

Dynamic Response: Real-Time Adaptation for Music Emotion

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ABSTRACT

Music plays an enormous role in today's computer games; it serves to elicit emotion, generate interest and convey important information. Traditional gaming music is fixed at the event level, where tracks loop until a state change is triggered. This behaviour however does not reflect musically the in-game state between these events. We propose a dynamic music environment, where music tracks adjust in real-time to the emotion of the in game state. We are looking to improve the affective response to symbolic music through the modification of structural and performative characteristics through the application of rule-based techniques. In this paper we undertake a multidiscipline approach, and present a series of *primary music-emotion structural rules* for implementation. The validity of these rules was tested in small study involving eleven participants, each listening to six permutations from two musical works. Preliminary results indicate that the environment was generally successful in influencing the emotion of the musical works for three of the intended four directions (happy, sad and content/dreamy). Our secondary aim of establishing that the use of music-emotion rules, sourced predominantly from Western classical music, could be applied with comparable results to modern computer gaming music was also generally successfully.

Categories and Subject Descriptors

J.5 [Arts and Humanities]: Performing Arts

General Terms

Music

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Keywords

Computer Music, Emotion

1. INTRODUCTION

The incorporation of sound into media first appeared around the turn of the century with its use in cinema; here live orchestration was used to cover the extraneous sound of the movie projector. However the music also served as a means to highlight and explain the story plot [3]. These early psychological underpinnings are present today, with the field of video games and film scoring having matured into the essential story-telling role that it now plays. The current generation of computer games employ two distinct forms of music: cut-scenes and game-play. While cut-scene scoring has evolved to a level of sophistication paralleling that of the cinema, game-play music has lagged. Much of today's game-play music is event based¹ and uses looped audio tracks associated with event triggers as a means of coordinating music and on-screen action. With this type of approach the music becomes repetitive, leading to a collapse of user interest as a result of a move from a state of music expectation to music certainty [18]. This occurs after a short to medium gaming period, when the user becomes adept at determining game-state information from the music track. Once a player determines level-difficulty/game-state information from the track, the music ceases in a functional role and becomes a mild distraction; it is at this point the user begins to 'tune it out'. This differs to cinema and cut-scene scores where, although also largely event-based in nature, the music is fluidic on an intra-scene level. This behaviour results from its close integration with the storyline, where the music operates under a continuous adaptation principle. By this we mean that the music continuously adapts to the progressing storyline throughout the scene, reflecting intra-scene events. While storyline emotion is largely quantised at the scene/event level, the ignorance of intra-scene emotional flux reduces the purpose of music to simple event notification. As we know from cinema, the ability of a film score

¹ An event typically refers to either a movie scene change, or important knowledge being obtained resulting in modification of in-game emotion of the current scene

to bring about a change in the user's emotional state is profound. This ability results primarily from the subtle reflexive control between the storyline and film score throughout a single scene. This fine degree of control is possible as the composer has the opportunity to fine tune the score to match the linear narrative of the film.

The current level of sophistication employed in the modulation of symbolic gaming music to reflect the emotion of game-play events is low. Typical methods involve the use of pre-generated MIDI files which are mixed and loaded at run-time, commonly through the use of Direct Music producer [19]. However this method is limited by an inadequate level of granularity that does not match the dynamic nature of game play, in which there is little ability to predict ulterior user actions over a long timescale and respond to subtle changes in the moment-by-moment mood changes in the game. Just as computer graphics made the move from pre-rendered objects to real-time rendering so too must computer music. Examples of this trend include "No One Lives Forever" [26], where location based triggers were tied with game-AI states to produce truly adaptive music [1]. However, the music was far from the emotionally adaptive form seen in cut-scene music, with simple harmonic, loudness and tempo techniques being used to affect change. Generating and adapting emotionally meaningful music in real-time poses a series of theoretical and technical hurdles not faced before by the music world. To achieve this requires an understanding of how music rules relate to the emotion perceived by the listener.

