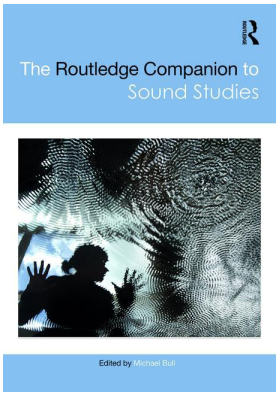

The Routledge Companion to Sound Studies

Bull Michael

Sound and music in networked media

Publication details
https://www.routledgehandbooks.com/doi/10.4324/9781315722191-32
Magnusson Thor
Published online on: 02 Nov 2018

27

SOUND AND MUSIC IN NETWORKED MEDIA

Thor Magnusson

Introduction

The Internet is an ideal platform for most forms of musicking (Small, 1998): it is now used extensively in the composition, performance, dissemination, and listening of music. The ecology of media musicians operate in today is substantially different from the one where music was written on physical media, released by a relatively small number of major labels, sold in shops, selected for play by radio DJs, and reviewed by established writers in the printed press. We have moved from this hierarchical situation to one where music-sharing websites, video channels, social media, and online artist profiles on the Web provide listeners with greater access to the world's music via both commercial and alternative channels. Our new musical media have three key characteristics that separate it from older formats: they are networked, multimedia, and processor-based. This enables us to write music in the form of code, opening up the potential for interactivity and non-linear music that might include visuals and tactile outputs via the screens, sensors, and motors of our player devices. For this reason, the Internet is not merely a different conduit for distributing and communicating about music: it presents a drastic change in terms of which media properties musicians have at their fingertips for composing, performing, and listening to new music.

The computational nature of processor-based media allows for interactivity, generativity, and greater awareness of space and time. Moreover, the Internet's technical communication protocols provide the condition for revolutionised practices in sharing and listening to sound and music. They allow for streaming audio from servers to clients in the forms of computers or mobile devices, and current peer-to-peer technology is so effective that the music we listen to might not even be streamed from a server, but "picked up" from existing packages already in transit on the net. Live music can now be streamed directly to people's mobile media devices (often referred to as "phones"), equally as video or audio only. Networked musical performance is being explored by musicians in distributed locations across the globe, where real-time collaboration is streamed to listeners in one or more locations. Composers and producers work on new music over the Internet via dedicated software packages, e.g, *Digital Musician* or *OhmStudio*, or online code repositories, such as Github. Listeners communicate, share, and collaborate via diverse online social media. Platforms now exist where listeners can contribute to the creative process of an artist in the studio, and artists are setting up channels for fans to take part in the

creative process. Crowdsourced music networks enable musicians to perform in warehouses or people's homes outside the traditional music industry settings (see, for example, Sofar Sounds – www.sofarsounds.com).

There is no shortage of accounts on now the Internet has altered the production, dissemination, and consumption of music (Leonhard 2008; Leurdijk & Nieuwenhuis 2012; Wikström & DeFillippi 2016). Whilst the music industry is still adapting to the transformed media landscape by experimenting with diverse competing business models, research and hacker labs across the globe are developing innovative techniques of musicking that reflect the qualities of our new media. The nature of this new technology is so open, flexible, and fast-changing, that when the music industry arrives at a comfortable business model, new musical practices will have appeared that threaten those very structures, requiring a further move, a chasing, and a reinvention of how to deal with the new developments. The changes discussed here differ from the media-technological evolution of the past, as the current transformations are not simply those of new distribution formats (for example, vinyl, cassette, CD, or MP3), but in what we define as being at the core of musical practice, bringing about a re-assessment of our notions of creator and listener. With the new processor-based and networked media, music itself is continually reinvented through critical experimentation and re-evaluation: a situation is emerging, where, in addition to musical content, style, and social context, musical creativity also involves a critical engagement in the way music is created, disseminated, and listened to.

This chapter responds to this transformation in media practices by asking: what do the unique qualities of the Internet offer sound artists, creative musicians, and researchers? What does it mean when listening devices are not simply readers of linear data, but processors that can calculate, respond to time, location, motion, emotion, activity, and general network/social network data? Composers are now faced with an abundance of new compositional parameters brought about by this new interconnected medium, for example the potential for non-linear and generative algorithms, multimedia content, spatiotemporal awareness, interactivity, and interagency. If former technological developments, such as the transition from mono to stereo playback formats, added important parameters to musical expression, we might argue that the affordances presented by current music technologies might transform music in an unprecedented scale. The musical context discussed in this chapter is, therefore, one where the function of being on networked and processor-based media is integral to the composition, dissemination, and listening of a specific type of new music.

