ADAPTIVE GAME MUSIC:

THE EVOLUTION AND FUTURE OF

DYNAMIC MUSIC SYSTEMS IN VIDEO GAMES

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1. Introduction

Imagine yourself playing your favorite video game. Perhaps you are engaged in a heated battle with the Covenant alien race in one of the installments in the *Halo*[1] series, or perhaps you are racing a super-charged car through crowded city streets in a *Need for Speed*[2] game. No matter your game of choice, you are performing actions and experiencing their real-time results within the context of a virtual world. In this "virtual reality" all of your decisions and micro-actions add up over time to comprise a macro level consisting of the overarching plot of the game you are playing. Throughout the course of a given video game, you are interacting with a complex set of cause-and-effect scenarios that produce varying results and conversely influence the course of events within the greater story.

This is the essence of video games; they progress in response to player input. Because of this, game experiences inherently contain the human elements of variability and unpredictability. The timings of game events in almost all video games are necessarily variable, and the exact sequences of player inputs and choices are all but unpredictable. Some players may successfully complete a set of required actions on their first try and move through a game stage/level in just minutes, while others might play over that same part of the game for dozens of tries before completing all objectives – perhaps taking hours or even days to do so. Story lines are directly

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[1] *Halo*'s first installment was released in 2001. The series is a futuristic First Person Shooter, with users playing as an advanced soldier battling hostile alien species.
[2] The *Need for Speed* series has been producing games since 1994 and is centered around street racing in customized cars.

influenced by player input – they only move forward when users progress in ways that satisfy game parameters. Because of these characteristics, video games are typically described as being *nonlinear*.

Video games are, at their core, interactive and nonlinear storytelling platforms. The inherent “human” variability and cause-and-effect-based outcomes result in unique and unpredictable gameplay experiences for users. More than one player having the *exact* same experience in any given game is rare (and statistically improbable). This is still true in games that are not particularly complex. Even relatively simple games such as *Tetris* (1984) or *Snake* (1978) have an almost endless number of possible combinations and results.

There are innumerable variable elements in any gaming experience, but the large-scale games of the last two decades take gaming experiences to an entirely new level of complexity. Modern games, particularly ones developed for dedicated game consoles or personal computers, often feature detailed levels, game engines with artificial intelligence, and dozens of hours of unique gameplay. All of these advances add new levels of interactivity and unpredictability to the experience of playing a video game.

With the evolving potential for narrative scope in current games, the goal of telling a compelling story is more attainable than ever. An underlying key of any story is emotional arc. Making a user/viewer/player experience the subconscious pull of a story makes for a thrilling experience. It is a logical to assume that any element that could compliment and stir the emotions would be amongst the highest priorities in any medium.

One of the most potent influencers of emotion in any form of media-based storytelling is music, which is critical in eliciting the appropriate reaction in the experiencer. When used effectively, music directly interfaces with an individual's psyche without him or her being aware of it. This is used to great extent in film, where soundtracks play a fundamental role is expressing the sentiments of the story being presented. The same practice is used to an even greater degree in games, the interactive nature of which allows for dynamic and adaptive music systems[3] that communicate feelings in real time to accompany a user's actions. A powerful score can make the difference in a game being exclusive (feeling external to the player, not captivating) or immersive (drawing the player into the game, engaging them on a deep level). It has been shown that audio and music are the most important game elements in evoking emotional responses from users (Carlile, "Psychophysics of Immersion and Presence"). One could argue that music is more important in satisfying the artistic goals in games than in any other medium.

One of the main objectives of game titles is to be as captivating as possible. An effective means of creating a convincing alternate reality within a game is to involve players on a subconscious level. Thus, music plays a vital role in the effectiveness of video games. It can act as a bridge that allows players to lose themselves in a story,

[3] Adaptive music is music that changes in accordance with game conditions. See pages eight and nine for a detailed definition.

encouraging personal investment in the events that unfold. Games rely on engagement, which is entirely dependent on the creation of an almost instinctive sense of “being there.” By subliminally drawing players into the gaming experience, music leads to greater gameplay interaction. A powerful music system can create a mesmerizing gaming experience, but a poorly integrated music engine can be abrasive and ultimately distracting for a player. Karen Collins, a researcher and author in the field of game audio, perhaps summarizes this best in her book *Game Sound*: “a disjointed score generally leads to a disjointed playing experience” (158).

While appropriate music is essential to gaming experiences, integrating music in games has been a technical and aesthetic struggle from the beginning. What has defined playtime music since the advent of audio in games has been the constant battle, and subsequent compromises, between the technical abilities of game consoles/computers and the creative and aesthetic desires of composers. For many years, the highly limited audio capabilities of game systems forced musicians to create unique sounding scores through innovative uses of primitive sound peripherals and audio engines. As technology progressed, the sound quality and scope of game music improved. First came more powerful sound chips[4], followed by the ability to have full bandwidth CD-quality music. This has now progressed to the current state of the art:

[4] Sound chip - microprocessor integrated circuit unit devoted solely to audio computation and creation. Present in computers, game consoles, and other electronic devices, prevalently in the mid 1970’s- mid 1990’s. These typically had a set number of “voices” (number of sounds that could be produced at any one time) and an oscillator with multuiple waveforms that could be “played” by code information that contained pitch, filter, amplitude, sampling, and envelope information. Specific types through the years include Programmable Sound Generators (PSG), Frequency Modulation Synthesis (FM Synth), and sample-based Pulse-Code Modulation (PCM) (Collins, 12; “Sound Generators of 1980’s Computers”).

surround sound playback, better-than-CD-quality music, real-time mixing, and multichannel support.

Beyond the technical challenges of game music, there has been an even greater challenge to game composers and producers since the dawn of the video game era – the aforementioned unpredictability and nonlinearity of games. Using music to compliment the stories within games that are dynamic and variable has been a unique task that has troubled game designers, audio producers, and composers for decades. Music outside of games has traditionally been a linear art form, with compositions typically having a beginning, middle, and an end. In most cases, there has not been significant variation within this basic structure. The main problem of game music at a very fundamental level has been how to make a typically linear art form such as music fit into the nonlinear environment of video games.

For many years, the most common solution to this issue has been composing and utilizing “looped” music, where each piece is written so that its end transitions seamlessly into its beginning. This type of writing allows a piece of music to be played cyclically in a constant loop from beginning to middle to end and back to the beginning, as long as needed. This technique was employed in some of the earliest games that featured music (*Space Invaders* [1978], *Asteroids* [1979], *Dig Dug* [1982]), and is still often used.

The pinnacle goal of game soundtracks, though, is music that does not merely loop, but that changes concurrently with game conditions. Music content that is elastic enough to underscore numerous event possibilities is necessary to compensate for human variability and create truly immersive gaming experiences. Music of this type is known as *adaptive music*. Achieved through a combination of compositional foresight and careful integration, adaptive music responds and changes in accordance with events in a game. It must be inherently flexible, ready to shift mood and intensity when needed.

The terms "dynamic" and "interactive" are often used interchangeably with adaptive music. For the purposes of this thesis, I argue that specific distinctions must be drawn. *Dynamic* music is essentially synonymous with adaptive, though the term itself is more vague[5] (Clark, 1). The term *interactive* music, however, is not precisely the same as adaptive music and is often used incorrectly in discussions involving variable music systems. Interactive actually refers to music that a user *directly* interacts with. Examples of interactive music are music-based games such as *Guitar Hero* and *SingStar*, where user input directly affects a musical performance. In essence, adaptive/dynamic music responds as a player interacts with the *game*, while interactive music responds as a player interacts with *the music itself* (Hayes, "Adaptive Audio Concepts and Workflow").

The focus of this discussion will be primarily on adaptive/dynamic music. While games that utilize interactive music are no doubt popular and impressive in their

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[5] "Dynamic" music may also at times refer to the dynamic range in a piece of music. Dynamic range is the difference between the quietest and the loudest elements in a piece of music or a recording (McDaniel, Shriver, & Collins, 273).

own right, they do not demand the unique compositional, production, and implementation considerations that games with adaptive soundtracks do.

2. History of Adaptive Music

Nonlinear music is by no means exclusive to video games. Composers have been experimenting with randomized and interactive techniques for hundreds of years. Some of the earliest known examples consist of a series of musical games called *Musikalisches Würfelspiel* (or, "musical dice games") that came about in the mid-18th century. These games most commonly utilized dice, coins, or multi-faceted tops and a musical grid or reference page to determine musical variables, as well as orders and combinations of different measures and phrases. In most cases, each game would have a constant harmonic structure on which all of the variable elements would be based, so no matter the order the player determined, the music would remain relatively consonant (Berndt, Hartmann, Röber, and Masuch, 54).

These games purported to give anyone the ability to compose music, with each game having a large number of possible outcomes. They became very popular in Europe from the mid-late 1700's to the mid 1800's. Johann Phillip Kirnberger (1721-1791), a student of Johann Sebastian Bach (1685-1750), was the one of the first composers to introduce the concept of a randomized, dice-controlled piece of music. His dice-based piece *The Ever Ready Composer of Polonaises and Minuets* was released in 1757 and later revised in 1783 (Oron and Stevenson, “Johann Phillipp Kirnberger”).

The most famous *Musikalisches Würfelspiel* was published under the name Wolfgang Amadeus Mozart, though due to inconsistent historical proof it is not definitively known whether Mozart did any of the composing. This take on the game had an impressive array of possibilities. It can still be played today, delivering unique results (Noguchi, "Musical Game in C K.516f."). As mathematician and author Michael Gardner points out,

> …the pool of possible outcomes is so large that any waltz you generate with the dice and actually play is almost certainly a waltz never heard before. If you fail to preserve it, it will be a waltz that will probably never be heard again (Gardner, 629).

Using my previously set designations, the aforementioned musical dice games could be considered interactive and nonlinear music, but not adaptive. If the dice music somehow responded to a separate board game or story being played out, it could be considered adaptive. No technology existed at the time to allow for such an intelligent music system, and certainly nothing that could be compared to a modern day audio engine in a video game. It is fair to say that there has been interactive music in games for hundreds of years, but the same cannot be said for adaptive music.