2. Current Research

Research into the rules of musical emotion is divided largely between two camps, the structural and the performative. Structural aspects relate largely to the notated music score itself, while performative rules are concerned with the interpretive performance of the score as it is rendered for audio playback. Research into the structural and performance aspects of music have been ongoing since the turn of 20th century. While the structural aspects of music relating to emotion have received continuous attention, it was not until the mid 1970s that performative emotion research began [6, 10] in earnest. Precisely what aspects of music fall under the title 'structural' or 'performative' is still open to interpretation, its amorphous nature due in part to the evolution of Western music notation. In the baroque era, performance articulations on the score were all but non-existent², but by the classical period had developed into a memorable stricture³. By the early 20th century serialist composers were routinely annotating their scores with detailed performance markings. Throughout history, folk music's relying on aural transmission between performers where improvisation is privileged, has routinely maintained interpretive knowledge as a cultural artefact. In this paper however, we have adopted the

² In Johann Sebastian Bach's Brandenburg Concerto No. 3, no mood or tempo indications were added. Due to the period's rigorous conventions on composition, no tempo indication was required.

³ Beethoven's piano sonata number 31, third movement was notated "Adagio ma non troppo; Arioso dolente; Gaa; Allegro, ma non troppo; L'istesso tempo di Arioso; L'inversione della Fuga"

approach put forward by Gabrielsson and Lindstrom [9], where a balance of notated and culturally implied interpretive parameters are assumed. Annotation [7] refers to immanent and performed musical accents, where "Accents may be either immanent to a (notated) musical work or added to the music during performance" [21, 22].

Structural rules attempt to explain information encoded in a musical work by the notation of the composer. Those falling loosely into this category include: tempo, mode, loudness, pitch, interval, melodic range, direction and motion, harmony complexity, tonality, rhythm, timbre, articulation, amplitude envelope and musical form. Performative rules refer to all the score variations a performer employs (e.g., rubato, vibrato, intonation). These occur both as a means to personalise the performance [10] and as a result of a human's natural emotion transference characteristics [11].

Due to the lengthy timescale over which this field of research has been carried out, numerous techniques have been used to gauge the emotional response of music and the derivation rules associated with it [24]. This diversity has complicated any collation processes, as have the numerous methods of gathering data. For example, the oft-used 'open ended' technique of research respondents inditing a paragraph response does not easily correlate with other measures such as the rating scale, where respondents select a numerical intensity value for each of the emotions in a pre-selected list. Over the past century, many empirical musical studies have been conducted, in [8] 81 studies were compiled and comparatively reviewed. The scale of such indexing is outside the scope of this work; however we have performed a comparative review of existing major summary works.

3. Music-Emotion Rules

3.1 Collation

For meaningful results to be deduced, a common metric of emotion representation must be used. We have selected the 2 Dimensional Emotion Space (2DES) [20] as the base metric for the following three reasons. First, its continuous numerical form is well suited to a computational implementation. It allows for a greater degree of control in the application of music-emotion rules where, for example 'fast tempo' can be given a variable range ↔ emotion influence value. Second, we have independently developed an advanced 2DES tool for gathering emotional response data. The data presented here is to be integrated with future collected data sets. Thirdly, the widely used Hevner adjective circle response measure translates well into the 2DES system, with a detailed translation process described in [24]. Table 1 provides a summation of the studies examined [8, 9, 11, 24]. In this work we focused primarily on indexing structural music emotion rules. These rules are sorted by an octal-based form of the 2DES system (traditionally divided into quadrants), as illustrated in figure 1.

