

Examining the Effects of Experimental/Academic Electroacoustic and Popular Electronic Musics on the Evolution and Development of Human-Computer Interaction in Music

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Abstract

This article focuses on how the development of human-computer interaction in music has been aided and influenced by both experimental/academic electroacoustic art music and popular electronic music. These two genres have impacted upon this ever-changing process of evolution in different ways, but have together been paramount to the establishment of interactivity in music as we understand it today; which is itself having wide-ranging implications upon the modern-day musical landscape as a whole - both in the way that we, as listeners and audience members, purchase and consume music as well as conceptualise and think about it.

Keywords: Human-Computer Interaction; Interactive Computer Music System; Brain-Computer Interfacing; User-Interface; Graphical User Interface; Digital Audio Workstation

Introductory Notes

The concept of interactivity has its roots in post-structuralist theory and the open interpretation of art and literature (cf. Barthes, 1991; Eco, 1989; Storey, 1997). When applied within a musical context, it could be used to describe anything ranging from free improvisation in jazz, and individual interpretations of the score in the performance of orchestral works, to the touchscreen-based interactive music applications and games for Android and iOS devices which are so prevalent today. In order to maintain the focus of this article, the wider scope of the concept of interactivity with regards to music will not be addressed, and the article will instead deal directly with the recent history and development of interactivity in music using electronics.

Early and Experimental Interactive Works and Systems

Experimental/academic electroacoustic music is, for the most part, responsible for laying the foundations upon which human-computer interaction (HCI) in music has been built. Long before the emergence of interactive computer music systems (ICMS) in popular electronic music culture, the potentialities of HCI within music were being explored by pioneering individuals such as Michel Waisvisz. *The Hands* (Waisvisz, 2006; Waisvisz et al., 1984-2006) was a sensory-based interactive system responsive to non-musical gestures transmitted via wearable controllers

attached to the fingers and hands of the user, and thus showcased a loose basis for the design of ICMSs to be used by non-expert musicians. Laetitia Sonami's Lady's Glove (Sonami, n.d.; Sonami, DeMarinis, & Bongers, 1991-2001), which was developed and manufactured in conjunction with Bert Bongers in its 4th and 5th generations, is conceptually similar to The Hands - utilising hand/wrist-mounted controllers to capture gestural, non-musical input data used to influence the musical output of the system - yet in some ways is more refined in terms of operational simplicity and efficiency; especially in the later incarnations, the designs of which were subject to the added influence of Bongers. Despite the dependence of these systems upon nonmusical control-gestures, which have been inherent in the evolution of ICMSs aimed at non-expert users (as evidenced by many more modern examples such as Incredibox (So Far So Good, 2011-present), NodeBeat (Sandler, Windle, & Muller, 2011-present) and PolyFauna (Yorke, Godrich, & Donwood, 2014 - all of which will be discussed later on), it can be assumed that the fluid and efficient operation of both of these devices would be subject to a relatively steep learning curve, due to the fact they were both designed to be used in performance only by their respective creators. The work and performances of electronic ensemble HyperSense Complex (Burton, 2003; Langley, n.d.; Riddell, 2005, n.d.; Riddell, Langley, & Burton, 2002-2005) also exemplify sensory/gestural musical interaction for trained/professional performers and musicians utilising wearable motion-sensor controllers.

Another electronic ensemble, The Hub (Bischoff et al., 1987-present; Brown, n.d.; Early Computer Network Ensembles, n.d.) is responsible for advancing the field of 'Computer Network Music' - a genre of electronic/electroacoustic music which explores the potentialities of enabling multiple performers to collaborate and interact with each other in improvisational composition and performance through a shared, connective ICMS via individual user interfaces or instruments. In this instance, The HUB itself acts as the central computer juncture through which each of the participating members can connect via a wired local network. Global String (Plohman, 2000; Tanaka, n.d.; Tanaka & Toeplitz, 1998-2001) is another example of an ICMS representative of Computer Network Music. In contrast to The HUB, however, the system was designed not for use by a specific ensemble of musicians involved in its development, but as a gallery installation for public use. In developing Global String, Tanaka and Toeplitz expanded upon the ideas established by The Hub through the use of the internet as the central juncture through which a potentially infinite number of remote users could interact with the users in the installation performance-space. The installation consisted of a physical string connected to a virtual string network, which would transfer analogue pulses of the real string, measured by vibration sensors and converted to digital data to any users actively connected to the virtual string network. The responses of these users, performed on the virtual string, would provide audible and visual feedback directly to the physical performance space. The concept of Computer Network Music is still relevant today although, as in the examples provided, it is far more common within the context of experimental electroacoustic

sound-art/audiovisual gallery installations and performances than it is within popular electronic music ICMS design.

