances could help design such a feature.

6. CONCLUSIONS

The creation of a brain-controlled movie, specifically the close collaboration between the film director and two composers to create the score, led to the development of a system that allowed them to accompany screenings of the interactive narrative live. This innovation is relevant considering the popularity of live film scores and increasing interactivity of storytelling. At present the live score conducting system for *The MOMENT* incorporates the prior

knowledge of the director (as Intermediary Conductor) and composers (as performers), which allows them to improvise around unpredictable narrative content and technical failures. Our study of the implementation of this system at two public performances suggests that further developments are needed in order for other musicians and sound technicians to be able to accompany the interactive movie with confidence and freedom across the tension of real time montage. The incorporation of additional automation and narrative metadata within the system would support live musical responses to unpredictable and unfamiliar content as it is selected scene-by-scene.

7. ACKNOWLEDGEMENTS

This work was supported by the Engineering and Physical Sciences Research Council [grant numbers EP/L015463/1, EP/M02315X/1, EP/L019981/1, EP/M000877/1], the Arts Council England Grants for the Arts, and the National Council of Science and Technology of Mexico (CONACyT). Special thanks to the cast and crew of The MOMENT, our FACT and B3 Media partners, Live Cinema UK for distributing the film, and the Reykjavík International Film Festival and Lakeside Arts for inclusion in their programs.

8. REFERENCES

[1] Ramchurn, Richard and Chamberlain, Alan and Benford, Steve. Designing Musical Soundtracks for Brain Controlled Interface BCI Systems. In *Proc AM'18*, pages 28:1–28:8. ACM, 2018.

[2] Richard Ramchurn and Sarah Martindale and Max L. Wilson and Steve Benford. From Director's Cut to User's Cut: to Watch a Brain-Controlled Film is to Edit it. In *CHI'19*. ACM, 2019. (In Press).

[3] S. Atkinson and H. W. Kennedy. *Live Cinema: Cultures, Economies, Aesthetics*. Bloomsbury Publishing USA, Dec. 2017.

[4] A. R. Brown, M. Horrigan, A. Eigenfeldt, T. Gifford, D. Field, and J. McCormack. Interacting with Musebots. In *Proc NIME'18*, pages 19–24, 2018.

[5] A. Chamberlain. Are the robots coming?: Designing with autonomy & control for musical creativity & performance. In *Proc. NIME'17*, page 54. ACM, 2017.

[6] A. Chamberlain. Surfing with sound: An ethnography of the art of no-input mixing: Starting to understand risk, control and feedback in musical performance. In *Proc. AM'18*, page 32. ACM, 2018.

[7] J. Eaton, W. Jin, and E. Miranda. The Space Between Us: A Live Performance with Musical Score Generated via Affective Correlates Measured in EEG of One Performer and an Audience Member. In *Proc. NIME'14*, page 4, 2014.

[8] P. F. Fadnes. Improvising the Deluge. Live film scoring and improvisational practices. *Jazz-hitz*, (01):107–123, Oct. 2018.

[9] A. R. J. François, E. Chew, and D. Thurmond. Performer-centered Visual Feedback for Human-machine Improvisation. *Comput. Entertain.*, 9(3):13:1–13:13, Nov. 2011.

[10] S. Gilroy, J. Porteous, F. Charles, and M. Cavazza. Exploring passive user interaction for adaptive narratives. In *Proceedings of the 2012 ACM International Conference on Intelligent User Interfaces*, IUI '12, pages 119–128, New York, NY, USA, 2012. ACM.

[11] S. W. Gilroy, J. Porteous, F. Charles, M. Cavazza, E. Soreq, G. Raz, L. Ikar, A. Or-Borichov, U. Ben-Arie, I. Klovatch, and T. Hendler. A brain-computer interface to a plan-based narrative. In *Proceedings of the Twenty-Third International Joint Conference on Artificial Intelligence*, IJCAI '13, pages 1997–2005. AAAI Press, 2013.

[12] S. Giraldo and R. Ramirez. Brain-activity-driven real-time music emotive control. In *Proc. ICME3*. University of Jyväskylä, Department of Music, 2013.

[13] C. Greenhalgh, S. Benford, A. Hazzard, and A. Chamberlain. Playing fast and loose with music recognition. In *Proc. CHI'17*, pages 4302–4313. ACM.

[14] M. Grierson, C. Kiefer, and M. Yee-King. Progress Report on the EAVI BCI Toolkit for Music: Musical Applications of Algorithms for use with consumer brain computer interfaces. *Proc. ICMC'11*, 2011.

[15] S. L. Groux and J. Manzolli. Disembodied and Collaborative Musical Interaction in the Multimodal Brain Orchestra. In *Proc NIME'10*, pages 309–314.

[16] M. Kallionpää, C. Greenhalgh, A. Hazzard, D. M. Weigl, K. R. Page, and S. Benford. Composing and realising a game-like performance for disklavier and electronics. In *Proc. NIME'17*, pages 464–469, 2017.

[17] S. Knotts and N. Collins. The Politics of Laptop Ensembles: A Survey of 160 Laptop Ensembles and their Organisational Structures. In *Proc. NIME'14*, pages 191–194, 2014.

[18] C. Martin, H. Gardner, B. Swift, and M. Martin. Intelligent Agents and Networked Buttons Improve Free-Improvised Ensemble Music-Making on Touch-Screens. In *Proc. CHI'16*, pages 2295–2306.

[19] S. Mealla, A. Väljamäe, S. Jordà, and M. Bosi. Listening to Your Brain: Implicit Interaction in Collaborative Music Performances. In *Proc. NIME'11*.

[20] Mike Musgrove. Mario's New World: Symphonies. *Washington Post*, Aug. 2006.

[21] E. Miranda and A. Brouse. Toward direct brain-computer musical interfaces. In *Proc. NIME'05*, pages 216–219, 2005.

[22] Music Beyond Mainstream. Dear Esther Live. https://www.musicbeyondmainstream.org.uk/projects/dear-esther-live/, Visited on 2019-01-15.

[23] P. Rebelo and A. B. Renaud. The frequencyliator: distributing structures for networked laptop improvisation. In *Proc. NIME'06*, pages 53–56. IRCAM-Centre Pompidou, 2006.

[24] A. Renaud. Dynamic Cues for Network Music Interactions. In *Proc. SMC'10*, July 2010.

[25] H. E. Tez and N. Bryan-Kinns. Exploring the Effect of Interface Constraints on Live Collaborative Music Improvisation. In *Proc. NIME'17*, page 6, 2017.

[26] T. Tokunaga and M. J. Lyons. Enactive Mandala: Audio-visualizing Brain Waves. In *Proc. NIME'13*, pages 118–119, 2013.

[27] A.-K. Wallengren. To be in Dialogue with the Film. In K. J. Donnelly and A.-K. Wallengren, editors, *Today's Sounds for Yesterday's Films: Making Music for Silent Cinema*, pages 192–215. Palgrave Macmillan UK, 2016.

[28] J. Weinel. Representing altered states of consciousness in computer arts. In *Proc. EVA'15*, pages 80–87, 2015.

[29] B. F. Yuksel, D. Afergan, E. M. Peck, G. Griffin, L. Harrison, W. B. Chen, R. Chang, and R. J. K. Jacob. BRAAHMS: A Novel Adaptive Musical Interface Based on Users' Cognitive State. In *Proc. NIME'15*, page 4, 2015.