However, these dice-based diversions and the principle functionality behind them have had a profound influence on variable compositional techniques. Contemporary classical composer John Cage took great interest in such games, and partnered with fellow composer Lejarin Hiller to revisit them. The two composers put their focus on the *Musikalisches Würfelspiel* released by Mozart, rather than Kirnberger's earlier work. In 1969, the duo partnered with a computing student who created a virtual representation of the Mozart release called *DICEGAME*. Cage and Hiller were able to use this program to create seven different harpsichord solos, which utilized selections from Mozart's own piano sonatas and works from Frédéric Chopin, Ludwig Van Beethoven, Robert Schumann, and Louis Moreau Gottschalk, as well as Cage and Hiller's own pieces, all randomly assembled via coin toss (Vickery, 75). Here both statistical chance, as well as calculated computer algorithms created nonlinear, randomized music. This interaction between planned structures and chance elements is a direct precursor to the balance of games, where users create the randomized input, and the game algorithms determine the proper selection of music. It also reveals the potential of algorithmic and generative music. A self-composing music system based on parameters similar to *DICEGAME* would make for an effective dynamic soundtrack.

Compositional techniques for dealing with unpredictability and adversity actually pre-date the rise of these *Musikalisches Würfelspiel*. Baroque era (c. 1600 – 1750) composers commonly wrote pieces that could retain their musical coherence, even if only certain parts of them could be performed (i.e. only the sopranos and tenors in a choir). The practice of writing different parts that can work individually or collectively is called *rural composition,* and was used by composers such as Valentin

Rathgeber (1682-1750), Heinrich Schütz (1585-1672), and J. S. Bach. Rathgeber composed many works that were easily *reducible*, meaning they could be performed by small or large ensembles and still deliver the same musical message. Additionally, the concepts of counterpoint - a compositional technique of combining relatively independent melodic and harmonic lines into a single *texture*[6], and multiple counterpoint - the same theory of counterpoint, except any part can be exchanged with another - lend themselves to adaptability (Kostka and Payne, 87; Berndt, Hartmann, Röber, and Masuch, 54-55).

Another issue faced by Baroque composers was writing within the limitations of certain instruments. The harpsichord, for example, was popular at the time, but featured a limited dynamic range. Composing for the instrument required focusing on other musical variables to make up for lack of dynamics. Adding voices[7] and increasing rhythmic density were two commonly used techniques to emulate changes in volume. This issue is similar to what was faced by composers in the early days of console and arcade games, where the only audio sources were primitive sound chips that had limited voices and narrow dynamic range. Game composers could only have a set number of notes performed at any given time, so while increasing tonal density could be effective, it wasn't always a practical solution. One clever method that gained

[6] Texture - musical term for the interaction of the tonal musical elements of melody and harmony (Forney and Machlis, 23).

[7] Voices in a musical context is the number of simultaneous notes being played at a time. Adding more notes is referred to as adding voices, and the voicings of chords are how these notes are arranged and combined together.

popularity was programming very fast arpeggios[8] that were rendered at such speeds that they sounded like sustained chords.

Baroque and classical music, particularly the harmonic standards associated with these eras, also had a strong influence on metal and progressive rock music in the mid and late 20th century. These styles were a key influence on early game composers, so some of the same harmonic conventions that defined 17th and 18th century music also helped define late 20th century game music. A prime example is the music of the game series *Castlevania* (1986, first title), which was strongly influenced by Baroque music. The music in the series also owed much to the classical and romantic eras (Esch, *Music For a Tragic Prince*).

In the 18th and 19th centuries (which encompass both the Classical and Romantic periods) there was extensive experimentation with harmonic and melodic conventions. While experimentation with nonlinear music was limited, there was an emphasis on impressionistic, impassioned music. This emotionally charged era would go on to have significant influence on music for narrative constructs such as theatre, film, and video games. Modest Mussorgsky's (1839-1881) *Pictures at an Exhibition*, though linear in nature, exhibits many parallels to modern film and game music. Each movement corresponded to a picture in an art gallery, and there were promenade sections in between the main movements to indicate walking through an exhibition (hence the title of the piece). The use of odd meters, short thematic statements, and

[8] Arpeggios – Technique where the notes with in a musical chord are played in sequence, instead of at the same time.

key and mood changes were all meant to represent different elements of walking through a gallery and experiencing different works (Jewell, 1). This use of aural imagery had a profound influence on music for many visual mediums. The ways in which subtly shifting music follows players as they travel through the various levels of a game has many similarities to this impressionistic piece.

Another composer whose work had tremendous influence on programmatic music was Richard Wagner (1813 – 1883). He is most well known for his many iconic romantic works such as *Flight of the Valkyries*, as well as his revolutionary approach to opera. However, his largest single contribution may be the popularization of the concept of a *leitmotif*, which is a musical theme that represents and/or is associated with a certain individual, location, or concept. In theatre, film, and games, characters and settings typically have recognizable leitmotifs in their respective scores. Wagner used leitmotifs extensively in his operatic works, and his techniques for integrating them have directly influenced the musical conventions of film and games scores, even over a century since his death.

Wagner was also noted as idealizing the creation of the “total art work,” a piece that would have “a unity of drama, text, design, and movement” (Sherrane, "The Romantic Era: Richard Wagner"). By this definition, video games may be the closest thing to a total artwork that humans have yet achieved. Had he been born 150 years later, Wagner could have been a prominent and revolutionary game composer.

It is also worth noting that in Wagner's operatic works there were many parallels to video games. In fact, the nature of music for games has many of the same issues and conventions as composing for the theater. For centuries, a common technique in musical theater productions has been composing pieces that have specified sections that *vamp*, or repeat as long as needed until the appropriate series of events have transpired on stage. Musical "pit bands[9]" must be flexible in their performance in order to time musical events with the on-stage action. In this respect, vamping music for theatre serves as a solution to many of the same issues that are present in games. It is no coincidence that many games use vamp-like structures where certain parts of levels trigger micro-loops within pieces of music that continue until the appropriate conditions have been met.

Looking further on, the first half of the 20th century saw an explosion of musical expression on many fronts. Though this time period is most commonly associated with Tin Pan Alley pop songs, big band swing, and the emergence of jazz and rhythm and blues music, not to mention the birth of rock 'n' roll, there were also some very progressive movements involving nonlinearity occurring on the classical front. For example, Earle Brown composed a piece in 1967 titled *Event-Synergy II*, which featured two ensembles, each with its own respective conductor who used hand motions to indicate and trigger which of four events/phrases/techniques they had to play. The conductors completely determined the course of the piece of music, and the

[9] Pit Band - term often used to describe theater music ensembles, as they often perform below audience and stage level in a pit.

scope of different combinations was large (Vickery, 76-78). There are many ways in which this is similar to a game engine "telling" the game score what different events and emotions it must trigger.

Karlheinz Stockhausen also experimented with dynamic music. His *Piano Piece XI* (1956) is made up of a single sheet of music that defines 19 separate musical sections. The performer is instructed to play the sections in any order, deciding the arrangement as the piece is performed. This concept is very much in line with the concept of horizontal re-sequencing in games[10], where there are related musical segments and ideas that are triggered in whatever order best fits the game's events (Morgan, *Twentieth-Century Music*).

One specific genre of modern classical music that has had a tremendous influence on game scores in recent years is *aleatoric* music. Compositions that are aleatoric in nature feature elements that are left to chance, as well as performance decisions made by musicians (Jewell, x). This style is very much reliant on chaotic and unpredictable musical variables. The most iconic (and revolutionary) example of this style is Krzysztof Penderecki's *Threnody to the Victims of Hiroshima*, a piece for 52 string instruments that features extended and non-traditional playing techniques. Penderecki invented many new notation symbols for the piece to represent full-range glissandos, percussive playing, and nontraditional bowing techniques. *Threnody* is itself atonal and arrhythmic in nature, leading to a chaotic, uneasy, and even scary emotional experience. The piece had an immediate impact on chamber music when

[10] See "Compositional Approaches" section for a more in-depth discussion on horizontal re-sequencing.

premiered in 1960. It heavily influenced other atonal works of the era, and composers such as Morton Feldman and Pierre Boulez went on to further push the boundaries of aleatory music.

This compositional approach has had a lasting effect on programmatic music as well. Linear scores from Bernard Herrmann (*Psycho*), John Williams (*Raiders of the Lost Ark*) and Mark Snow (*X-Files*) relied heavily on this technique. However, the chaotic nature of aleatoric music may fit nonlinear video games better than any other medium. In games, more modern scores such as those to *Dead Space 1 & 2* by Jason Graves, and *Dante's Inferno* and *Bioshock 1 & 2* by Garry Schyman are fundamentally aleatoric in nature. In these examples and other games that utilize this writing technique, adaptive music systems are able to trigger short segments of atonal chaos in response to game events. In the *Dead Space* games, for each new enemy who attacks or surprises the player (a space soldier on a spaceship full of deadly monsters), a short cue of high-pitched violin squelches, brass falls, and/or intense percussion is triggered (Graves and Schyman, "The Art of Noise"). As aleatoric pieces are already dissonant and free-meter, almost any musical component in a piece can be combined with others to great effect.

A quote from theorist Holger Schulze shows one reason that aleatoric music specifically works in scores:

> We simply cannot bear to be surrounded by anything that is literally meaningless and generated by chance. We forget its aleatoric genesis and find ourselves involved in a mental game, a heuristic fiction (Schulze, 61-65; Vickery, 74).

And a quote from Boulez himself gives insight into why nonlinear music specifically fits mediums such as video games so well: “listening time is no longer directional, but time bubbles, as it were,” (Boulez, 178; Vickery, 75). Game music is also less directional, and the “time bubbles” completely vary depending on user interaction.

Aleatoric experimentations may have been more influential on nonlinear scores than any other contemporary classical efforts. It is no coincidence that so many game soundtracks are incorporating variable aleatoric elements into their respective audio engines. These developments served as a capstone of sorts for contemporary nonlinear music influences on games.