Composing

As mentioned above, in the twentieth century our common sonic media have been reading machines of linear data: sound is represented as magnetic values on tape, transcribed as incised grooves on vinyl, or stored as numbers in digital file formats. The media players – such as the tape machine, the turntable, or the CD or MP3 player – faithfully reproduce this data as amplified electronic currents reaching the loudspeakers. These file formats maintain the linear nature of a much older tradition, that of musical notation. Music stored as instructions for human or machine playback in a linear format is so engrained in our thinking that it can take some effort, both for musicians and the industry, to begin thinking outside this paradigm and discover the new compositional strategies offered by contemporary technology.

In typical accounts on the origins and functionality of common Western musical notation, we find a file format, a standard, where composers write works with a varied degree of control, which defines how much space the interpreter has for creative expression. With musical

notation becoming increasingly determining (a word not necessarily to be seen as negative) in the twentieth century – to the degree that it began to stretch the technical capabilities of performers, as in the music of Xenakis, or even be physically impossible to perform, as in the work of Ferneyhough – experimental musicians, often working with musical machines in the form of tape recorders and computers, began to be interested in writing music in non-linear formats. Whilst live musical performance is never identical, and improvisation, or extemporisation, are important elements in any musical culture, it could be said that in Western classical music this element of difference became increasingly subjugated during the Romantic period, and not finding its way back until in mid-20th-century experimental music.

We must acknowledge, however, that on a closer look into the genealogy of musical notation we discover that the musical score is of a much more complex nature than typically portrayed: since its diverse origins in many geographical locations and historical periods, the contemporary musical score has potential for non-linear interpretation, user input, and contextual (or "site-specific") performance. Here, we find precedents in an artistic method often called "generative arts." This production method, and related ontological view of the art work, can be traced back to antiquity, or rather, the idea of creating rules, tools, structures, or machines that reproduce instances from a certain recipe can be found in human cultures of all times. Examples include Chinese wind chimes, Indian textile templates, Islamic tiling, or, say, the algorithmic rules in the *Musikalisches Würfelspiel* often attributed to Mozart.

Since the 1950s, composers have experimented with non-linear, open, generative, algorithmic, stochastic and aleatoric music (the terms are many) via alternative methods of writing, adding syntax or secondary notation, or otherwise augmenting the graphical symbols we have come to think of as musical notation. But what these approaches have in common is to engage the creativity of the performer and delegate parts of the musical composition to the instrumentalist, or even non-trained performers as we find in the example of Cornelius Cardew. Other composers, such as John Cage, embraced the incidental, the aleatoric, or the random as important elements in their music. In the words of Gerhard Eckel, from 1996, who sees the change in technology effectively affording the potential of a "new musical artefact":

> The traditional musical artefact is the score (that is a text) or the tape in the case of electronic music. Typical for the old musical artefact is that it represents music linearly in time, that is that the representation of music is organised along a time line. By new musical artefact I understand a representation of music which describes music in terms of a model, in terms of mechanism capable of generating the music (the meta-composition). Thus, the fundamental difference between old and new artefact is the absence of a linear text, implying the absence of the traditional.
>
> *(Eckel 1996)*

Henri Pousseur's work *Scambi* could illustrate and give context to where we will be heading now: in 1957, Pousseur spent time in Studio di fonologia musicale di Radio Milano and realised a piece of recorded synthesized sounds stored on short pieces of tape that were to be arranged by the performer of the piece. Pousseur wrote a musical score with careful instructions on how to arrange the tape loops according to specific generative rules. Interpreting the work meant arranging the tapes into one piece, a process that made its execution quite difficult and laborious. This example demonstrates how changes in thinking in the 1950s – also expressed in the post-structuralist theories of Barthes, Derrida, Eco, and Foucault – began to lay the foundations of the way we work with sound in an age of networked processor-based computers.

Graphic scores, verbal notation, poetic instructions, and other experimental formats, developed since the 1950s for writing music, are conceptual and technical predecessors to the generative or algorithmic approaches we find in new media. Twentieth-century experimental musicians critically questioned almost every convention of musical practice that had been established over the past centuries: how can music be ruptured in space and time? (Does the performance have to happen at one location? Can it take place in many sessions? Is there a need for the stage? How can sound be spatialised?). How can we rethink the link between the composer and the interpreter? (How might composers delegate their authority? How can the musical piece benefit from the unique experience of each performer?), how can we reconsider the relationship between the work and the audience? (What possibilities open up when music becomes interactive? What is the role of the listener in such music?).