Further examples of interactive sound-art installations designed for public gallery spaces include 'Gestation' by Paine (1999-2001, 2013) and 'Bystander' by Gibson and Richards (2004-2006, n.d.) - part of the larger project 'Life after wartime'. Both 'Gestation' and 'Bystander' interpret and respond accordingly to the number and movements of individuals within a multichannel installation environment; however, 'Bystander' incorporates the use of an additional parameter by responding dynamically to the collective attentiveness of the audience. By collecting this data and applying it as an influential factor in the generation and evolution of the audiovisual output from the system, the audience can systematically learn, during the process of experiencing and interacting with the system, how to impart a certain level of control over the resulting output.

The central premise of Bystander is that the more quiet and attentive the audience, the more aesthetically coherent and semantically divulgent the 'world'. Ideally visitors can gain the 'trust' of the space and perform a dance of intimacy with the 'world' and its complex narrative matrix. (Gibson & Richards, n.d., p. 1)

Although both systems allow for the generation of musical output without assuming or requiring any prior knowledge of the operational protocols on behalf of the participants, they offer little or no direct and precise control over the subsequent soundscape to any one individual within the collective group, whose movement through the various sections of the installation space over time is expressed in the composition generated by the algorithms encoded into the system architecture. When coupling this with the lack of feedback provided to the audience defining to some extent how the musical output of the system is influenced by the input data - especially in Gestation - it could be construed that both systems are more randomly reactive than interactive. This is also true of the La Maison Sensible system, or The Sensitive House (Emory, 2015; Lasserre & met den Ancxt, 2015; Lasserre, met den Ancxt, Ajima, & Nagemi, 2015), which is another, more modern audiovisual gallery installation - although it is instead designed to respond to the physical interactions between the audience/users and the walls/objects within the performance environment. Again, the design of such systems is heavily influenced by the stylistic/aesthetic traits of experimental/academic electroacoustic music, as their functionality is largely geared towards generating arrhythmic, at times chaotic musical results and soundscapes inherent to the genre; as opposed to the more rigidly structured form/style typical of popular electronic music.

This trend is exemplary of the majority of ICMS installations designed for non-expert public use. The design and functionality of Stepsequencer (Stepsequencer, n.d.; synthhead, 2014a; Timpernagel et al., 2013-2014) by schnellebuntebilder, however, stands in contrast to this observation. An audiovisual installation designed to be controlled simultaneously by a small

number of participants via both physical and digitally projected control-objects located on the floor of the performance space, in a manner reminiscent of the classic arcade game Dance dance revolution, or Dancing stage (DDR, n.d.; Konami, 1998-present), Stepsequencer affords precise control to the users over specific aspects of the musical output, and generates popular electronic/dance music in response to their actions. 1000 Hands by Universal Everything (Kaganskiy, 2013; Pyke et al., 2013; Tucker, 2014) is another multichannel interactive gallery installation, the musical output of which is somewhat inspired by popular electronic music, although its primary focus is on generating visual responses to the interactions of the audience as opposed to audible ones. Interfacing with the system requires audience members to use their own touchscreen devices in order to draw images and shapes which are then transmitted to and shown on the display of the installation. This reliance upon screen-based interfacing as the mode-of-interaction with the system is something which is paramount to the design of the vast majority of ICMSs inspired by popular electronic music, most of which exist as apps and games to be controlled via either handheld touchscreen devices or non-touch-sensitive, web-browser-based graphical user interfaces (GUIs).

There are numerous other approaches to ICMS design that have contributed greatly to the development of HCI in music throughout its history but have become less common in recent years; likely due to the increasing influence of popular electronic music upon the area. Inter-Harmonium (Miranda, n.d.a; Miranda & Brouse, 2005a), BCMI-Piano (Miranda, n.d.b; Miranda & Brouse, 2005a, 2005b) and Eunoia (Chow, 2013; Park, 2013; Park, n.d.; synthhead, 2014b) are all exemplary of brain-computer interfacing systems and are reliant upon a technique known as Electroencephalography, or EEG, which is used to measure brain-patterns as voltage fluctuations by attaching sensors to the scalp.