3. The Advent of Video Games

3.1 Early Emergence of Games

It was not long after the original aleatoric experiments gained momentum among the contemporary music factions that the first video games also began to emerge. At the time, neither had much influence on the other. As noted, though, both have now risen to prominence more or less simultaneously thanks to the increasing use of aleatoric methods in game music production.

There is great debate about what was the true first-ever game, and this thesis will not seek to add to the argument. Instead, it will be noted that games did not become widely available or achieve mass pop culture acceptance until the 1970’s.

In the early years of popular games, audio capabilities of this were limited. Still, even the 1972 game *Pong*, one of the first mainstream game titles, had rudimentary sound effects. Music and audio beyond simple reinforcing sounds require significantly more technical abilities, though. Game music and higher functioning audio would prove to be rather difficult to introduce.

As noted earlier, music within games has always seen a struggle between technical limitations and creative desires. This section will seek to outline technical developments in games, giving an overarching summary of game audio development from inception to present day. Examples of adaptive music in games will be reserved for Appendix A, "Case Studies," which appears at the end of this thesis.

3.2 Game Audio Development

Game audio before the early 1990's was generated with very limited sound chips. The resultant audio produced through these means possessed a highly synthetic aural aesthetic, sometimes referred to as "8-bit[11]," "Chiptunes," or "Chip Music." It was a tremendous technical achievement to create any sort of coherent music through these means, not to mention making it functional within the context of a game, and evocative to players. Development teams were often excited that the technology worked at all. As Mike Pummell, a composer in the early days of Acclaim software, notes, "Early on, you were just thankful to get sound out of the thing" (Belinkie, *VG Music, Not Just Kid Stuff*).

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[11] 8-Bit – Refers to digital audio bit depth, which represents the resolution of each sample in a set of audio data. 8-bit was a very limited standard, as CD standard is 16-bit and DVD's are capable of 24-bit. Greater bit depth allows for greater fidelity, but also makes for larger file sizes (Collins, 13).

One of the most significant developments in early game audio came in the mid 1980's – the adoption of the Musical Instrument Digital Interface standard (MIDI). The regulated format was created as a means of transmitting musical data between different synthesizers and other pieces of audio equipment. It saw across-the-board acceptance by synthesizer manufacturers and allowed for musical information to be transmitted as data and "performed" by a synthesizer or computer. Once it was adopted by the game industry, it allowed composers to export finished pieces in a format that they were already using, and have the same information understood by game consoles. This all but ended the days of composers having to program their scores into game engines through detailed scripting languages (or having to hire someone to convert a score to code). For the first time, composers could write with standard music equipment and computers and have the confidence that everything would effectively transfer to the game.

The 1990's saw significant advances in game music possibilities as well. The Super Nintendo Entertainment System (SNES) and Sega Genesis consoles both featured large upgrades in audio capabilities. A 1992 add-on to the Genesis called Sega CD featured a compact disk drive that provided full CD-quality, prerecorded audio soundtracks, allowing for unprecedented audio fidelity. Games for the Sega CD platform were the some of the first console games to stream prerecorded music tracks[12]. Realistic sounding scores with recorded human performances marked a

[12] The first game to feature continuous, pre-recorded music is somewhat debatable, but it is generally accepted that *Ys*, a Turbografx-16 CD title released in 1989 was the earliest such release (Kalata, "Ys").

dramatic aesthetic shift in game music. For the first time, the sonics of game soundtracks were competitive with commercial music releases. Sega even founded its own music group and built professional recording studios to usher in the new era of game music. One of the first recordings to come out of these studios was for *Sonic CD* in 1993, and it may have been the first game score to stand up to commercial music in aural and compositional quality (McDonald, 2).

New consoles built on the potential of Compact Disc technology were introduced in the mid 1990’s with Sega’s Saturn and Sony’s Playstation. As noted, the CD standard meant each had the capability for full bandwidth, pre-recorded audio. These consoles were the first to be centered around CD technology, as previous generations had only released separate add-ons, if anything. Each also featured improved sound chips, giving the alternative option of using MIDI files to play internal synthesizers instead of using prerecorded music files. These sound generators were a great improvement over the limited 8-bit chips and could more realistically mimic orchestral and rock instruments. The increased audio quality of prerecorded music came at a high storage space cost, so the ultra-low storage space alternative of rendering the music in real time based on pure data was an attractive option for certain games (Marks, 11).

The Nintendo 64 was also introduced in this era, and featured the most powerful sound chip in a gaming system to date. Much like in games for Playstation and Saturn, 64 scores often relied on sound generators to avoid storing and streaming audio content. The 64 also relied on game cartridges rather than CDs, so full CD-quality audio and music were not completely possible. The only practical way to incorporate pre-recorded music into games was through compressed audio files, usually in formats such as the *MP3*[13]. These files could be stored on and played from the cartridges. Interestingly, there was a bit of a lull in adaptive soundtrack efforts during this time. The advent of prerecorded music meant that game music was set and recorded ahead of time, and therefore was not as flexible once it was in the game. Quite simply, it is easier to manipulate audio code information than it is a full, pre-recorded orchestral composition. The significant strides of full-bandwidth audio actually set back variable music efforts for some time.

The next era of dedicated game systems was the 128-bit console line, beginning with the Sega Dreamcast in 1998 and continuing with the Sony Playstation 2 (PS2) in 2000, and Nintendo Gamecube and Microsoft Xbox in 2001. These featured even more capable sound chips, greater storage space, and the capabilities for better-than-CD audio. This infrastructure allowed for powerful scores to be incorporated as both prerecorded audio files and sound generator-driving MIDI files (McDonald, 2004). It was due to these capabilities that adaptive music began to return as a force in console games of the early 2000's.

The "next-gen" (and still current) console line included the Microsoft Xbox, Nintendo Wii and Sony Playstation 3. This new era of machines feature a substantial

[13] *MP3* (MPEG Audio Layer III) – Compressed (reduced size and quality) digital audio codec that is used to reduce file sizes of sound files. "Lossy" (a loss in quality) compression is utilized to create files that sound nearly the same as uncompressed audio, but at a fraction of the size.

upgrade in audio capabilities over previous generations. All feature powerful audio processors with numerous DSP effects, increased audio channels, and more horsepower and storage to work with (Marks, 345-346). The audio implementation in games for this generation has been significantly more advanced than prior iterations. Franchises such as *Battlefield*, *Uncharted*, and *Forza Motorsport* have ushered in a new standard of sonic realism. Capabilities for adaptive and generative scores are greater than ever as well, as will be detailed later. It is during this current era that we see dynamic soundtracks return to the forefront of game music.

4. Compositional Approaches to Adaptive Music

Due to the complex, nonlinear nature of modern video games, compositional approaches for adaptive scores must, from the outset, be different from scores for linear media. Composers must think ahead and write music that can shift moods, switch to different sections, or cut out at any time (Marks & Novak, 24). Musical changes in a game are based on game states, which refer to discrete experiences within the game. Typical game states are influenced by such things as intensity, number of enemies, winning vs. losing, building vs. battle, stealth/detection, rewards, and many other variables. Music assets are usually broken down into component parts to allow for more flexibility. The game engine then takes these components and reassembles them to fit the game state. Composers must understand how the game will use these musical components, and write accordingly (Moore, "Creating Adaptive Music”).

In working with adaptive music systems, there are two main approaches employed by composers: vertical re-orchestration and horizontal re-sequencing[14]. Vertical re-orchestration takes a musical foundation that is typically emotionally ambiguous and then features different harmonizations, rhythmic elements, and instrumentations that can be faded in and out in real time as the music plays. This allows the same basic piece of music to elicit different reactions in the player – all depending on which elements are triggered by the game engine (i.e. dissonant harmonies and arrhythmic elements for tension, or consonant harmonies and very beat-centric percussion for happiness or calm).

Horizontal re-sequencing involves writing music that can shift to different musical sections, in any order, at any time, without being noticed by the player. Sometimes these different sections are "glued together" by short musical statements, while sometimes crossfades (the simultaneous fading out of one piece of music as another piece fades in) are used. In some cases the transitions are straight and abrupt, which can work effectively in certain scenarios, but this also creates the undesired potential for the player to become less immersed in the game (Hayes, "Adaptive Audio Concepts and Work Flow"). An offshoot of this technique is called horizontal branching, which features linear compositions that can branch into different sections or other pieces, much as a tree branches out.

Most game releases feature music systems that use a combined approach. Horizontal re-orchestration is often utilized when transitioning between significant

[14] Specific examples of these techniques can be found in Appendix A: Case Studies.

events within a game such as level changes, boss battles, and victory fanfares. Layering and vertical re-orchestration are usually used to compliment more subtle and gradual game changes, morphing and evolving to support the game state. Horizontal branching, transitions, and segments can also have different orchestrations, allowing for even short transition cues to have several different instrumentation possibilities. Vertical, layered compositions can have stingers and short musical statements triggered overtop at any point as well. While more complex than either approach on its own, the combined method can yield the most transparent and immersive aural experience.

Further within these macro approaches, there are many different ways of adding micro-variability. Karen Collins lists “Ten approaches to variability in game music” in her book *Game Sound* (147). These are:

1. Variable tempo
2. Variable pitch
3. Variable rhythm
4. Variable volume/dynamics
5. Variable DSP (Digital Signal Processing)/timbres
6. Variable melodies (algorithmic generation)
7. Variable harmony (chordal arrangements, key or mode)
8. Variable mixing
9. Variable form (open form)
10. Variable form (branching)

All of these can be used to great effect to add variety to game scores. While variable form and mixing were already discussed, changes in musical constructs (pitch, tempo, rhythm, etc.) and timbres (DSP) can be used to subtly affect musical impact. These smaller changes can be applied to components of a composition or an entire piece in real time. When combined with overarching re-orchestration and re-sequencing, lower-level adaptive effects can give emotional “fine tuning” to the overall coarse expressive adjustments of soundtracks. Each additional variable element that can be incorporated in a music engine allows for that much more flexibility. The most effective dynamic scores incorporate most or all of these techniques, at both the macro and micro level.