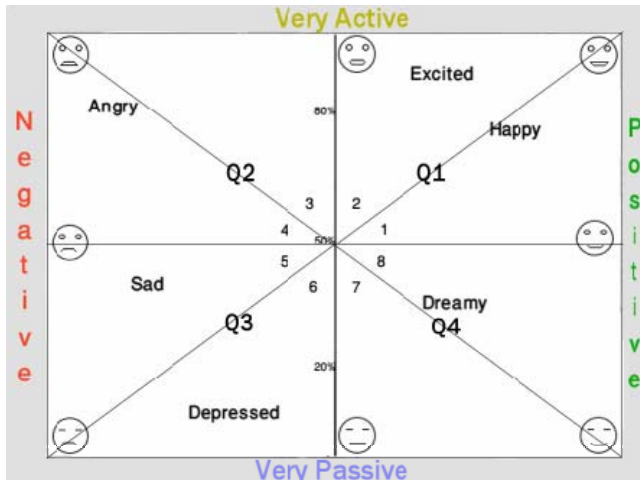


Figure 1. 2 Dimensional Emotion Space in Octal Form

Sorting by octant aids the implementation process where the system is primarily concerned with the desired emotion, not

music rule type. Table 1 summarises the musical rules that reportedly are associated with each octant. Beside each rule type in table 1 is the number of studies (in parenthesis) which yielded the same result, rules found in three or more studies are emboldened. Those rules found in two or all three of the compilation studies investigated are italicised. Due to the fact that the works examined each reviewed a large number of studies, overlapping sources were frequent, as such duplicates were discounted in the music-rule study tally. The paper count is not completely accurate, as music-rule paper counts could not be extracted from [11]. It should be noted that while the progressive work of [16] has been reviewed, the results have not been included as it required a level of musical sophistication which exceeds our system's present capability. Specifically, it required a partial implementation of Meyer's music tension model [18] along with advanced music-theory concepts. Similarly, music-emotion rules from the compilation studies that also required a high degree of sophistication were not included.

Table 1. Comparative 2DES literature Review

Octant	2DES Octant Rules
1	<i>Mode Major(19), Tempo Fast(16), Harmony Simple(8), Loudness Loud(7), Articulation Staccato(5), Pitch High(3), Rhythm Flowing(3), Pitch Range High(2), Pitch Variation Large(2), Pitch Contour Up(2), Note Onset Rapid(2), Rhythm Smooth(2), Rhythm Activity(2), Loudness Medium(1), Loudness Soft(1), Loudness Variation Small(1), Loudness Variation Rapid(1), Loudness Variation Few(1), Pitch Low(1), Pitch Range Low(1), Pitch Contour Down(1), Timbre Few(1), Rhythm Rough(1)</i>
2	<i>Tempo Fast(20), Loudness Loud(10), Mode Major(8), Pitch High(4), Pitch Variation Large(4), Harmony Simple(4), Note Onset Rapid(4), Pitch Range High(3), Pitch Contour Up(3), Articulation Staccato(3), Articulation non-legato(2), Harmony Complex(2), Rhythm Flowing(2), Rhythm Activity(2), Rhythm Smooth(2), Loudness Variation Small(1), Loudness Variation Few(1), Loudness Variation Rapid(1), Pitch Low(1), Pitch Range Low(1), Pitch Variation Small(1), Pitch Contour Down(1), Timbre Few(1), Timbre Many(1), Tempo Slow(1), Vibrato fast(1), Rhythm Complex(1), Rhythm Firm(1), Metre Triple(1), Tonality Tonal(1)</i>
3	<i>Mode Minor(14), Loudness Loud(9), Tempo Fast(9), Harmony Complex(8), Note Onset Rapid(5), Pitch Contour Up(5), Pitch High(4), Pitch Range High(3), Pitch Variation Large(3), Loudness Soft(2), Rhythm Complex(2), Loudness Variation Large(2), Timbre Sharp(2), Articulation Non-legato(2), Pitch Variation Small(2), Articulation Staccato(2), Note Onset Slow(2), Timbre Many(1), Vibrato Fast(1), Rhythm Rough(1), Metre Triple(1), Tonality Tonal(1), Tonality Atonal(1), Tonality Chromatic(1), Loudness Variation Rapid(1), Pitch Low(1)</i>
4	<i>Mode Minor(12), Harmony Complex(6), Articulation Legato(3), Pitch Variation Small(3), Tempo Fast(3), Loudness Loud(2), Loudness Soft(2), Loudness Variation Large(2), Note Onset Rapid(2), Note Onset Sharp(2), Note Onset Slow(2), Timbre Sharp(2), Loudness Variation Rapid(1), Pitch High(1), Pitch Low(1), Pitch Range High(1), Pitch Variation Large(1), Pitch Contour Up(1), Pitch Contour Down(1), Timbre Many(1), Harmony Melodic(1), Tempo Slow(1), Articulation Staccato(1), Rhythm Complex(1), Tonality Atonal(1), Tonality Chromatic(1)</i>
5	<i>Tempo Slow(15), Articulation Legato(6), Mode Minor(7), Harmony Complex(7), Loudness Soft(3), Harmony Simple(3), Pitch Low(3), Note Onset Slow(3), Pitch Range Low(2), Pitch Contour Down(2), Rhythm Firm(2), Loudness Loud(1), Loudness Variation Small(1), Loudness Variation Few(1), Pitch Variation Small(1), Pitch Contour Up(1), Mode Major(1), Timbre Few(1), Timbre Soft(1), Harmony Melodic(1), Note Onset Rapid(1), Vibrato Deep(1), Rhythm Smooth(1), Tonality Chromatic(1)</i>
6	<i>Loudness Soft(5), Tempo Slow(5), Pitch Variation Small(3), Articulation Legato(3), Note Onset Slow(3), Pitch Low(3), Pitch Range Low(2), Loudness Variation Rapid(1), Pitch High(1), Pitch Contour Down(1), Mode Minor(1), Timbre Few(1), Harmony Complex(1), Vibrato Deep(1), Metre Duple(1), Tonality Tonal(1)</i>
7	<i>Tempo Slow(10), Loudness Soft(9), Articulation Legato(5), Note Onset Slow(3), Pitch Low(2), Pitch Range Low(2), Pitch Variation Small(2), Timbre Soft(2), Harmony Simple(2), Mode Minor(1), Loudness Variation Rapid(1), Loudness Variation Few(1), Pitch High(1), Note Onset Rapid(1), Vibrato Intense(1), Rhythm Smooth(1), Rhythm Flowing(1), Rhythm Firm(1), Metre Duple(1)</i>