EEG is a difficult signal to handle because it is filtered by the meninges, the skull and the scalp before it reaches the electrodes. Furthermore, the signals arriving at the electrodes are sums of signals arising from many possible sources, including artefacts like the heartbeat, muscle contractions and eye blinks. (Miranda & Brouse, 2005b, p. 2)

As a result, the data collected by the EEG can only be used to modify the sound generated by these systems in a very general and flexible way; and it is because of this that the technique is best applied to experimental electroacoustic systems and very rarely adopted by those which aim to enable users to interact with the system and/or other users through the system in the collaborative, improvisatory composition and performance of popular electronic music.

Additionally, pieces such as 'Maritime' by Rowe (1992, 1999; Drummond, 2009), 'Voyager' by Lewis (1993, 2000; Drummond, 2009), 'Music for Clarinet and ISPW' by Lippe (1992, 1993) and

'Pluton' by Manoury (1988; Puckette & Lippe, 1992) are examples of score-driven ICMSs, or 'score-followers'. These type of systems are responsive solely to musical input from acoustic instruments and are often specifically created for the performance of a particular composition. For a modern-day interactive system to be designed in this way is very uncommon as most are tailored towards facilitating the composition and performance of electronic music (popular or experimental) in fun, exciting and unique ways that are able to captivate the creativity and imagination of both novices and experts alike. In a similar vein, and one which epitomises the changing approach to ICMS design over time from systems intended for use in performance only by their designers (such as The Hands [1984-2006] and Lady's Glove [1991-2001]) as well as 'score-followers' (such as those described above), both of which require from the user a level of expertise in interacting with the system and/or instrumental proficiency, to those which we regularly encounter today as installations, apps and games aimed at both novices and more experienced users alike, the HyperInstruments project (Hyperinstruments, n.d.; Machover, 1986-present) originally focused on the expansion of traditional acoustic instruments to allow for an extension of range in performance techniques and possibilities for professional musicians but has, since 1992, devoted much of its attention to the development of sophisticated interactive music systems for non-expert musicians such as Drum-Boy (Machover, n.d.a) and Joystick Music (Machover, n.d.b).

Web and Touchscreen-Based Interactive Music Apps and Games

The shift in focus of ICMS developers to designing systems which accommodate novice-level users and musicians, along with increasing internet speeds and, in particular, the ever-growing presence of touchscreen devices such as smartphones and tablets have, together, paved the way laid out by the above systems for the expansion of musical interaction into mainstream popular culture from the relatively niche area of experimental/academic art and research. NodeBeat (Sandler et al., 2011-present), Kinetic (humbleTUNE, 2011-present) and Bloom (Eno & Chilvers, 2008) are all relatively similar ICMS apps for Android/iOS devices designed around gravity mechanics/ physics modelling and generative algorithms to create audible results which are stylistically ambient, and which blur the boundaries between popular and experimental electronic musics. Both NodeBeat and Kinetic are fundamentally dependant upon the principle of motion, with the former generating musical output from the interactions between moving 'nodes' and 'generators', which float around the display and form temporary connections when coming within close proximity of one another, and the latter generating sound as a result of node/ball-like objects impacting and bouncing off the four sides of the screen. In NodeBeat, the user is able to influence the generation of musical output in a number of ways, including: key signature/scale and lowest octave, oscillator wave-shape and ADSR envelope shape, reverb/delay level; the number and variable velocity and connection-proximity of nodes/generators as well as disabling movement

altogether for either nodes and/or generators and enabling 'gravity' which uses the accelerometer within the smartphone or tablet to manually influence the directional movement of the nodes/generators; tempo and quantisation value. The background of the display is also playable as a key-locked keyboard. Kinetic offers a similar but less in-depth level of control, while the GUI background of Bloom is also playable as a keyboard, but the generation of musical output is subject entirely to evolutionary algorithms. The simple mode-of-interaction, engaging GUI/animations and musical constraints of these systems are attributes which lend themselves well to supporting intuitive interaction for non-expert users, as well as the generation of musically coherent results which should appeal to the same demographic. The drawback, however, of imposing these limitations is that this type of system can struggle to captivate more experienced users/musicians beyond the point of initial intrigue.