This section has raised some of the questions composers posed when they were able to start thinking about their work in a non-linear way, embracing the novel qualities of the new media. There are no simple answers to the question of how we compose for media players that can sense movement, temperature, brightness, touch; that know the time of the day, the date, geographical location, GPS coordinates of work, home or school; that can parse big data from its user's social networks such as friends' behaviour, distance between people, key locations, and communication patterns; that can sense user patterns, daily routines, bodily activity, and in some cases biological data, such as heartbeat, temperature, food consumption, sleep cycles, etc. All this data can be applied as compositional parameters that define how the music is rendered when played. Like the context specificity of an Indian raga, which is played at specific periods in the year and at specific times in the day, our new music can adapt to how many times it has been listened to, what other music has been played previously, which friends have listened to it, when and where, and in what context. This is a music where rhythm might depend on temperature, the equalisation of the bass might change depending on the time of the day, and the lyrics adapting to the age of the listener, for example! The possibilities are infinite and, as will be further argued in this chapter, it is highly unlikely that any standards for composition, product descriptions, or strategies of evaluating these pieces of music will be established, as this technology will continually evolve, and continue to involve further our personal data, body, and life in general.

Performing

In his 1977 book *Noise: The Political Economy of Music*, Jacques Attali famously argued that music is always ahead of other cultural domains in adopting and adapting to new technologies and business models. Observing the development of music technologies, it is clear that whenever a new technological infrastructure appears at any level of society (with corresponding changes in equipment and production practices), a musician will apply this technology in musical composition or performance. In the context of this chapter on sound and music in networked media, it is relevant to mention that one of the earliest electronic musical instruments was indeed a networked instrument, the *Telharmonium*, which would transmit audio to people's homes via the wired telephone network. Invented by Thaddeus Cahill in 1896, the instrument was live on the wires in 1900–01 in Washington, D.C., but the instrument was later transported to New York, where concerts began in 1906 to subscribed users. The Telharmonium was initially successful, but technical and financial difficulties resulted in the service ending in 1908. As an initial excursion into music technology performance and dissemination, the Telharmonium was an important predecessor for ideas that were to manifest later in the 20th century.

By the late 1970s, technologies for electronic music had evolved so far that various composers began experimenting with composing interactive music. The performer could play his or her instrument, which would be connected to a computer. The computer could be programmed such that it "read" or "listened" to what the performer was doing and responded appropriately according to how the composer had programmed the computer. In this context, Joel Chadabe coined the term "interactive composing" in 1981 "to describe a performance process wherein a performer shares control of the music by interacting with a musical instrument" (Chadabe 1997: 293). Interactive music is a process where the performer reacts to a system, which in turn reacts to the performer. For Laurie Spiegel the potential for interactivity is a positive thing:

> This doesn't imply a dilution of musical quality. On the contrary, it frees us to go further and raises the base-level at which music making begins. It lets us focus more clearly on aesthetic content, on feeling and movement in sound, on the density or direction of experience, on sensuality, structure and shape – so that we can concentrate better on what each of us loves in music that lies beyond the low level of how to make notes, at which music making far too often bogs down.
>
> *(Spiegel 1986)*

For Spiegel, the listener at home would not only perform, but compose as well. Computer software can respond to something the performer does and this response creates a new action with the performer. In such a situation, the listener becomes a composer, a performer, an improviser, or an interactive listener. Indeed, the traditional musical terminology of a composer, performer, and listener – which can be contextualised with Shannon's (1948) information theoretical model of a transmitter, channel, and receiver (with unwanted noise always entering the channel) – proves to be insufficient and outdated in this new context. For this reason, new terms are being introduced, such as "comprovision," "interactor," "prosumer," and more, to reflect the new situation, and how new subjectivities form with changed technological infrastructure and methods. In 2000, Josephine Bosma addresses this new reality of collaborative composing, so elegantly predicted by Attali (1985) in 1977 in a stage he called "composing," by coining the word "musaic" in an essay for the new media festival Futuresonic:

> Musaic is like a tapestry, a mosaic, or an ocean of sound bites and samples ranked and ordered according to individual taste or choice. Musaic is the condition of music and sound once it is channeled [sic] through computer networks like the internet. Music is no longer a finished, static product that can be taken for granted. On the contrary, the listener becomes the producer of her or his own sound environment. The listener is also composer and musician; for want of a better term, a "musicianer".
>
> *(Bosma, 2000)*