8	Mode Major(12), Harmony Simple(5), Tempo Slow(3), Articulation Staccato(3), Loudness Soft(2), Pitch Contour Up(2), Loudness Variation Few(1), Pitch High(2), Pitch Range High(1), Pitch Range Low(1), Pitch Low(1), Mode Minor(1), Timbre Soft(1), Vibrato Intense(1), Rhythm Smooth(1), Rhythm Flowing(1), Tonality Tonal(1)
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3.2 Primary Music-Emotion Structural Rules

The results of collating the rules in table 1 reveal a tendency for particular rules to dominate the emotional spectrum. This set of core rules relate to the musical elements, mode, tempo, loudness, harmonic complexity and articulation, with each present in all of the emotion octants. These rules constitute a set of *primary music-emotion structural rules* that would seem to provide a generalised emotion indicator for the music. Accompanying this are less frequent music-emotion rules such as rhythm, timbre, tonality, and so on. These rules form the much larger and varied set of 'secondary music-emotion rules'. Secondary rules seem to act in concert with primary rules to colour the emotion, texturing the work to increase musical interest [17]. Indeed, this notion finds support in everyday speaker-listener situations. Occasionally we may suddenly hear an unknown person in the distance yelling with a loud voice, raised pitch/tension in an active or agitated manner. Often we may be uncertain as to whether this person is angry or happy. The listener requires additional listening time, or audio information, to distinguish the speaker's state as the two emotions share a similar set of primary rules. If a listener is uncertain about the intensity of one or two rules, state confusion may result. Examining [11], table 11 details that the acoustic cues for happiness and anger are markedly similar, a situation also paralleled in sadness-tenderness. The personification of these rules can be seen in figure 2, illustrating a perfect reflection of opposing rule subtypes in the 2DES octants along their respective axes. For example, 'Major & Simple' has its opposite subtype 'Minor and Complex' reflected about the axes separating quadrants 1, 4 from 2, 3. While Note Onset [Rapid, Slow] appeared in many octants, it was not included as it is a performative rule. Where a rule received octant support from only two studies, the octant was partially whited out (see pitch low and staccato). With the set of music-emotion rules outlined in table 1 and an identification of a potential primary music-emotion structural rule set, we can now move to implement and test the veracity of these claims in our dynamic music environment.