Two web-based ICMSs, which are also aimed at novice musicians but are more directly influenced by popular electronic music due to their reliance on sample/loop playback as opposed to algorithmic generation, are Incredibox (So Far So Good, 2011-present) and Patatap (Brandel, 2012-present; Brandel, 2015); while this influence is also evident in that the generated musical output is much more akin to dance music than the ambient music of NodeBeat, Kinetic and Bloom. At the time of writing, Incredibox exists in four iterations comprised of different, loop-based material, but the user interacts with all of them in exactly the same way: by choosing between multiple cartoon characters - each of which has assigned to it a particular loop - in order to create a lineup of characters who appear to 'sing' the instrumental sounds/effects and lyrics of the arrangement as it plays. Patatap, on the other hand, requires users to trigger short samples - different banks of which can be accessed by pressing the spacebar - using their computer keyboard.

Finally in this category, there are a large number of interactive music games available for iOS/Android touchscreen devices which draw influence from the classic Xbox game series which includes titles such as Guitar Hero (Harmonix, Neversoft, Budcat Creations, Vicarious Visions, & FreeStyleGames, 2005-present), Rock Band (Harmonix & MTV Games, 2007-present) and DJ Hero (FreeStyleGames & Exient Entertainment, 2009). Specifically, Cytus (Rayark Inc., 2012-present) and Dynamix (C4Cat Entertainment, 2014-present) are almost carbon-copies of these games, despite the musical content being far more electronically/dance-oriented; Deemo (Rayark Inc., 2013-present), Beat Beat Volcaloid (Kestrel Games Studio, 2013-present) and Full of Music (Handicrafter, n.d.-present) all also operate in the same manner, although the first two bring a story-based structure to the format and the latter allows users to play along to their own music collection. The global appeal of these games over the past decade demonstrates more clearly than anything else the potential within mainstream popular music culture on the whole for HCI in music to thrive.

Music-Creation Apps/Virtual Instruments

The increased prevalence in recent years of touchscreen technology in everyday life has, of course, also contributed to a sharp rise in the development of applications to be used in tandem with, or even to take the place of, professional audio software and outboard gear such as digital-audio workstations (DAWs), hardware synthesisers and Musical Instrument Digital Interface (MIDI) controllers as an integral part of the composition, production and performance of electronic music. The most prominent of these is Reactable Mobile (Jordà, Kaltenbrunner, Geiger, & Alonso, 2003-present). First conceived as a touchscreen-based tabletop hardware instrument before being developed as an application for Android and iOS devices, the Reactable systems are better defined as digital modular synthesisers than ICMSs due to a lack of two-way communication functionality between the user and computer. Because of this, Reactable and Reactable Mobile are primarily aimed at experienced electronic musicians and, as a result, the ability to interact with the system to the full extent of its possibilities is subject to one's knowledge and experience-level in relation to the GUI, which requires users to form connections between different objects or 'crystals' - each with a specific function (oscillator, filter, sequencer, etc.) - in order to generate sound. This is, however, something which Reactable have recently moved to address through the introduction of a new table-top hardware instrument, the Reactable Experience, developed for implementation in museum and gallery installations as well as other public spaces such as hotel lobbies, etc. (The New Reactable Experience, n.d.).

Similarly, Audulus (Holliday, 2011-present; Subatomic Software Audulus, 2014) and Jasuto (Wolfe, 2008-present) are both music-creation applications that do not incorporate the use of any two-way communicative capabilities between user and computer. Like Reactable, they are both modular in their design; allowing users to connect different sound-source/effect objects, etc. together to create virtual instruments and the like. Jasuto is focused entirely on synthesis, while Audulus offers greater potential for experimentation with not only sound-design but also control of external instruments, MIDI devices, etc. and is more like a stripped-down, simplified version of the modular programming environments Max/MSP (Puckette, 1988-present) and Pure Data (Puckette, 1996-present). Both of these systems aim to provide intermediate-level electronic musicians with an introductory route into the areas of modular sound-design and visual programming, respectively - in particular Audulus, which allows for novice programmers with little or no experience to explore the creative potentialities of working within a modular programming environment and to incorporate this into their music-making process without the need to undergo the extensive learning-curve required to gain a relative level of knowledge and proficiency with regards to the visual programming languages used in Max/MSP and Pure Data.