5. Generative Music

An approach for adaptability and variability that has the greatest potential for flexibility is music that can compose itself in real time. Generative music, sometimes referred to as algorithmic music, allows scores to be written and rendered in real time based on a set of assigned parameters and limitations. Though less commonly used for variable music systems than are pre-recorded music files, generative and algorithmic music will likely play a significant role in the future.

In this approach, computer algorithms or other preset factors are used to create a unique, randomized musical experience. One of the first examples of this technique was in the LucasArts game *Ballblazer*, released in 1984. The score was unique with every new play of the game, due to an algorithmic music engine. Composer Peter Langston set the algorithmic parameters so that the music flowed smoothly with game changes and transitions. While effective in its transitional capacity, Langston noted that the programmed rhythmic and melodic elements created music that was, simply put, uninteresting.

There have been other attempts at incorporating generative music in games since *Ballblazer*, though few have been in mainstream games. However, there have been many games and applications that have been created that focus on generative music composition as an end result. The applications are focused on making the algorithmic music, and that, in essence, *is* the game.

There are of course exceptions. One very recent and notably successful use of generative music in an AAA[15] game title was the score to *Spore*, a PC/platform game released by Electronic Arts in 2008. The score was a result of the collaboration between famed electronic musician/composer Brian Eno and the EA development team. Together, they created a generative music playback system, with the PureData programming environment as a conduit. This environment allowed them to devise a system that produced improvised music consisting of different rhythmic elements, basslines, harmonic progressions, ambiences, and melodic/harmonic counterpoints.

In the game, this music system succeeded in producing subtle, unobtrusive music. This was necessary, as *Spore* gameplay could span multiple hours depending on the player's decisions, whereas repetitive music could have engendered a sense of annoying monotony. The generative music system avoided this entirely. The game itself is based on players creating creatures, tribes, and civilizations and the evolution

[15] AAA games refer to the largest-scale games in the industry. Scope, budget, and sales are all usually immense. This can be considered the video game equivalent to a blockbuster film.

of these creatures and groups is based on every decision that the player made along the way. The music changes with every step of evolution, keeping pace with the game progression.

There is also an included section where players can produce and edit their own music. When players reach a level where they can build and control their own cities, they are given different musical options. Players' choices of different beats, ambient elements, and melodic statements then directly influence the direction of the algorithmic soundtrack (McGowan, "Interactive Music in Games").

Spore proved the power that could be harnessed in generative music systems. While still in the minority, algorithm-based scores have proved their viability in the game industry. In coming years, as technical capabilities increase and new audio technologies are introduced, generative music will likely play a greater role in game music (Kosak, "The Beat Goes on"). As game console sound chips become more sonically powerful and realistic, music generated in real time could be competitively authentic sounding, while requiring a small storage footprint. The greater flexibility afforded could also allow for soundtracks with high levels of variability. Systems like the Lucas Arts *iMuse*[16] could be reintroduced with improved sound quality. That said, generative music will most likely never replace pre-recorded music entirely, but the two concepts could be used in tandem to create scores that sound both authentic and consistently unique.

[16] See "Case Studies: *X-Wing Series*," p. 50.

6. Testing Adaptive Music Systems

A difficult challenge in creating adaptive music is testing how the musical elements will actually function. Most standard composition and digital audio production software is very linear in nature. Timelines, markers, timecode, and other placeholders don't particularly lend themselves to nonlinearity.

There are workarounds available, though. Composing and mixing using stems – or groups of similar instruments or parts that all are submixed through the same output – allows entire instrument sections to be weaved in and out with the control of just one track. This can be of particular use when testing a composition that uses vertical re-orchestration. Various musical layers, set to different stems, allow different combinations to be brought in and out of the composition to see how they work together and if crossfades work as adequate transitions between different gameplay states.

While most linear-based Digital Audio Workstation software (DAW's) can be used to test vertical re-orchestration, it is very difficult to experiment in real time with horizontal re-sequencing. For this task, other software is more suitable. The most prominent is *Ableton Live*, a program based on composing and organizing nonlinear and loop-based music. Originally gaining traction with the DJ and electronic music community, the program has enjoyed broader appeal as a more fluid alternative to traditional linear music production. Different musical sections called "scenes" can be triggered on the fly in *Live*, and elements of different scenes can be mixed together (since all of the sections loop at the same tempo) and all loops are locked together. This is the essence of horizontal re-sequencing – switching between different segments of music at any time. Different elements of a composition can be loaded, looped, triggered, and altered in real time within *Live*, allowing a composer to experiment with how a composition will dynamically flow within a game.

Even with DAW possibilities, audio middleware and proprietary audio engines are still the ideal place to test how adaptive music components will work together and within the game. Contrasting these benefits is the greater amount of time required to transfer audio content into the middleware and/or engine. A certain amount of parameter assigning and program tweaking is also necessary to get to the point of actually testing how the dynamic music system works. Still, this approach does give the most accurate representation of how the score will function in a game. Sound artists are able to test directly within the same software that integrates the music. This has the invaluable benefit of seeing and hearing the score as it will sound in the finished product, even if it is just an in-progress build[17] of the game. Though there is the lag time of exporting audio files, importing them in the audio engine, and then assigning parameters to control the different segments, it can often be a worthwhile investment.

While no doubt beneficial, this whole process is often reserved for the final stages of a project's development. Due to the aforementioned slower production

[17] Build – Game industry term for a fully rendered version of a game/piece of software. Every time a game project is exported into a standalone form, this is a new "build" of the game.

pipeline, composers often avoid testing within middleware and audio engines until the very end of the production process. DAW sub and stem-mixing, fluid arrangements in *Ableton Live*, and other non-game integration testing approaches are much more time-efficient and less creatively-stifling, and are used much more frequently. Until audio middleware catches up in workflow speed and creative aesthetic, this is how things will remain.

7. The Evolving Industry of Adaptive Music Composition

With each successive year, adaptive music increasingly becomes the standard in the game industry. Once reserved for only the most ambitious, biggest-budget games, dynamic music systems are becoming commonplace in even relatively small, independently produced titles. Game companies of all sizes realize the important role that an immersive, adaptive soundtrack can have on the greater impact of a game. The importance of a dynamic score is by now so obvious that any medium or large budget game project is all but required to have an adaptive soundtrack (though the level of adaptability varies considerably from title to title).

Smaller and independent games don’t always have the financial or technological resources to develop such a music system, but even these usually still incorporate some basic layering/vertical re-orchestration and/or horizontal re-sequencing. There is an occasional reversal of this trend too, as some independent developers are more willing to takes risks and allot considerable resources to the audio department. Smaller projects often have greater flexibility to integrate variable music systems. In these cases, the nature of the soundtrack is a creative choice of the developer, rather than a practical decision. Much like independent films are more likely to examine difficult subject matter and make bolder aesthetic decisions, smaller interactive projects are more likely to be edgy and boundary breaking.

The pervasiveness of adaptive music in all sizes of games is leading to new prerequisites in composer skill-sets. The ability to compose an adaptive score is quickly moving from a specialized area of expertise to a necessity for those hoping to create game soundtracks. Developers of all sizes increasingly understand that a high-quality immersive soundscape can be the difference between a powerful game and one that misses out on its full potential. As this predisposition continues, more studios will require composers to write with adaptability in mind.

Another trend that will advance the rise of dynamic scores will be the continued reduction of production costs associated with composing and implementing a variable soundtrack. As noted, the art of composing such a score will become less of a specialized skill, and this widening talent pool will drive down the costs associated with adaptive music composition. The video game industry is a marketplace, and money is still the greatest agent of change. An increasingly cost-effective and available selection of nonlinear composers may push forward variable scores as a standard even more than the simple recognition of their importance to game quality.

Additionally, technological standards for flexible music implementation will begin to take hold. There are currently dynamic music engines available within *FMOD*, *Wwise*, and *Miles* middleware applications, as well as in Microsoft *DirectMusic* and many other proprietary technologies that various game companies keep restricted. Between these different options there are many similarities, but the differences are great enough that learning each individual system requires a considerable investment of time and mental energy.

Because of this disparity, one can logically conjecture that these different dynamic music integration engines will follow a similar development route as most other technologies: certain conventions and options will begin to be adopted in increasing numbers by the greater industry, and these will take hold and eventually comprise the standard feature set. Many parallels can be drawn when comparing the development of audio engines and middleware to the development and technological standardization of computer DAW's. While there are many different DAW options currently available, most of them uphold the same basic conventions in key commands, visual layouts, folder structures, and file formats. This was not always the case though, as early digital workstations had very dissimilar protocols and nomenclature from one program to the next – just as dynamic music engines do today. As adaptive music becomes more pervasive in games, implementation engines will start to develop the same de facto standards in operations we now see in DAW's. This consistency in integration will further streamline the adaptive music production process.

Here we see a three-way push in the elevating prominence of variable music systems. Game developers are increasingly realizing the importance that adaptive scores have to game quality. The number of game audio professionals who are competent at producing dynamic music is growing, and thus the cost of incorporating such soundtracks and decreasing. Software standards are being adopted and agreed upon with greater consistency. Therefore, game composers must be ready for these trends as they achieve widespread acceptance. The ability to write and produce an adaptive score is now all but a job requirement for composers creating music for games, and must be viewed as a necessary skill to learn.

8. The Future of Game Music

8.1 Production Developments

As we have seen, adaptive music in games has had a notable history that has culminated in an era of unprecedented technical capability and aesthetic quality. The influence of hundreds of years of nonlinear and randomized music composition, the evolution of game audio capabilities from limited synthesized sound chip music to fully orchestral scores, and the emergence of a strong, competitive game music industry have put adaptive music efforts in a powerful position. Game systems are better able to handle dynamic music systems, game studios are more willing to budget in adaptive music efforts, and the abilities required to compose and produce adaptable scores are quickly becoming requirements for game composers. The current era is truly exceptional.

Still, it is the future of this field that holds the greatest possibilities. The technical capabilities of audio middleware and game audio engines are not only increasing, but they are also becoming ever more uniform. Competing audio middleware systems are beginning to resemble each other.