4. Real-time Music-Emotion Test System

4.1 Aims

In this experiment, our central aim is to gauge the effectiveness of the primary music-emotion structural rule set in influencing the emotion of selected musical works. The environment implements a subset of the compiled music-emotion rules outlined in table 1, using principally the set of primary music-emotion structural rules outlined in section 3.2. While the system implements octant-unique rules, commonly there exists little difference for octants which share the same quadrant. As such, our central aim is to influence the emotion of musical works *towards* particular quadrants rather than associating absolute emotional states with particular rule sets (eg, make happier). That is, we expect the rule sets when applied to the music to provide a relative differential in the perceived emotional state.

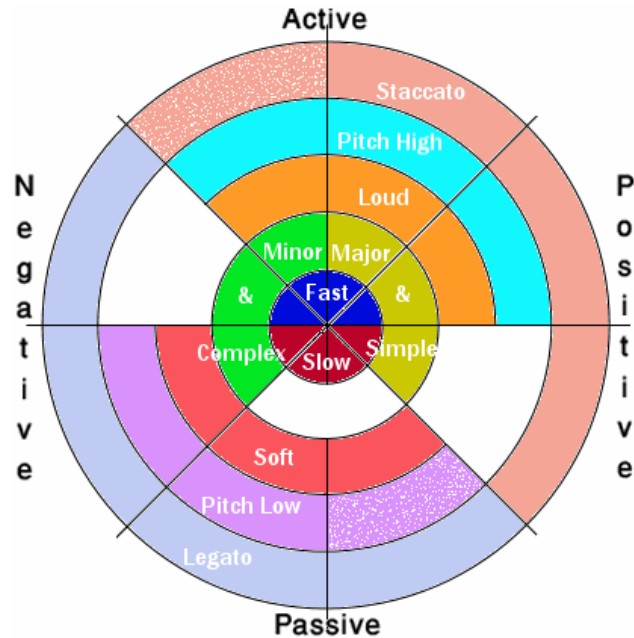


Figure 2. Primary Music-Emotion Structural Rules

Our second aim is to determine if the music-emotion rules in table 1 that were derived chiefly from Western classical music can be applied to the variegated stylistic world of computer game music.

4.2 Music Rule System

The architecture developed allows for the real-time influencing of the emotion of musical works. Operating on symbolic input, the system generates real-audio output. In this study audio sine waves were produced as means of reducing the complicating emotional effects introduced by instrument harmonics. The emotion-adaptation architecture is layered above the open-source AiME music engine [2].

The system implements the following structural rules: mode [major, minor], tempo [faster, slower], loudness [louder, softer], articulation [more staccato, more legato], pitch [raise, lower], harmony [partial simplify]. As the system is still in embryonic form, only rules which could operate with a localised note-based context were used. We did not require the system to possess an understanding of large scale musical structure or to modify audio waveforms. As a result, the rule harmony [simplify, complexify] could not be wholly implemented, specifically the increase of harmonic complexity. The simplification of harmony was partially achieved by filtering every 2nd/3rd note from the harmony MIDI input. As increasing harmonic complexity was not implemented, it was speculated that participants would encounter difficulty in distinguishing quadrants 1 and 2.

In this particular round of testing, the music emotion rules were applied to the entire duration of the work. While future tests will

examine real-time modifications, using a previously developed 2DES user response capture tool, this test was only designed to see if the rules could successfully shift the perceived baseline emotion of the work.