Like those discussed above, there exists a multitude of music-creation apps and games designed for handheld consoles and Android/iOS devices with more experienced electronic

musicians in mind. Although this is the target demographic, and the majority of these apps are not so much 'interactive', they all promote music-making for non-experts in some capacity. Be it through their design and intended functionality or their market-placement in terms of price-range when compared to that of professional audio hardware and software, as well as only requiring the use of technology most novice musicians will already possess (as opposed to potentially expensive, specialised computer equipment) - a smartphone or tablet - applications like these make taking the first steps as an electronic musician accessible to anyone. KORG's DS-10 (Sano & Mitsuda, 2008), DSN-12 (KORG Inc., 2014; synthhead, 2014c) and M01D (KORG Inc., 2013) for Nintendo DS/3DS, iMS-20 (KORG Inc., 2010-present), iM1 (KORG Inc., 2015; Rogerson, 2015; synthhead, 2015) and iElectribe (Korg iElectribe, 2010; KORG Inc., 2010) for iOS, and Arturia's iProphet (2014; Arturia iProphet, 2014; synthhead, 2014d) are all fully functional virtual-analogue/digital emulations of their classic hardware counterparts. An abundance of traditional analogue/digital synthesisers from small, independent developers such as Heat Synthesizer (Schneider, 2013-present) and FM Synthesizer/SynprezFM II (Desprez, n.d.-present) for Android are also available; as are many more experimental/ forward-thinking synthesisers, which aim to take advantage of the potentialities afforded through interfacing with the instrument via a touchscreen, like Arpio (Randon, 2014-present), Ether Surface (Batchelor, 2014), Ethereal Dialpad (Smith, 2011) and Photophore (Dika, 2014-present; synthhead, 2014e), also for Android and iOS. Additionally, Novation have released a free-to-download iOS version of their Launchpad MIDI controller (2009), Novation Launchpad (Focusrite Audio, 2013), while plenty of third-party developers have released their own imitations of the hardware/software, such as Launch Buttons (Nowak, 2015) for Android. Even more developers, however, have exploited the advantages software holds over hardware in order to improve upon the original concept of the hardware button-matrix MIDI controller by allowing for users to create entirely unique and fully customisable control-surface layouts from scratch. Such applications include TouchOSC (Fischer, 2008-present), Livkontrol (Imaginado, 2011-present; synthhead, 2014g), touchAble (Blomert, Garcia, Keppmann, Blomert, & Kapp, 2010-present) and Lemur (Slater et al., 2011-present) - a software iteration of JazzMutant's famous Lemur (Largillier, Joguet, & Olivier, 2007) MIDI/OSC multi-touch hardware controller which, along with the discontinuation of the hardware version, serves perfectly to exemplify the changing music production/performance market and thus the development priorities of pro-audio companies.

As well as virtual instruments and MIDI/OSC controllers, there are a number of iOS and Android apps which aim to negate entirely the need to work within a DAW when producing electronic music. Included in this category are Akai Pro's emulated version of the famous MPC series of hardware samplers (1988-present), iMPC (2012-present), and Native Instruments' emulation of their Maschine range of grooveboxes (2009-present), iMaschine (2011-present); as well as more DAW-like examples, namely Image-Line's FL Studio Mobile (2011-present), KORG

Gadget (2014-present; Aisher, 2014; Nagle, 2014), Caustic 3 (Single Cell Software, 2013-present) and G-Stomper Studio (Planet-H, 2013-present).

Likewise, the influence professional audio hardware and software has had on the development of mobile music-making solutions and ICMS design is reflected in the design of applications within more recent, professional-level hardware devices aimed at providing an introduction to electronic music production for beginners. For instance, the Ableton Push (2013), Novation Launchpad Pro (2015) and Native Instruments Komplete Kontrol S-Series MIDI keyboards (2014; Griffiths, 2014) all utilise intelligent back-lighting of pads/keys to denote the notes and root-notes within a chosen key signature/scale, while the Ableton Push even allows for the entire button-matrix grid to be 'locked' in key, meaning chromatic notes are not available unless chosen by the user, and standard triads within the key can be formed using the same hand-shape anywhere on the control-surface.