This growing consistency also involves the inclusion of more production-oriented tools embedded directly within middleware engines. The lines between audio/music production software and audio integration middleware are more blurred with each new iteration. Audio middleware developers are catering more to composers and sound designers instead of solely audio programmers, and this trend appears to be gaining momentum. These same developers are also reaching out in an effort to make their feature sets directly accessible to content producers, with goals of shortening production pipelines and allowing for more efficient and flexible audio integration.

Firelight Technologies' *FMOD Studio* is on the forefront of this transition. To be released in 2013, the middleware suite will feature components that look and function in a similar manner to audio workstation software. This expansion on the current *FMOD Designer* (and related suite) will feature real-time mixing that uses a DAW-style digital mixer with insert-style effects[18], effect sends[19], and support for

[18] Insert Effect – Audio signal processing that is introduced directly in the signal path of an audio channel. Sound must pass directly through the insert modifier before moving on to the main mix.

hardware control surfaces like MIDI mixer and keyboard controllers. Early sneak peeks of the program reveal that it may also integrate audio editing options and its user interface will bare a close resemblance to a typical DAW. The aesthetic and layout is quite reminiscent of *Ableton Live*, and this is no accident. The developers admit their admiration for *Live*, and they certainly recognize the extent to which the music community is now using the program for music production and performance ("FMOD Studio Demonstration").

Conversely, the possibilities of DAW software adding feature sets for interactive content are looking increasingly plausible as well. A fairly recent development that has not yet led to any major influence in game audio, but that has serious potential to do so, is the introduction of *Max for Live*, a version of the object-oriented programming environment *Max/MSP* created by Cycling 74 that works directly within *Ableton Live*. Users can employ *Max* to create new instruments, audio effects, and MIDI manipulators that can be inserted on tracks in *Live* just like any other plugin. *Max* has existed on its own for decades and is a very powerful programming environment. One of its principal attributes is that just about any information in the program can "talk" to any of the other information. For example, data input from a webcam can be channeled to affect audio parameters through a simple means of data reinterpretation. The programming environment has been used to develop innumerable plugins, standalone programs, and middleware. It has also been

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[19] Effect Send – Audio signal processing that is *not* introduced directly in the signal path of an audio channel. A sound source is split and sent to a separate effect-only bus channel. The level of the send can then be mixed with the level of the dry, unaffected original source.

used to create real-time adaptive music engines in games. The fact that both *Ableton Live* and *Max/MSP* have both been used separately in game and game audio production show that their merger could have great possibilities for real-time music production and auditioning within interactive content. *Max for Live* represents the most intriguing current possibility for the convergence of production and integration, but there is certainly more to come in the future.

Over the next few years we will continue to see audio production software adding more and more integration-oriented features and audio middleware programs incorporating additional production-oriented capabilities. In the future it is likely that there will be little that distinguishes production software from middleware.

Another development that may further blur the line between audio production software and middleware is the *iXMF/Interop* format, a shell file format that is currently being developed by the Interactive Audio Special Interest Group (IASIG). This is not the first file standard of its kind; two other commonly used container/shell standards are the OMF and AAF file formats. These allow DAW session data and audio files to be encapsulated into one file that can then be read by a large number of audio and video production programs. *iXMF/Interop* would allow all audio data and files to be encapsulated into a shell format that would also include programming code and implementation information. This would create a standard format in game audio integration, and audio for any interactive medium. This would build upon an existing shell format, the *XMF*. The IASIG defines the original *XMF* as:

> *XMF* (eXtensible Music Format) is a low-overhead, meta file format for bundling collections of data resources in one or more formats into a single file. It was developed by the MIDI Manufacturers Association and published in October of 2001.

The *iXMF* would be the interactive *XMF*, allowing for

> … an open-standard, cross-platform means for audio artists to bundle audio content files with general information and audio implementation instructions.

The group also notes how the *iXMF* could spur industry progress:

> Initially, it will be highly beneficial for the game industry, and since it may be used in any interactive audio application a potential to expand or create markets in other areas exists. This new file format will put artistic control into the hands of the artists, keep programmers from having to make artistic decisions, eliminate rework for porting to new platforms, and reduce production time, cost, and stress ("IASIG Interactive XMF Workgroup").

The *iXMF/Interop* standard could truly revolutionize the game audio industry. Faster, more efficient audio and music pipelines, greater cross-compatibility, and more artistic game audio integration could usher in a new era of audio development.

Both the advent of DAW-specific technologies such as *Max for Live* and coming format standards like the *iXMF/Interop* container codec are very promising for game audio and music production. It may be possible to one day export a project into a single format that can be read by audio middleware or game engines. The technology already exists with the *AAF*, *OMF*, and *XMF* formats, so it is realistic to posit that more interactive options are coming.

Audio software plugin manufacturers may play a large role in this game audio cross-pollination and eventual merger. iZotope Software, developers of popular audio plugins for traditional linear mixing, mastering, and restoration, has strongly asserted itself in the game audio community in recent years. The 2012 Microsoft release *Forza Motorsport 4* featured a version of iZotope's *Trash* distortion plugin that was directly integrated in the sound engine (Westner, "iZotope Game Audio Technologies"). The company also recently partnered with Audio Kinetic, creators of the popular audio middleware *Wwise* (*WaveWorks Interactive Sound Engine*) to integrate various iZotope audio effects directly into their audio engine. This is added to the already included McDSP *ML1 limiter* and distortion effects – components that were previously only available for *Pro Tools*. Additionally, Audio Kinetic has partnered with Audio Ease to offer Altiverb impulse responses for *Wwise's* integrated convolution reverb[20] ("Audiokinetic Products"). Firelight is not far behind either, as the new *FMOD Studio* will feature effects from iZotope, McDSP, AudioGaming, and Little Endian ("FMOD Studio").

We are beginning to enter an era where audio effects will not necessary have to be "baked" directly into audio files. Rather, one audio file will be able to be processed in real time in a myriad of different ways, increasing flexibility and decreasing storage needs.

These DSP effects can also be added to music in real time. Of particular interest are beat-synchronized effects, which could be used to manipulate compositions in real time in accordance with game conditions. Tempo-synced delays,

[20] Convolution Reverb – Type of reverb that utilizes audio "impulse" definitions (delay and reverb characteristic "snapshots") of real acoustic spaces to create mathematical/algorithmic representations of each space. This allows the reverb characteristics of any aural space to be applied virtually to digital audio, through a simple mathematical expression.

filter modulation, multi-mode filter arpeggiation, and even live stutter editing and looping are all effects that exist in linear music production and could be easily ported into game engines. Interestingly, iZotope recently partnered with famed Electronica composer BT to release the plugin "Stutter Edit" for performing musical chopping on the fly. Though this software is currently limited to use in traditional digital audio workstations, it could eventually be integrated into a game engine. As iZotope has already asserted itself in the game audio market, there is a possibility that we could see more of its and other companies' music-oriented plugins added to audio middleware. The possibilities of this type of plugin in a game audio engine are exciting, and the ramifications to game music are profound. Many plugins of this nature could be applied to a composition in real time in a game, allowing for nearly infinite variations.

With such an industry leader taking such a large stake in game audio, it is not out of the question to assume that other plugin manufacturers will follow their lead. Perhaps even a DAW developer or virtual instrument company will enter the fray as well, and more musical tools will be built into existing audio middleware and game audio engines.

The day may not be very far off where a composer could open a *Pro Tools* multitrack session, complete with group-bussed stem mixes, individual tracks, effects inserts, automation, and dozens of different audio regions, export the session into a single file in the *iXMF/Interop* format (or an equivalent), and then open that file in *Wwise* and have all of the files, tracks, automation, and metadata transfer over and open flawlessly. The game engine could then be mapped to the *Wwise* session, allowing different game parameters to control different elements of the mix. The game itself could "ride the faders" of the different stem mixes, DSP parameters, and even the master transport. This could allow for a significantly adaptive and immersive score. And all the composer would have to do for this was export his or her existing DAW session in the right format.

8.2 Game Engine and Interface Progress

The possibilities for the breadth and intensity of adaptive music are also great. As the future of game development spurs new technologies for player-game interaction, music systems will have more and more data that can be used to affect musical messages. Games will become increasingly immersive, and will rely to a great extent on music to engross users. Music is already one of the most important controllers of mood and engagement in current games and its role will only increase in importance as games move ever closer to life-like virtual reality. In this future of powerful simulation, adaptive music will be absolutely critical. No longer will it just be a helpful tool, rather it will be a main ingredient in the recipe of emotional engagement.

There are exciting developments for the near future of dynamic music as well. Expansions on current game interfaces will soon yield more opportunities for flexible music systems. With technologies such as Microsoft's *Kinnect* infrared motion detection and motion-sensing controllers from Nintendo and Sony, games now have the unique ability to know where a player is and what he or she is doing. This has proved to be a popular trend and has led to new means of interacting with game environments. Still, the potential of these interfaces has not as yet been realized to it's full potential.

Rather than utilizing motion detectors, adaptive music systems could soon rely on *emotion* detectors. Cameras that track posture, jitters, and eye movement, controllers that sense heart rate and perspiration changes, microphones that detect vocal reactions, and game data that show differences in player reaction times and movement techniques could all be used to inform dynamic music engines on what specific emotional state a user is in. This data could then be used to tailor the musical content directly to their condition.

An April 2012 patent application by Microsoft reveals that the company is already planning on introducing such features with their Kinnect system and/or other "depth camera" technologies in the future. It explains 3D audio[21] and augmented reality[22] achieved by player tracking systems. In any surround sound or virtual 3D sound environment, there exists a "sweet spot" where the mix sounds ideal and accurately encapsulating for the listener. However, when single or multiple players are involved, it is unlikely that they will always be directly in this sweet spot. Microsoft

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[21] 3D Audio – Sound that completely envelopes a listener, where audio emitters can be identified by the listener in all directions. Can be achieved through surround sound setups, headphones, and phase-based stereo audio manipulation.

[22] Augmented Reality - The realtime enhancement of reality through digitally-generated sensory influencers. In this context, game sound effects and music would be applied in real time to affect individuals.

would hope to solve this by tracking a player's position and movements and adjust the audio mix accordingly to sonically optimize their location. Other methods of measuring player states, such as optional sensors and audio-based positioning through console and controller microphones, are two other possibilities (Baldwin, "Microsoft Applies for Patent on Augmented Reality, 3-D Audio").