4.3 Music Selection

Two pieces of music were selected for testing. The first was a Mozart string quartet, and the second was a fragment from the computer game “Legend of Zelda, The: The Ocarina of Time” [20]. The Mozart was selected as it aptly represents a traditional work of Western classical music. This work provides a base line to gauge the effectiveness of the music emotion structural rules which were sourced from Western classical music. In contrast, the music from Zelda is typical of modern-day computer gaming music. Unlike the Mozart, the Zelda work was based on a modal scale and appeared to move between both major and minor keys. The MIDI files for each of the works were split into their respective instrument components so as to allow the harmony simplification rule to be applied more easily.

4.4 Participant Testing

Testing involved 11 participants, each with varying musical backgrounds. All participants rated themselves as avid listeners, with all but one having practical musical experience (instrumental or vocal). Four participants rated themselves as possessing advanced musical training. The use of trained over non-trained musicians for study’s such as this is still a matter of some debate. While there is some evidence that indicates non-musically trained listeners cannot discern advanced musical information [23], others results signal they can [14], or they do so with a higher noise ratio [27] or delayed reaction [5].

The study began with a short tutorial phase to educate the participant on the 2DES representation. The tutorial explained the basis of the two axes system, along with position the approximate positions of emotion terms. It was explained these positions were the result of statistical studies [4, 24]. Following these explanations, the nature of perceived emotion was discussed. The participant was instructed that they were to respond to what they perceived to be the change in the musical emotion, not what emotion they experienced (induced) as a result of the change [7, 12, 15].

Each user was given a diagram of the 2DES system for result taking, similar to that of figure 1. It was explained that the user would first hear an unaltered version of a Mozart work, and to consider that the emotion of this be in the ‘neutral/unaltered’ position; occurring at the intersection of the arousal-valence axes. Next the participant would be played an altered version of the Mozart, at the conclusion of which they would be asked to place a mark on the 2DES sheet to indicate how they perceived the emotion of the altered work had shifted relative to the first, unaltered version. This procedure was repeated twice more, with the user responding to three variations of the Mozart in total. The emotional alterations for each participant were selected so as to provide a broad cross-section (e.g., octants 3, 8 and 5). This procedure was then repeated for the Zelda gaming music, with a different set of alterations used.

5. Results

5.1 Quadrant Influence

A summary of the combined Mozart and Zelda testing results are listed in table 2. As a means of weighted comparison, the likelihood of a participant guessing the correct quadrant/half is provided. Examining row 3 we see that our music-emotion influencing environment was moderately successful in influencing perceived emotion towards particular quadrants, with a weighted accuracy improvement of 130% over that of a guess. As quadrant accuracy results are dependant upon the user perceiving both the correct arousal and valence level, their respective results have been included. Examining user response results for arousal and valence we see a noticeable accuracy discrepancy between the two. While the architecture was highly successful in influencing the arousal level of musical works, the system boasted a weighted guess improvement for valence of only 24%.

Table 2. User Responses for Quadrant, Arousal & Valence

Accuracy	Quadrant	Arousal	Valence
User Response	57%	90%	62%
Guess	25%	50%	50%
Weighted Response Improvement over Guess	130%	80%	24%

The reduced ability to influence perceived valence requires further examination. A break-down of individual quadrant accuracy results are listed in table 3. Here accuracy refers to the number of times the quadrant was selected correctly, selection skew and rate refers to the number of times the quadrant was selected but incorrectly. For example, in row 1 while the first quadrant had a high accuracy rate, here quadrant 1 was selected 81% of quadrant was the intended quadrant. However, quadrant 1 was over-selected 56% of the time (12 times instead of the correct 6 number of occurrences).

Table 3. Quadrant Summary

Quad	Accuracy	Selection Skew	Selection Rate %
1	81%	Over	56%
2	26%	Under	56%
3	71%	Over	3%
4	50%	Correct	-

Examining the results of table 3, it becomes evident why a reduced accuracy result for valence was achieved. As predicted (see section 4.2), participants experienced a degree of difficulty in distinguishing the emotional influences of quadrant 2 from quadrant 1. As selection skew and rate illustrate, often participants would select quadrant 1 over quadrant 2. As the two quadrants lay on opposite sides of the valence axes, this resulted in a reduced valence accuracy value.