This was written in the context of 1990s net art (or net.art – a distinction too complex to delve into here) which, in a modernist tradition of exploring formal qualities of media, focused on the conditions of the net as a platform for creation and communication, as expressed by Tilman Baumgaertel in an article written in 2002:

> Net art addresses its own medium; it deals with the specific conditions the Internet offers. It explores the possibilities that arise from its taking place within this electronic network and is therefore "Net specific." Net art plays with the protocols of the Internet, with its technical peculiarities. It puts known or undiscovered errors within the

> system to its own use. It deals creatively with software and with the rules software follows in order to work. It only has any meaning at all within its medium, the Internet.
> *(Baumgaertel 2002)*

In his 2005 article on Net music in the journal *Organised Sound*, Golo Föllmer surveys the field emerging in the previous decade of distributed online music. Framing the problematics of net music as those of space, time, and the machine, Föllmer presents a typology that includes categories such as remix lists, soundtoys, hypermusic, instruments, algorithmic installations, networked performances, and more. This classification served well and gave an accurate picture at the time, but is less relevant today, as the practical context is now more fluid, heterogeneous, and multimediated than we had a decade ago. With maturing hardware and software technologies – for example, HTML5 (with its just-in-time compilation, OpenGL rendering, and WebAudio API) and new virtual reality software development kits – we find that collaborative, distributed, multiuser, and intermedia approaches have enabled the production of work that is less focused on form or genre, equally involving elements from the arts, music, and performance. Indeed, what Föllmer points out, somewhat presciently, is the role of the user as a maker, something we find very strongly in contemporary maker cultures: "The greatest depth of interaction can take place when the complete musical environment, including sound material, compositional apparatus and interaction design, is open to be influenced or even constructed by the user, as is the case with authoring software" (Föllmer 2005: 191). Today, entering shops such as the Rough Trade record store in Shoreditch, one finds that, in addition to now selling books, coffee, and muffins, there is a considerable shelf space dedicated for maker technologies, such as the Arduino microchip computer, modular synth-building equipment, and necessary soldering implements.

Much has happened in the field of networked music since Föllmer's text. For Pedro Rebelo, a practitioner of networked music, the advent of network music marks a shift in the power structure of traditional performance, as the "fragmentary, fleeting and dynamic nature of networked relationships presents opportunities for conceiving of creative practice in a manner that does not rely on the centrality of the theatre company or the concert hall" (Rebelo, 2009, 388). As a result of this interest in networked music, we have seen the Networked Music Festival (http://networkmusicfestival.org), themed journal issues on networked music (for example, Contemporary Music Review in 2005 and 2009, and Organised Sound in 2005 and 2012), new protocols being applied in all major software packages such as the Open Sound Control (a UDP/IP and TCP/IP protocol that can send data over networks), and bespoke sound games appearing, many of whom are created as multiuser spaces for collaboration. In these musical environments the distinction between playing music and playing a game becomes blurry, as, for example, in the *Guitar Hero* game, the performance is both about playing and scoring points. We might be entering a period where the game studies concept of "gameplay" (Salen & Zimmerman 2004) will be a relevant criterion for musical compositions. The next section will provide a short contextual history – not an exhaustive one, but highlighting some important threads leading to the situation in which composers and music technologists now find themselves.

Listening

Above we have discussed how new computational telecommunication technologies afford new ways of composing and performing music. But how do we listen to this music? Where can we listen to it? What channels are there for listeners to engage with these new works? Questions such as these exemplify the problems involved in creating a channel, a form, a set of criteria for understanding this new form of music. Since there are no specific compositional conventions

or technological standards to adhere to, this has inevitably resulted in a rather chaotic picture of where to find and how to engage with such music. This confusing landscape can be illustrated by an excursion through the history of networked and computational music. The following description of experiments, projects, inventions, and artists points to instances that exemplify the potential of the new technologies. If the two sections above have explored the compositional and performative concerns that underpin this approach of thinking about music, the projects below can give an indication of the heterogeneous roles listeners have in these projects.

Networked digital computers provide a new context for musical creativity and it is appropriate to solidly base our tracing back with Elisha Gray's *Musical Telegraph* from 1874, Clément Ader's *Theatrophone* demonstrated in 1881 in Paris at the Exposition of Electricity, and Thaddeus Cahill's *Telharmonium* from 1896, already mentioned above. These technological inventions can be seen as predecessors of distributed music consumption that explored many of the concepts musicians are currently dealing with. Real-time performance over distance, subscription services, electronically generated sounds, and remote, yet live, musicians are all issues that are still being experimented with, and reinvigorated via online media.