Again, none of the apps mentioned here can be described as 'interactive' in terms of facilitating communicative collaboration in composition and performance between human and computer; there are, however, a number of systems which aim to achieve this in interesting and engaging ways. FRACT OSC (Flanagan, Nguyen, & Boom, 2011-present) - for Windows/Mac - and PolyFauna (Yorke et al., 2014) - for Android/iOS - are both examples of open-world musical exploration games whereby, as you move through and interact with the virtual environment, the generated musical output evolves in accordance with your actions. FRACT OSC also includes elements of traditional synthesis and problem solving which enhance the overall level of immersion when experiencing the game. Synthesizer 7DRL (Hybrid of an RPG and Synthesizer, 2015; TheBroomInstitute, 2015) is another web-based ICMS in the form of a complex role-playing game (RPG) based around the fundamental concepts of subtractive synthesis. In addition, there are various other ways in which HCI manifests within mobile applications and games; both within the context of music and outside of it. For example, 80 Days (Inkle Studios Ltd., 2014) is an interactive novel-based game, while Navichord (Kutuzov, 2014; synthhead, 2014f) is an educational tool for learning the fundamentals of music theory and harmony.

HCI in Popular Electronic Music Records/Releases

One of the more significant developments in terms of HCI in popular electronic music in particular has been the emergence of official music releases from established artists being packaged as interactive apps and games, as opposed to the traditional recorded format. Possibly the most important and well-publicised of these is Biophilia by Björk (2011), who has not only provided a platform for interactive performance techniques in more popular veins of electronic music through extensive performances utilising the Reactable modular synthesiser (Jordà et al., 2003-present), but has also been a pioneering figure in composing and designing ICMSs for screen-based

interfaces aimed at providing non-expert musicians with the freedom to engage actively in creating and influencing musical pieces as they listen to them, through her work on Biophilia. Each composition embodies its own unique interactional model and interface, many of which rely on generative algorithms inspired by biological and physical processes found in nature to provide appropriate responses to the input of the user. Lady Gaga also released the album *Artpop* (2013) as an interactive application for Android and iOS, Skrillex has created an audiovisual interactive website for the single *Doomy poomp* (2014; Division Paris, Skrillex, & Creators Project, 2014) - enabling users to 'remix' the music video using the keys on their computer keyboard to trigger short GIFs as the track plays - and there are numerous websites, such as *DaftPunKonsole* (Dellidj, n.d.) and *iDaft* (Najle, 2010-present), which implement the same technique to enable users to re-imagine popular dance songs - in this case *Harder, better, faster, stronger* (Daft Punk, 2001) and *Technologic* (Daft Punk, 2005) - by triggering loops and one-shot samples over the top of an underlying groove. The concept has even been transferred to more 'underground' music genres, as evidenced by the *Teengirl Fantasy EP Thermal* (2014; DJ Pangburn, 2014; Teengirl Fantasy & 4real, 2014) - a web-based application enabling users to enter and interact in different ways with a unique virtual world for each song on the EP (four in total) - and the *Sword and sworcery EP* by Superbrothers (Superbrothers, Jim Guthrie, & Capybara Games, 2011-present) - 'an exploratory action adventure [game] with an emphasis on audiovisual style' (Superbrothers *Sword & Sworcery*, n.d.), much like *FRACT OSC* (Flanagan et al., 2011-present) and *PolyFauna* (Yorke et al., 2014).

There are also examples, such as *Reactable Gui* Boratto (Boratto, Jordà, Kaltenbrunner, Geiger, & Alonso, 2012) and *Reactable Oliver* Huntemann (Huntemann, Jordà, Kaltenbrunner, Geiger, & Alonso, 2012), of established dance music producers and DJs releasing select compositions for use with pre-existent music-creation systems, whereby users are able to simply watch back the recorded performances of the artists themselves, or to interact with them on whatever level they choose, be that the evolution and development of the form and structure, sounds and effects, the addition of newly synthesised melodic, harmonic and rhythmic material, or a complete reassembly of the constituent parts with the addition of new parts and lines in order to create an entirely unique reinterpretation of the piece. The same is true of sound packs, released by artists such as Mad Zach, for use with Ableton Live (2001-present) and Traktor (Native Instruments, 2000-present) along with specific MIDI controllers like the *Midi Fighter* (DJ TechTools, 2009-present) or *Ableton Push* (2013) and, more recently, the introduction of Native Instruments' new audio format *Stems* (Ramley, 2015), which allows musicians to purchase music in the form of its individual constituent parts/stems (drums, percussion, bass line, vocals, etc.) with the aim of providing amateur remixers/bootleggers with higher quality materials, and thus promoting ingenuity and creativity in the popular electronic music scene.