From the results of table 3, we can tentatively say that our dynamic music environment was generally successful in

influencing the emotion of musical works towards three of the four quadrants: 1, 3 and 4. In post-testing, a number of users expressed difficulty in selecting quadrant 2 as both the unaltered Mozart and Zelda works were upbeat and happy. Thus, it is believed that it was the combination of insufficient quadrant-distinguishing rules and the choice of happy musical works that resulted in the lower-than-average performance for quadrant 2 accuracy. This result though is in keeping with similar research which also experienced difficulty in accounting for perceived valence [13, 25], where melodic contour was cited as a possible correlating factor. As discussed, melodic contour was not implemented by our system at this time.

5.2 Mozart-Zelda Comparison

The second aim of this study was to determine if the music-emotion rules listed in table 1 could be applied effectively for works of both the classical and modern computer gaming genres. A break down of user responses for the Mozart and Zelda works are listed in table 4.

Table 4. Mozart – Zelda Quadrant Comparison

Quad	Accuracy	Selection Skew	Selection Rate %
M 1	100%	Over	56%
M 2	22%	Under	67%
M 3	75%	Over	13%
M 4	56%	Over	6%
Total	62%		
Z 1	63%	Over	56%
Z 2	31%	Under	44%
Z 3	67%	Under	6%
Z 4	44%	Under	6%
Total	52%		

From these early results, we can state that the environment appears successful in its goal of influencing the emotion of both a classical music work and that of a typical computer game composition. With an accuracy discrepancy of just 10%, the environment exceeded initial expectations of user response accuracy for the Zelda work. The disparity between the quadrant one accuracy results of the two works can be attributed to the fluctuating tonal centre of the Zelda work. The application of major/minor rules had little effect on the overall sound of the Zelda work, resulting in increased participant confusion between quadrants 1 and 2.

6. Conclusions and Future Directions

Traditional computer gaming music engines do not adequately allow for musical variations that reflect the emotional state during game-play. In this paper we argued for the need of a dynamic music-emotion engine, capable of responding in real-time to the game in play. Working with a multi-disciplinary approach, a large body of music-emotion rules were collated and

comparatively reviewed for implementation. From this, a core subset known as *primary music-emotion structural rules* were extracted. This rule subset was successfully implemented in an early model of the dynamic music environment. Selecting two musical works for examination, one classical, the other a fragment from a popular computer game, a small case study of 11 participants was carried out. Early results indicate that the set of primary music-emotion structural rules were successful in influencing the emotion of musical works towards three of the four quadrants (1: happy, 3: sad, and 4:dreamy).

It was discussed that the lack of quadrant 2 distinguishing rules and the choice of musical works was principally responsible for the reduced quadrant 2 accuracy rates. Finally, the results of this study indicate that the use of music-emotion rules taken primarily from Western classical music were effective in influencing the emotion of modern computer gaming music. The results of these early studies indicate that further exploration and refinement of musical rules is likely to be fruitful in our search to enhance the musical contribution to computer gaming experiences.

The most significant hurdle, identified by previous studies and reinforced by this experiment, was emotive differentiation on the valance axis. While further refinement, and addition, of rules may improve the ability to differentiate on this scale, particularly between quadrants 1 and 2, in the computer gaming context extra emotive cues provided by the visuals and narrative would also help to clarify any ambiguity. We anticipate that taking into account triangulated emotional cues may also vary the balance of musical rules that are required within multi-media contexts such as computer games, and future work may explore variations between rule sets for stand-alone and integrated music.

In our current work, the music environment will be extended to incorporate further structural rules and to add performative music-emotion rules, in an attempt to cover a larger spectrum of emotion dynamics with greater accuracy. To achieve an increased rule-implementation rate, the environment will also incorporate an understanding of large scale musical structure and integrate with our accompanying Affective Performance framework for listener feedback [17]. This will allow for a comparison between the effectiveness of primary music-emotion structural rules, and the complete set of implemented structural rules. Future test studies will also investigate the affects of real-time rule application/removal, while broadening the spectrum of music works examined.

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