In the history of electronic music we find multiple modular (networked/collaborative) approaches for ad-hoc assemblage building, where electric sound generating devices are connected together via diverse means. This was initially done through voltage control (VC) currents, where the output of one device might control some functionality of another device. When synthesizers began to be mass produced and popular amongst musicians of all styles (from baroque to contemporary to popular music), the need for a common protocol became pressing, and in 1983 we saw the birth of the MIDI protocol (Musical Instrument Digital Interface). With MIDI, machines played by one or more performers could be synchronised. However, although MIDI was necessary and solved certain problems of communication between commercial devices, it was seen by many as a reactionary and limited protocol that focused too much on the established Western tonality and musical theory, at the cost of experimental approaches in contemporary music, as well as world musics. Although useful, MIDI eclipsed the development of more experimental work taking place using the digital computer. An example worth mentioning is the League of Automated Composers, a group founded in the late 1970s at Mills College, California. Consisting of John Bischoff, Jim Horton, and Rich Gold, this collective developed a system of networked KIM-1 microcomputers that enabled improvised performances that explored human-machine, as well as human-machine-human interactivity, by means of a computer network. Tim Perkis became a member of the group, which soon after morphed into another ensemble, The Hub, later joined by Chris Brown, Scot Gresham-Lancaster, Mark Trayle, and Phil Stone. The Hub would write software for their personal computers, which would communicate according to custom protocols. Based in the bay area, these composers were instrumental in organising events featuring experimental networked music, represented for example by the 1986 festival "THE NETWORK MUSE – Automatic Music Band Festival" with a primary focus on networked music (Brown & Bischoff 2002).

In the 1980s, performers started looking into the use of satellite technologies for interconnected performances across distant locations. In 1985, Godfried-Willem Raes (Ghent), Charlie Morrow (New York), and Phil Dadson (New Zealand) worked on a performance called *International Solstice Radio Satellite Project*, which was an interactive multicast broadcast supported by the Flemish National Public Radio. Another example, from 1994, is a collaboration between video artist Steina Vasulka, Morton Subotnick, and David Rosenboom, where they explored satellite tele-performance between three locations (Santa Monica, New York, and Santa Fe) in an event they called "TeleConcert." The Vasulkas also worked with artist and theoretician Don Foresta using the MARCEL network for networked high bandwidth artistic performances in the 1990s and 2000s. In 1997, musician Sergi Jordà developed the *Faust Music Online* system for the Catalan

theatre and performance group La Fura dels Baus. The software was written for the Windows 95 operating system, and when installed, the user could contribute to a real-time soundtrack used in the performances of the Faust show, as well as listen to and build upon existing works. Jordà mentions that such user collaboration is effectively a musical "exquisite corpse," referencing the famous Surrealist game of illustration. The Faust Music Online software ran online for many years and inspired a generation of computer musicians to think of a musical instrument, and indeed a musical piece, as something that can exist online, be performed by amateurs as well as professional composers, and collaborated on, shared. and stored. Another example is the use of the Internet in sound installations: in 2000, Atau Tanaka and Kasper Toeplitz created a piece called *Global String*, a multi-site network music installation, connected via the Internet. The string was a thick physical wire (12 millimetres in width and 15 metres in length), that could be plucked, but the resonating body of the instrument was the telecommunication network itself, consisting of small TCP/IP packages and the inbuilt latency of the network. The wire connected to other wires elsewhere in the world and the sound from the installation was the collected resonance of the wires, modulated by the latency of the Internet.

An important event for online and networked music is the development of the Open Sound Control (OSC) protocol. This UDP/IP and TCP/IP 32-bit protocol offers a drastic speed increase compared with MIDI, as well as higher numerical resolution. (The 8-bit MIDI protocol would for example only offer 127 note or velocity values, often considered crude by trained performers.) The intention behind the protocol was to establish a communication channel between computers, between different software applications, between software and hardware. The OSC protocol was implemented in diverse experimental software in the early 2000s (see Wright 2005), but has now become a standard in many commercial software packages. Much of the networked musical work today, where control information or code is exchanged, uses this protocol. For example, during the recent Network Music Festivals, performances have been given with performers situated in diverse locations across the globe, as we find with the system used by the group Glitchlich, which uses custom-built networked software that fuses the idea of a musical piece and a networked instrument, or co-located as exemplified by the live coding ensemble Benoit and the Mandelbrots, where the four members of the band sit on stage with connected laptops and live code an audiovisual performance (Magnusson 2014).