All of these concepts and innovations will surely be used to better inform music engines. Having information on game states *as well as* player states would certainly benefit any variable music system. Games would be able to interpret a player's current emotional state, and then adapt the musical experience to fit or alter that state. If it was sensed that he or she was not frightened enough during a horror scene, the music could become increasingly tense and dissonant until the desired fear levels were detected.

It will only be at this point that music will be able to "play the player" equally as well as the player can play the game. There will undoubtedly be other technologies that will be used to measure player states and the effect of soundtracks on them. Adaptive music will become an increasingly personalized experience.

This will require more powerful and flexible music systems than exist today. Likely, a combination of prerecorded music with extensive horizontal re-sequencing and vertical re-orchestration coupled with generative and MIDI-based music will be obligatory since, at a certain point, there will be no plausible way to compose and record enough unique music to adequately cover an immersive and realistic gaming experience. In these scenarios music that can write and render itself based on the game states *and* player states will be necessary. Computers will never replace composers, but algorithmic-based elements will increasingly bridge the content and interactivity gaps.

With rising industry support, an increasingly skilled workforce, evolving production and integration software, increased standardization in software and file formats, new possibilities in user emotion tracking, and a hybrid approach of integrated pre-recorded music and real-time generated scores, the future of adaptive game music is undoubtedly bright. These trends will continue to push dynamic scores forward, and the quality of overall gaming experiences will improve as a result. As the advent of augmented reality and realistic virtual simulations draws near, game music is in a good position to rise to the occasion and allow for previously unheralded levels of immersion.

9. Adaptive Music In Games and Beyond

We are now seeing nonlinear writing styles emerge that have until recently been esoteric in nature. Games are the only practical, widely used medium that allows for nonlinear music playback. Listeners will experience game composers' music differently than they will music of most programmatic and chamber music composers. The interactive nature of games has always allowed game music to stand as a unique artistic style, but recent strides in game audio capabilities have taken things to an entirely new level.

The unique medium of games has also served as an ideal vehicle for classical art music of the 20th Century. Styles of music based on nonlinearity and chance events that saw little popularity among the general public have suddenly been at the core of some of the last decade's most popular game franchises. This aleatoric music has proven to be a perfect fit with unpredictable gaming experiences.

What we are seeing in game music engines may eventually lead to a new means of experiencing music itself. If interactive file formats and playback vehicles become more commonplace, musicians may begin to release more nonlinear music commercially. "Active" listening may begin to occur with listeners having the options to mix elements of songs differently, change orchestrations, alter arrangements, and manipulate tempos.

Early evidence of this can be seen in electronic music "mashup[23]" and remix communities. For years, artists have released vocal-free, acapella, and multitrack/stem mix versions of their songs so that others could remix and reinterpret them. An interactive music experience could allow for realtime remixing. This naturally leads to an aesthetic in which music is released that has no true linear version, just individual components. Music could be distributed as related chunks and segments, letting active

[23] Mashup - A relatively new genre of music that combines and superimposes snippets and/or loops of many different songs together into one hybrid song collage. Consistent tempos and keys tie the different elements together, creating a unique amalgamation of sound.

listeners complete the musical experience. In this scenario, the consumer/producer takes on the role that is currently served by video game engines.

Having even more manipulative capabilities over music and production elements would likely interest listeners who enjoy interaction. Humans clearly enjoy having the ability to control narrative storytelling, which the rise of video games, (not to mention interactive digital visual novels and choose-your-own-ending stories) has proven. The technology already exists to make nonlinear listening a reality, as it is the backbone of all dynamic game music systems. All that is needed is enough consumer appetite and artist support. Trends suggest that this level of demand will come; it's a matter of *when*, rather than *if*.

10. Concluding Thoughts

10.1 Main Concepts

After enduring a lull during the introduction of full-bandwidth audio support in gaming systems, adaptive music has returned to the forefront of game development. With each coming year, dynamic soundtracks move ever closer to being the expected norm in game music. Due to greater industry enthusiasm, expanding technological standardization, and an increased talent pool, the costs – in time and money – of incorporating flexible music systems are decreasing. Decades of experiments, proven successes, and professional acceptance have led to an environment where creating and implementing an adaptive score is more readily achievable than ever before.

Soon, new data input methods will allow for even more adaptability. Hardware will be able to monitor both game and player states, and will tailor the musical experiences to match. As we move ever closer to augmented and virtual reality experiences, dynamic scores will play an even bigger role in spurring user immersion.

As adaptive scores become ever more commonplace, the processes of game composers are being altered. Soundtracks must now be understood as combinations of different components, not as linear, looping pieces. Both the hundreds of years of nonlinear music experimentations and the ever-changing limitations of game consoles have had great influence on dynamic music. Re-sequencing, re-orchestration, generative music, and realtime parameter manipulation have now become the standard approaches to this new era of music, and these concepts will only increase in complexity in the future. Future games will feature a mix of prerecorded tracks, MIDI-driven sound chips and samples, and algorithmically generated musical elements, allowing for exponential variations.

While games are currently the only widely accepted medium that supports this nonlinear music, the concepts of adaptive and interactive music may soon be applied outside gaming. A trend of “active listening” may develop where music is presented as components, and with different variables and outcomes. The listener will decide instrumentation, arrangement, and other elements in much the same way that game engines currently determine the same characteristics in dynamic systems. It is very likely that game music will be looked back on as the catalyst for nonlinear music's rise in acceptance and popularity.

10.2 Call for Research

In researching this topic, it is evident that there is a significant lack of published data and theoretical analysis on adaptive game music. Perhaps it is because the majority of the experts in this field are too busy applying their knowledge and working in the industry, or perhaps it is that audio in games has also only recently become a popular topic in the education realm. In reality, it is likely a combination of these and many other factors. No matter the causation, there is a glaring lack of published research in this field.

It is my hope that as more composers become adept at producing dynamic soundtracks and more institutions offer courses and degrees in game audio, there will be a larger number of individuals willing and interested in furthering the academic research facet of this increasingly important topic. An enlarged pool of professionals and students will hopefully lead to more papers and theses like this. The need and opportunity are significant in a field that will have a great impact on the future of game audio and potentially, all future music listening experiences. Adaptive music is here to stay, so it follows that we strive to better understand and document its evolution.

Appendix A: Case Studies

This selection is by no means an exhaustive list of adaptive music titles. Each example shows a specific technique or a noteworthy accomplishment. There are literally hundreds, if not thousands of games that could be included in this list.

1. *Space Invaders* (Arcade, 1978)

The first video game to feature an adaptive score, *Space Invaders*, was released as an arcade unit in 1978. A simple four-note motif looped endlessly as long as the game was played the tempo of this loop increased in speed the longer the game was played. This would raise tension in the game, and ideally raise the player's heartbeat at a subconscious level (Collins, 12). Note: *Asteroids* (1979) also used a short loop of tones that sped up as the game progressed and is sometimes mistakenly considered the first game to have an adaptive score (George, "All About Asteroids").

2. *Super Mario Bros*. (Nintendo Entertainment System [NES],1985)

While still 8-bit, *Super Mario* features some of the most iconic game music of all time. The score was written by famed games composer Koji Kondo and features some adaptive elements. Most notably, the tempo of the music doubles when a player is running out of time to complete a level. (Nelson and Wunsche, 23; "Koji Kondo").

Its catchy monophonic[24] melodies are still recognizable more than two decades after the game was released[25].

3. *X-Wing* Series (Super Nintendo Entertainment System [SNES], 1993)

Lucas Arts' and Totally Games' *Star Wars*-based franchise, whose first installment was in 1993, featured MIDI versions of John Williams's compositions. The pieces were broken down into components and analyzed. The score was implemented with the *iMUSE* music engine, which was patented and exclusively used by Lucas Arts. It allowed for complex interactions between gameplay and a library of music segments, loops, cues, and transitions. Because of this technical superiority to other audio systems, the games' soundtracks featured levels of adaptability that were unrivaled at in their time. The *iMUSE* engine went on to be used by Lucas Arts to great success in many subsequent titles (Clark, 1).

4. *Myst* (Mac, 1993)

Developed by Cyan, *Myst* made huge strides in the implementation of dynamic game music. The highly ambient score blended with the diagetic[26] sound effects to create an immersive audio environment. Because it was computer-based, it had audio

[24] Monophonic – capable of producing only one note or sound at a time. Integrated sound chips usually featured several monophonic "voices."

[25] A survey in the late 1990's revealed that 66% of college students could hum and indentify the main *Mario* theme, while only about half knew the theme to *Star Wars*. Very few pieces of music in any form – film, pop, classical, or theater – see the lifespan and iconic status that this game theme did, not even one of the most successful movie franchises of all time (Belinkie, *VG Music, Not Just Kid Stuff*).

[26] Diagetic - Sounds eminating from within the virtual game world.

capabilities exceeding those of contemporary console games. Most importantly, the ability to stream pre-recorded music files instead of playing synthesized sounds with code or a MIDI file resulted in a much higher-quality music experience. Primitive use of vertical re-orchestration and layering techniques allowed the soundtrack to be less repetitive, and more dynamic than other game scores of the time (Paulus, 8).

5. ***Tomb Raider*** (Playstation, 1996)

One of the first game titles to feature nonlinear music cues was *Tomb Raider*, released by Eidos in 1996. This popular game featured selective music placement based on what was occurring in the game in lieu of having background music continuously playing (Lendino, "Get in the Game").

6. ***Quest for Glory V: Dragon Fire*** (Mac & Windows, 1998)

Released by Sierra for PC's in 1998, *Dragon Fire* made huge strides for adaptive game music as a whole. Composer Chance Thomas describes the ways in which *Dragon Fire* was innovative for its time.

> *Quest for Glory V* was one of the first American games to use a live orchestra. We designed one of the world's first adaptive music systems using digital audio streams while everyone else was still using MIDI. The *Quest for Glory V* soundtrack album sold more than 50,000 units, which was remarkable at that time. And it was the *Quest for Glory V* score that first opened the dialog with the National Academy of Recording Arts and Sciences about bringing game music into the Grammy Awards.