The release of popular electronic music in these formats, either as standalone interactive applications, or as source material which effectively transforms previously reactive music-making

software into an interactive, collaborative environment shared by user and composer, is a direct result of the ideologies posited by post-structuralism with regards to openness in a work (cf. Barthes, 1991; Eco, 1989; Storey, 1997), which have had particular resonance within popular electronic music and 'club culture'. Rather than playing the original recorded version of a piece during a performance, 'DJs often favour remixes because they keep their playlists fresh ... but still deliver a level of familiarity that they can be confident crowds will respond to' (This is the Remix, 2010, p. 25). In fact, prior to the emergence of 'live' electronic music performance (as opposed to playing records/CDs/WAVs as part of a DJ set) made possible by technological advancements in both hardware and software, many producers would create one-off 'VIP mixes' of their compositions and distribute the recording to a select few of their counterparts, in order to provide audiences with yet another unique take on the original work among the numerous official remixes commissioned by the record label.

Following on from this, the integration between Ableton Live software (2001-present) and button-matrix MIDI controllers such as the Akai APC40 (2009), Novation Launchpad (2009) and DJ TechTools Midi Fighter series (2009-present) paved the way for spontaneous, improvisatory 'live' performances of recorded works to be fluidly and efficiently crafted through a process of breaking down a composition into its constituent parts and further dividing these up into individual loops/clips, to then be played back in any order and number of combinations - resulting in the ideal solution for artists looking to construct imaginative and bespoke live performances. The idea of the 'VIP mix' also evolved so that producers/DJs would distribute the stems of their compositions to allow others to individualise and re-contextualise a work in a manner unique to their particular performance-style; as did the process of composition whereby similar techniques to those implemented in performance are now utilised to capture an essence of 'liveness' in the recording.

The acceptance of the ['live'] remix in popular electronic music culture has rewarded DJs with 'the status of artist, and this has necessitated a redefinition of such familiar concepts as musical instrument, performer and the role of audience in performance. (Fikentscher, p. 52 - cited in Moorefield, 2005, p. 105-106)

The recent progression, outlined above, towards widespread interest in and exploration of interactive music systems (particularly games and album/single releases), on the part of the audience and composers/programmers, respectively, was the next logical step in the development of popular electronic music. Coincidentally, this most recent development also addresses an issue pointed to by Barthes (1977) in his paper 'Musica Practia', when he proposes the existence of 'two musics ... the music one listens to [and] the music one plays' (p. 149). Barthes argues that 'passive, receptive music, sound music, [has] become the music (that of concert, festival, record, radio): playing has ceased to exist' (Barthes, 1997) and that, in contrast to the popular music of the

late nineteenth and early twentieth centuries - an era made famous by the music publishers of Tin Pan Alley in New York City - when the written score, rather than the recording, acted as the primary musical artefact and simplified piano/vocal lead-sheets were the common unit of sale, 'The amateur, a role defined much more by a style than by a technical imperfection, is no longer anywhere to be found' (p. 150). Not only do interactive releases encourage novice musicians to engage in actively exploring their creativity and musicality, they also go some way to replacing some of the 'special' qualities (aesthetics, artwork, etc.) that are missing from the sterile experience of purchasing music from digital downloads stores.

Summary

To summarise, experimental/academic electroacoustic music was of great importance to the initial stages of exploration into HCI in music; in large part due to the melodic/ harmonic, rhythmic and timbral/textural freedom associated with the genre. The relative lack of strict stylistic constraints lends itself well to experimentation with a wide range of design-models and techniques, as is exhibited by the examples discussed in this article. Although experimental interactive audiovisual installations are still relatively commonplace nowadays, it is the rise in popularity in recent years of popular electronic music that has been the driving force behind the transition of HCI in music into mainstream popular culture. Not only do the ideological values with regards to what is expected by the audience/listener from live performance and personal listening experiences - through live remixing and officially commissioned/bootlegged remixes respectively - favour HCI as a way of consuming music, but the more rigid generic construct of popular electronic music, in comparison to that of experimental electroacoustic music, also promotes the facilitation of more precise depth-in-control over the musical output of the system, whilst still achieving coherent and satisfying results, which is appealing to both novice and expert users/musicians alike. The combination of these two factors - along with technological advancements responsible for the recent surge in the availability and affordability of touchscreen devices such as smartphones and tablets for billions of people around the world - has, on the one hand, reined-in the experimentation inherent in the development of HCI in music throughout the eighties, nineties and early-mid two-thousands but, on the other, has enabled the field to reach new heights, and audiences that were before out of reach of what was once a relatively niche field of art/research.

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