With the technological infrastructure opening up avenues for artistic exploration involving the Internet as a medium for composition – not merely dissemination – the possibilities are immense. A good example might be John Eacott's work *Floodtide* (www.floodtide.eu), which uses information from tidal patterns in rivers, or the sea, and translates those in real-time into musical scores that are played by an orchestra in a particular performance location (for example at the Lighthouse by the Thames), and by people at home who can interpret the scores live using their instruments. Similarly, Andrew Hugill's work on the digital opera, the *Imaginary Voyage* series (www.theimaginaryvoyage.com), remediates the traditional opera in an online Web context. Composer Craig Vear has also worked on digital opera, called *A Sentimental Journey*, which was composed for networked laptops and musicians responding to generative visual scores (Vear 2016). There were two audiences for the piece: one "out there" on the Internet, and another "in here" in the same theatre space as the music performance. Reflecting on his piece, Vear says,

> Surprisingly, the general audience experience was one of unification, and as such, the audience (remote and local); the musicians, their music and their voices; the audio material and computer performers; and the idea of the book, memory and imagination existed in another (liminal) space.
>
> *(Sheil & Vear 2012)*

Computer games are, in many ways, an ideal environment for generative and interactive audiovisual media composition. Immersed as 1st or 3rd person avatars in 3D worlds, or operating with signs and animations in 2D worlds, the player can interact with the music, or "play" the music, indeed erasing any conventional distinction between playing a game and playing music. Japanese multimedia artist Toshio Iwai pioneered this field with work such as the *Otocky* game from 1987, via diverse audiovisual music systems, such as SimTunes in 1996, culminating in his *Electroplankton* in 2005. With games such as *Rez* or *Vib Ribbon* in the early 2000s, creators began exploring the role of sound as a functional element in the gameplay, as opposed to mere ornamentation. In Rez, for example, the player flies through a 3D visualisation of a computer network – a visual imagery often attributed to William Gibson's highly visual descriptions of cyberspace in his book *Neuromancer* – attacking viruses and other malevolent objects. The sound track changes dynamically depending upon the player's performance of the game. The gameplay consists of collecting targets that can be locked and then terminated by releasing the "lock-on" button, on a controller that gives haptic feedback to game events. The music is fast and rhythmic, seamlessly representing the events in the game, producing sets of quantised highlight notes and sound effects as part of the play mechanism. Vib Ribbon, on the other hand, enabled the user to load in their own music and the terrain in each level of the game would be generated from the musical events. This was done through a spectral, amplitude, and onset analysis of the music's sonic content. *Audiosurf* is a similar game that takes this idea to the third dimension. A dedicated research into audiovisual gameplay has been conducted by Nullpointer, whose games *AVSeq*, *In Ruins*, and *Permutation Racer* are practical research projects into generative audiovisual artforms (see www.nullpointer.co.uk). Other recent games, such as *Proteus*, *Panoramical*, or *Thumper,* make use of sound as an essential gameplay element and like Vib Ribbon, the sound and music has been composed specifically with the knowledge that the sound track will be constructed through the play. The generative nature of these games have demonstrably set their composers a challenge which they have risen to.

Since its inception, musicians have explored the potential of the Second Life virtual online world for real-time streamed global performances (Gagen & Cook 2016). There are diverse ways this can be done, but a popular mode is to perform as an avatar, streaming the music directly from the studio to an audience spread around the globe (www.youtube.com/watch?v=GnQlWNItxns). This is all happening in a virtual world, at a particular location inside the game. Although cruder in its appearance, a more modern and popular online world is Minecraft, where people can build houses, villages, and cities using blocks of different material types. Certain elements in Minecraft can be used to program, such as Redstone and Command blocks, and people have created complex musical sequencers, as if the user is inside a machine that generates the music. In Minecraft there are Mods that allow for streaming audio, others that offer environmentally sensitive music that changes as you navigate the world. With virtual reality headsets, such as HTC Vive and Oculus Rift, we now find games built in immersive 3D worlds where the user can build modular synths, navigate spaces, and generally be immersed in the music-making process via avatars that might even be motion-tracked people. This offers new channels for musical education, as distance learning might easily take place in these environments. Here, issues of embodiment, latency, distance, spatial arrangement, 1st vs. 3rd person perspectives, etc., become interesting research topics, as we get ready for playing, studying, and generally communicating in the virtual worlds.