Dragon Fire's many innovations raised game music to a new level of legitimacy among fans and critics and confirmed that dynamic music could have a great affect on the impact of a game soundtrack. For many games released today, live orchestras and audio-based adaptive music streams are standard place. These games owe much to Chance Thomas and *Quest for Glory V* ("Chance Thomas Interview").

7. *Tomb Raider Legend* (Playstation 2, Xbox, Xbox 360, Windows, Others, 2006)

In 2006, the *Tomb Raider* franchise was once again the vehicle for boundary pushing dynamic music techniques. *Legend* utilized a system devised by composer Troels Folmann that he called "micro-scoring." In this system, Folmann composed a large number of short musical phrases, themes, and statements, which were then cued up in real time by the game engine. The snippet that was cued at any given time was largely influenced by player actions and the game state. Different elements in the game (such as puzzle objects or different characters) had their own unique musical themes and short phrases (the concept of leitmotif). These components would be blended in real time with the base score, creating a seamless, dynamic music environment. Folmann goes into detail about the system

> You have to imagine that there are thousands of things going on in the game environment — the idea behind micro scoring is to support the major elements in the environment. An example can be a 5-second score for breaking pillars or rolling stones. While motion picture scoring would typically have a musical element to support such an action, it would normally be dismissed in the game world…micro-scores allow us to support that action. For *Tomb Raider: Legend*, we spent a long time creating a highly advanced proprietary streaming system that allows us to trigger micro-scores all over the game world. So,

> essentially, I can place scores for any change in the game ("Interactive Music in Games").

The concept of micro scoring has had a huge influence on modern game scores. Many of the *Tomb Raider: Legend* musical approaches can be seen in even the most recent games.

8. *Halo* Series (Xbox, Xbox 360, Mac, Windows, 2001-Present)

No discussion of adaptive game music would be complete without mention of the *Halo* series. The wild popularity of the original *Halo,* which was released on Xbox and later on PC and Mac, had a far-reaching impact on the game industry as a whole. The soundtrack quickly became iconic, and the main themes are now instantly recognizable to an entire generation of gamers. Developed in partnership between Microsoft and Bungie game studios, *Halo* utilized a dynamic music system that adapted and matched game action better than most scores of the time. The audio engine that made this possible was developed in-house and is still something of a trade secret. It has been expanded on as each new game has been added to the franchise – *Halo 2, 3,* and the most current *Reach* have had increasingly immersive audio experiences.

The audio team for these games, led by Bungie Audio Director and Principle Composer Marty O'Donnell, pushed the boundaries with each release. The music system uses a complex combination of vertical re-orchestration and horizontal re-sequencing, mixed with some randomization and variable elements to create a fitting yet non-repetitive score that manages to avoid subjecting players to the same musical sequences over and over, a common shortcoming in even the most current releases (O'Donnell, "From Myth to Halo").

9. *Killzone* Franchise (PS2, PS3, PSP, PS Vita, 2004-Present)

The *Killzone* franchise, features scores that utilize many different adaptive compositional approaches. In a radio interview that he did with BBC Radio 4, *Killzone I, II, & III* composer Joris de Man notes

> …the crescendos and all the dynamism in the music come from the music engine reacting to how you play and what's happening on screen. So if there are lots of enemies on screen or you're in an intense firefight then the music will really pick up and it will play one of the higher intensities of music, whereas if you're just…running around then the music engine will just pick a very low-intensity cue. So there might just be some sporadic percussion and some light string bits or synth sounds (Dey, "Approaches to Creating a Dynamic Audio Experience in Video Gaming").

10. *Red Dead Redemption* (PS3, Xbox 360, 2010)

The success of the game and soundtrack has shed light on *Red Dead Redemption*'s terrific adaptive score. Compositionally strong, the dynamic and ever-adjusting soundtrack makes for a highly immersive environment. The game has been praised for its deep, open-world gameplay – this wouldn't have the same effect if the music didn't follow the user-directed happenings within the game.

The entire soundtrack was composed using music *stems* or different elements of music that can be mixed in and out on their own. An example of a single stem would be a bass line or a percussion part. *Redemption* used a large pool of stems, all recorded in the key of A minor, at a tempo of 130 beats per minute. Different stems can be brought in and out of the audio mix at different times, depending on what is happening in the game. Because all of the stems share a common key and tempo, they can all be interchanged and matched with one another. This is a prime example of vertical re-orchestration, and has some elements of rural composition, (as mentioned in the “Adaptive Music History” section).

For example, when the player starts riding a horse, a signature bass line begins playing; when he or she begins to be chased by enemies, rolling timpanis are brought in. In this scenario, the game engine can create a unique musical experience for any set of events, just by cueing different stems to interact with each other. Quite simply, all of the efforts on the score have more than paid off. The game and its soundtrack have gone on to win dozens of awards ("Red Dead Redemption - Soundtrack Behind the Scenes”).

Appendix B: Professional Perspectives

Based on these trends discussed in this thesis, the author sought to find industry perspective on the future of adaptive music in games from professionals currently working in the field.

Lance Hayes, who composes music under the artist name DJ Drunken Master (DJDM) and whose credits include the *Forza Motosport* series (Microsoft) and *Gears of War* (Microsoft, Epic), recently shared some of his thoughts on adaptive music and its importance to career success. In regards to how critical the ability to compose adaptive music is to a composer's career prospects in the game industry, he states that "It's the cornerstone to everything that is happening in games right now, so I think it's very important" (Hayes, "Adaptive Music Thoughts").

Award-winning composer **Sean Beeson** shares his view of the increasing significance of adaptive music and notes a disconnect in the industry's view of adaptive music. He states

> I think adaptive music as a theory is very awesome[. E]xecuting it is not only a challenge, but the people who hire composers for games also don't realize the extra time/energy that is put into doing adaptive scores, and don't want to pay extra for it, so it is kind of a detriment to certain composers for doing that as well.

Beeson speaks from direct experience, as the majority of his soundtracks are for independent and mobile games, which don't usually have the budget for an in-depth adaptive music system. As noted earlier, in this class of games, there is usually a system of layering per the theory of vertical re-orchestration. Beeson notes the slight difference between “dynamic” and “adaptive” in such a system. “I have done some dynamic music (mostly layering) for games, but I don't know if I would call that adaptive... It is, but not in the *FMOD* sense” (referring to integration methods associated with the popular audio middleware) (Beeson, “Thoughts on Adaptive Music”).

Rik Nieuwdorp, an expert in dynamic game music and head of the adaptive music-focused composition/production company Claynote, shares views on a range of issues related to dynamic scores. In regards to the environment for composers currently in the industry, he notes

> In my experience the idea of implementing an adaptive music system in a game is still something that originates from the audio department (composers), who would like to make the most of the auditory experience of the game. This process is often a battle to convince the game developer to put in a little bit more of an effort programming-wise to gain a lot more of an immersive gaming experience. In these cases the composers usually already know how to design such an adaptive system, of course, and are familiar with the added value of adaptive music.

He also discusses how the variable soundtracks are becoming more of the norm:

> [B]asic adaptivity in game music is starting to gain ground in even the most high-profile games (games like *Killzone* or *Dead Space* for instance, as opposed to arty and/or indie games in which experimentation is permitted and sought after) due to technological advances and a general growth in attention to all aspects of game development. For these reasons I would describe the knowledge of composing for & designing adaptive music systems for games as highly valuable if not necessary for future game music composers (Nieuwdorp, “Future of Adaptive Music”).[27]

[27] It should be noted that the discussions in this interview led the to Nieuwdorp’s eventual writing of an article in *Control Magazine* addressing the same topics. It can be accessed at: <http://www.controlmagazine.net/2012/03/18/the-comeback-of-adaptive-game-music> (Nieuwdorp, *Comeback of Adaptive Music*).

The concept that adaptive music as a necessary career attribute is becoming more and more standard, and Nieuwdorp is not alone in thinking so. Previously discussed composer **Troels Folmann** shares a similar point as well:

> The ability to understand game technologies and mechanics is becoming increasingly important for the composer. The amount of complexity and micro scoring will increase in order to ensure a smooth and complimentary game experience. There is no doubt that adaptive mechanisms do change the way I compose and approach scoring.

He also goes on to prognosticate about the importance of dynamic scores in the future of game development.

> The trend of games – particularly next-generation 360 and PS3 – is one of complexity. Everything is getting more detailed, whether it's multiple translucent layers of textures, real-time generated light and shadow maps, massive streaming game worlds and so forth. Audio and music is no exception. The need for dissecting music into smaller fractions is becoming increasingly important in order to support the decisions and experiences of the player (Latta, "Interactive Music in Games").

This trend of complexity will continue to blossom as game music continues to evolve.

Heralded composer **Jason Graves** shares why technological developments have such an impact on creative abilities:

> A large part of truly adaptive and interactive game music is dependent on technology - RAM available, storage capacity, etc. However, the most important part of an adaptive score is the people who develop the games and HOW they implement the music. For *Dead Space*, Don invented a "Fear Emitter" that the music reacts to on a scale, from levels 1 to 4. I then composed all of my pieces with that four layer system and split each cue into four different layers of intensity. The game engine does the rest by interpreting the player's actions and fading up or down the different music layers accordingly.

He also speaks to where new technologies will take us, and what adaptive music will look like in five to ten years.

> I think everything is going to continue to get more and more interactive, and not just the way the music plays in the game….Games are finally starting to catch up a little bit with film and there's an amazing immersive, cinematic experience a few titles offer. Now they need to emphasize the biggest advantage games have over film - interactivity. Branching storylines, different plots or completely different endings based on the decisions the player made through the game. I hope in five years that's simply what's expected in any decent title (GSoundtracks, "Interview with Composer Jason Graves.")

It is clear from Graves' statements as well as the other composers that there is genuine excitement for the future of adaptive soundtracks. The coming years will indeed be exciting, and there is no doubt that these five composers will be right at the epicenter.