The mobile phone app is also an excellent platform for interactive musical works, since, via the phone's sensors and social networks, the composer can retrieve data about users or their friends, but also allow users easily to share their work. Smule is a pioneering company that has created instruments, such as the *Ocarina* (Wang 2014), rap-making software, such as the *Autorap*,

and other audio games. *Papa Sangre* took the audio game literally and got rid of all visual elements, so the game is sound-only. Locative media projects making use of geotracking have been created for "sound walk" projects where the listener walks around the city (or other spaces) and mixes the music. Projects such as *NoTours* (www.notours.org) or *UrbanRemix* (http://urbanremix.gatech.edu) enable composers to compose "in space," where the listener will receive different sounds depending on their navigation in a city or natural landscape. The majority of research into the interactive and collaborative platform of the musical app has been done in academic labs or hacklabs around the world, but there are pioneering artists who are picking up on developments, such as Brian Eno – a long-term advocate of generative music – with his *Bloom* app that allows the listener to perform the music, or Björk's *Biophilia* app that opens up the guts of the music and invites the listener onto an explorative journey.

The recent Web Audio API is a standard proposed by key actors in the media computing industry (Google, Mozilla, the BBC, etc.) with the aim of making an audio content platform that is supported by all browsers on all operating systems on all computers. This would solve many of the technical problems that game creators are constantly effaced with. This standard is new, but there is already an academic conference (WAC – Web Audio Conference) and diverse user groups for works created using it. (See for example https://musiclab.chromeexperiments.com.) At IRCAM in Paris, Norbert Schnell leads a project called *CoSiMa* (http://cosima.ircam.fr) which sets out to create a platform that can be used by composers and musicians to compose bespoke pieces of music for interactive co-locative performances (Schnell et al. 2015). In some of their early pieces – for example, *Chloé X Ircam, Terminal, and CollectiveLoops* – they invite people to pick up their mobile devices (phones, tablets, laptops) and log onto a Web page, which becomes people's instrument and notational score at the same time. The audience is then able to perform using the loudspeakers on their device, which at times has resulted in a multichannel audio piece of 1,000 distributed speakers.

Conclusion

By inspecting the diversity of possible approaches when thinking about sound on the Internet, it becomes clear that the myriad of new communication technologies has altered our conception of what a musical product is, how it is disseminated, and what our role as listeners is, thus challenging established business models and cultural critique. The Internet is clearly more than a mere conduit for music, it is a platform for computational systems to interact across space and time; where data can be exchanged, retrieved, and generated, affecting other nodes in the global network of musical apps, systems, and software. The Internet presents tools, methods, ideas, and ideologies that become part of the materials we use in musical composition and performance. With the practically infinite compositional affordances brought by the new media, it is unlikely that we will see an established standard for interactive, generative, networked compositions, but rather witness a mentality of innovation that explores which musical parameters have appeared for new musical thinking. And as we saw in this chapter, this is old news: musicians have always embraced new technology in their work and this will not change. Therefore, it is not simply the technical standards that will be fluid and reject concretisation, but also the social engagement with this new work: how it is marketed, disseminated, listened to, and discussed. Indeed, musicologists reviewing such work might need to have an understanding, if not practical knowledge, in computer programming, since a large part of the work is notated in code.

This chapter also discussed the liveness of notated processor-based music. Music has always been about difference, context, location, time – it has never been possible, even desirable, for a musical piece to be played exactly the same way, except for a very short period – a mere century!

– marked by the advent of sound recording. The signs are that with current developments, music will be moving into more adaptive media environments, with apps, games, and virtual reality becoming prominent musical platforms, both for live and composed music (which includes notated, recorded, and programmed music). As we have explored, one of the issues (not wanting to see it as a "problem") with the way new music is created for processor-based networked media, is that there are no software protocols, no hardware standards, no ideological, or aesthetic views on what an interactive and networked piece of music might be. Although this might be seen as a problem, perhaps in terms of reviewing or marketing, it can also be considered positive and exciting, since this diversity and lack of conventions becomes a condition of much invention and innovation. The chaotic picture is not merely due to heterogeneous aesthetics or lack of unified art forms, but can also be explained by the problems posed by how differently hardware manufacturers support software protocols, the variance between the three main operating systems (Linux, OSX, and Windows), different browser implementations of mark-up languages, non-conformity in security management, myriad of hardware protocols, persistent software updates, and so on.

This piece was written in 2016. After two decades of faulty and nauseating virtual reality headsets, we are now seeing products on the market that will drastically change the way we think about cultural productions and education. For composers, performers, and educators of music, this new addition to the media landscape is as drastic as the advent of the Web in the 1990s, and it is certain that musical practices are about to change in novel ways. When our musical media afford composition and performance that can be visual, spatial, locative, interactive, collaborative, tactile, evolving over time, etc., we enter a period in musical evolution where the distinction of playing music and playing a game becomes complex, where music becomes more than a linear sound-only file format, but becomes multisensory, interactive, and, undeniably, a phenomenon that rejects definitions.

References

Attali, Jacques. 1985. *Noise: The Political Economy of Music*. Minneapolis: University of Minnesota Press.

Baumgaertel, Tilman. 2002. *net.art 2.0. – Neue Materialien zur Netzkunst/New Materials towards Net Art*. Niirnberg: Institut fiir moderne Kunst, p. 24.

Brown, Chris & Bischoff, John. 2002. *INDIGENOUS TO THE NET: Early Network Music Bands in the San Francisco Bay Area* http://crossfade.walkerart.org/brownbischoff/IndigenoustotheNetPrint.html [accessed November 2016].

Bosma, Josephine. 2000. *Musaic, the Merging of All Sound Spaces* www.josephinebosma.com/web/node/77 [accessed November 2016].

Chadabe, Joel. 1997. *Electric Sound: The Past and Promise of Electronic Music*. New Jersey: Prentice Hall.

Eckel, G. 1996. "Camera Musica: Virtual Architecture as Medium for the Exploration of Music," in *Proceedings of the 1996 International Computer Music Conference*, International Computer Music Association, San Francisco.

Föllmer, G. 2005. "Electronic, aesthetic and social factors in net music," in *Organised Sound*, vol 10(3): 185–192.

Gagen, Justin & Cook, Nicholas. 2016. "Performing Live in Second Life," in (eds.) Whiteley, Sheila & Rambarran, Shara. *The Oxford Handbook of Music and Virtuality*. Oxford: Oxford University Press.

Leurdijk, Andra & Nieuwenhuis, Ottilie. 2012. *Statistical, Ecosystems and Competitiveness Analysis of the Media and Content Industries: The Music Industry*. Luxembourg: Publications Office of the European Union http://ftp.jrc.es/EURdoc/JRC69816.pdf [accessed November 2016].

Leonhard, Gerd. 2008. *Music 2.0* www.futuristgerd.com/2012/01/11/get-the-pdf-of-my-music-20-book-for-just-pay-with-a-tweet-or-facebook-post/ [accessed November 2016].

Magnusson, Thor. 2014. "Herding cats: Observing live coders in the wild," in *Computer Music Journal*, vol 38(1): 8–16.

Rebelo, Pedro. 2009. "Dramaturgy in the network," in *Contemporary Music Review*, vol 28(4–5): 387–393.

Salen, Katie & Zimmerman, Eric. 2004. *Rules of Play: Game Design Fundamentals*. Cambridge, Massachusetts: The MIT Press.

Schnell, Norbert, Robaszkiewicz, Sébastien, Bevilacqua, Frederic, and Schwarz, Diemo. 2015. "Collective Sound Checks – Exploring Intertwined Sonic and Social Affordances of Mobile Web Applications," in *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction*, New York, pp. 685–690.

Shannon, Claude E. 1948. "A mathematical theory of communication," in *Bell System Technical Journal*, vol 27 (3): 379–423.

Sheil, Áine & Vear, Craig. 2012. "Editorial," in *International Journal of Performance Arts and Digital Media*, vol 8(1): 3–9.

Small, Christopher. 1998. *Musicking: The Meanings of Performing and Listening*. Hanover: University Press of New England, p. 8.

Spiegel, Laurie. 1986. *Music MouseTM – An Intelligent Instrument* http://tamw.atari-users.net/Atari_Music_Mouse_Manual.pdf [accessed November 2016].

Vear, Craig. 2016. "Gesamtkomposition and the digital opera: A sentimental journey," in *International Journal of Performance Arts and Digital Media* vol 12(1): 61–81.

Wang, Ge. 2014. "Ocarina: designing the iPhone's magic flute," in *Computer Music Journal*, vol 38(2): 8–21.

Wikström, Patrik & DeFillippi, Robert (eds.) 2016. *Business Innovation and Disruption in the Music Industry*. Cheltenham: Edward Elgar Publishing.

Wright, Matthew. 2005. "Open Sound Control: an enabling technology for musical networking," in *Organised Sound*, vol 10(3): 193–200.