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Works Cited

"Audiokinetic Products." *Audiokinetic*. 2012. Web. <http://www.audiokinetic.com/en/products>

Baldwin, Roberto. "Microsoft Applies for Patent on Augmented Reality, 3-D Audio." *Wired Magazine: Gadget Lab*. 20 April 2012. Web. <http://www.wired.com/gadgetlab/2012/04/microsoft-applies-for-augmented-reality-3d-audio-patent/>

Beeson, Sean. "Thoughts on Adaptive Music." E-mail interview. 2 Feb. 2012.

Belinkie, Matthew. *VG Music, Not Just Kid Stuff*. Paper. Video Game Music Archive. 15 Dec. 1999. Web. <http://www.vgmusic.com/vgpaper.shtml>

Bernt, Axel, Knut Hartmann, Niklas Röber, and Maic Masuch. "Composition and Arrangement Techniques for Music in Interactive Immersive Environments." *Proceedings of the Audio Mosty Conference*. Audio Mosty Conference - a Conference on Sound in Games, Interactive Institute, Piteå, Sweden. 12 Oct. 2006. Electronic PDF.

Boulez, Pierre. *Orientations*. M. Cooper, Trans. Cambridge: Harvard University Press, 1986. Print.

Carlile, Simon. "The Psychophysics of Immersion and Presence." 2011 Game Developers Conference. Moscone Center, San Francisco. 1 Mar. 2011. Presentation.

Childs IV, G. W. *Creating Music and Sound for Games*. Course Technology PTR,

2006. Print.

Clark, Andrew. "Defining Adaptive Music." *Gamasutra*. 17 Apr. 2007. Web. <http://www.gamasutra.com/view/feature/1567/defining_adaptive_music.php>

Collins, Karen. *Game Sound*. Cambridge: MIT Press. 2008. Print.

Dey, Rachel. "Approaches to Creating a Dynamic Audio Experience in Video Gaming." *Rachel Dey - Game Audio Designer and Musician*. 2011. Web. <http://racheldeymusic.tumblr.com/post/4613919594/approaches-to-creating-a-dynamic-audio-experience-in>

Esch, Paul "Wallace." *Music For a Tragic Prince: A Look at the Music of Castlevania*. The Castlevania Dungeon. Web. <http://www.castlevaniadungeon.net/features/castlevaniamusic.html>

Forney, Kristine and Joseph Machlis. *The Enjoyment of Music*. 10th Ed. New York: W.W. Norton & Company, Inc., 2007. Print.

"FMOD Studio." *FMOD Interactive Audio*. Firelight Technologies. 2012. Web. <http://www.fmod.org/fmod-studio.html>

“FMOD Studio Demonstration.” Game Audio Network Guild Awards After-Party, Pyramind Studies, San Francisco. 8 Mar. 2012. Product Demonstration.

Gardner, Martin. *The Colossal Book of Mathematics: Classic Puzzles, Paradoxes, and Problems: Number Theory, Algebra, Geometry, Probability, Topology, Game Theory, Infinity, and Other Topics of Recreational Mathematics*. New York: W.W. Norton and Company, Inc., 2001. Print.

George, Gregory. “All About Asteroids.” *The Atari Times*. 7 September 2001. Web.

Graves, Jason and Gary Schyman. “The Art of Noise – Incorporating Aleatoric Music In Your Orchestral Scores.” 2012 Game Developers Conference, Moscone Center, San Francisco. 8 March 2012. Presentation.

GSoundtracks. “Chance Thomas Interview.” *GSoundtacks*. Web. <http://www.gsoundtracks.com/interviews/thomas.htm>

GSoundtracks. “Interview with Composer Jason Graves.” *GSoundtacks*. Web. <http://www.gsoundtracks.com/interviews/graves.htm>

Hayes, Lance. “A Composer’s Perspective on Game Audio – Adaptive Audio Concepts and Work Flow.” *Keyboard Magazine: Keyboard Blogs*. May 2011. Web. <http://www.keyboardmag.com/default.aspx?tabid=130&EntryId=329>

Hayes, Lance. “Adaptive Music Thoughts.” E-mail interview. 1 Nov. 2011.

"IASIG Interactive XMF Workgroup (IXWG)." *IASIG*. 1 Oct. 2009. Web. <http://www.iasig.org/wg/ixwg/>

Jewell, Michael O. *Motivated Music: Automatic Soundtrack Generation for Film*. Thesis. University of Southampton, 2007. Electronic PDF.

Kalata, Kurt. “Ys,” *Hardcore Gaming 101*. 27 Nov. 2010. Web. <http://hardcoregaming101.net/ys/ys.htm>

“Koji Kondo.” *IMDb: The Internet Movie Database*. Database Entry. 2011. <http://www.imdb.com/name/nm0464848>

Kosak, Dave. “The Beat Goes on: Dynamic Music in Spore.” *GameSpy*, 20 Feb. 2008.

Web. <http://pc.gamespy.com/pc/spore/853810p1.html>

Kostka, Stefan and Dorothy Payne. *Tonal Harmony*. 6th Ed. New York: McGraw Hill, 2008. Print.

Latta, West B. “Interactive Music in Games.” *Shockwave-Sound.com.* Web. <http://www.shockwave-sound.com/Articles/C01_Interactive_Music_in_Games.html>

Latta, Westlee. CDM Interview: Tomb Raider: Legend Composer Troels Brun Folmann on Adaptive “Micro-Scoring,” *Create Digital Music*. 11 Oct. 2006. Web. <http://createdigitalmusic.com/2006/10/cdm-interview-tomb-raider-legend-composer-troels-brun-folmann-on-adaptive-micro-scoring>

Lendino, Jamie. “Get in the Game.” *Electronic Musician*, 13 Oct. 2011. Web. <http://www.emusician.com/news/0766/get-in-the-game/142053>

Marks, Aaron. *The Complete Guide to Game Audio*. 2nd ed. Burlington, MA: Focal Press, 2009. Print.

Marks, Aaron and Jeannie Novak. *Game Development Essentials: Game Audio Development*. Clifton Park, NY: Delmar Cengage Learning, 2009. Print.

McGowan, Jim. “Interactive Music in Games.” *Bleeps and Pops*. 16 Oct. 2010. Web. <http://bleepsandpops.com/post/1329178272/interactive-music-in-games>

McDaniel, D., Rick Shriver, and Kenneth Collins. *Fundamentals of Audio Production*. United States: Pearson Education, Inc, 2008. Print.

McDonald, Glenn. “A History of Video Game Music.” *Gamespot*. 2009. Web.

<http://www.gamespot.com/features/6092391/p-2.html>

Moore, Lennie. "Creating Adaptive Music." 2011 Game Developers Conference. Moscone Center, San Francisco. 1 Mar. 2011. Presentation.

Morgan, Robert P. *Twentieth-Century Music: A History of Musical Style in Modern Europe and America*. New York: W. W. Norton & Company, Inc., 1991. Print.

Nelson, Chris and Burnkhard C. Wunsche. "Game/Music Interaction - An Aural Interface for Immersive Interactive Environments". *Eighth Australasian User Interface Conference*. Australian Computer Society, Inc. 2007. Paper, Electronic PDF.

Nieuwdorp, Rik. "Future of Adaptive Music." E-mail interview. 21 Feb. 2012.

Nieuwdorp, Rik. "The Comeback of Adaptive Game Music." *Control Magazine (beta)*. Control Magazine, 18 Mar. 2012. Web. <http://www.controlmagazine.net/2012/03/18/the-comeback-of-adaptive-game-music/>

Noguchi, Hideo. "Musical Game in C K.516f." *Mozart Studies Online*. 28 Dec. 1997. Web. <http://www.asahi-net.or.jp/~rb5h-ngc/e/k516f.htm>.

O'Donnell, Marty. "From Myth to Halo: Marty O'Donnell's Adventures with Adaptive Audio, Creative Collaboration and Geese!" 2011 Game Developers Conference, Moscone Center, San Francisco. 3 Mar. 2011. Presentation.

Oron, Aryeh and Joseph Stevenson. "Johann Phillipp Kirnberger (Composer, Music

Theorist).” *Bach-Cantatas.com*. Poets & Composers. December 2005. Web. <http://www.bach-cantatas.com/Lib/Kirnberger-Johann-Philipp.htm>

Paulus, Edo. “The Use of Generative Music Systems for Interactive Media.” Paper. 2002. <http://www.scribd.com/doc/62997591/The-use-of-Generative-Music-Systems-for-Interactive-Media>

Rockstar Games. "Red Dead Redemption - Soundtrack Behind the Scenes." *YouTube*. 29 July 2010. Web. <http://www.youtube.com/watch?v=vEsknPy5rvg>

Sherrane, Robert. "The Romantic Era: Richard Wagner." *Music History 102: A Guide to Western Composers and Their Music*. Ipl2. Web. <http://www.ipl.org/div/mushist/rom/wagner.html>

Schulze, Hogler. (2003). “Hand-Luggage: For a Generative Theory of Artifacts.” *Leonardo Music Journal, vol. 13*. MIT Press, 2003. Electronic PDF.

“Sound Generators of the 1980s Home Computers.” *Student-Run Computing Facility*. University of Cambridge. 28 Nov. 2005. Web. <http://www.srcf.ucam.org/~rga24/computer/music/>

Stevens, Richard and Dave Raybould. *The Game Audio Tutorial*. Burlington, MA: Focal Press, 2011. Print.

Vickery, Lindsay. "The Evaluation of Nonlinear Musical Structures." *Sound Scripts: Proceedings of the 2009 Totally Huge New Music Conference*. 2009 Totally Huge New Music Conference. Vol. 3. 2011. Electronic PDF.

Westner, Alex. “iZotope Game Audio Technologies.” 2012 Game Developers

Conference, Moscone Center, San Francisco. 8 Mar. 2012. Expo Floor Presentation.

Wilde, Tyler. “Portal 2’s Dynamic Music – An Interview with Composer Mike Morasky.” *Games Radar*. 13 April 2011. Web. <http://www.gamesradar.com/portal-2s-dynamic-music-an-interview-with-composer-mike-morasky-and-five-tracks-to-listen-to-now>