Exploring musical diversity: The role of stylistic context in harmonic expectation

Linda Adams, MPhil

Thesis submitted for the Award of

Doctor of Philosophy

School of Theology, Philosophy, and Music

Dublin City University

Supervisor:

Dr Patricia Flynn

December 2024

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Acknowledgements

I would like to express my gratitude to the Faculty of Humanities & Social Sciences, and everyone at the School of Theology, Philosophy and Music at Dublin City University for their continued support throughout my PhD. Thanks also to the School of Media at Technological University Dublin, formerly Dublin Institute of Technology (DIT), where I began this project. I'm grateful to Dr Charlie Cullen, my supervisor at DIT, for your support, guidance, and insight.

Thanks to my supervisor at DCU, Dr Patricia Flynn for your kindness and help over the last four years, for the care you've shown for my work, and for sharing some of your vast knowledge of just about everything.

Thank you to my friends at DCU for all the ceol, craic, coffee, gossip, and chats: Róisín, Laura, Barbara, Tony, Mark, Jenna, Matthew, Greg, Cormac, Siba, Yvonne, Dara, Freya, Hannah, Kevin, Holly, Rodrigo, Magda, Leanne, Laetitia, David, Yulia, and Vijay.

To my brilliant family – I'm beyond lucky to have such a kind, supportive, and hilarious group of people in my life. Thank you to Sarah, Richard, my Dad Johnny, my Nana Stella, Erin, Eva Rose, Jacob, all the Shero's, and Vlad.

Finally, to my Mam, who always believed I could do anything I put my mind to – it's because of you that I could do this.

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List of Abbreviations

ANOVA: Analysis of Variance

CP: Common Practice

ERP: Event-related Potential

LMM: Linear Mixed Model

MI: Modal Interchange

RT: Reaction Time

SFD: Special Function Dominant

Abstract

Exploring musical diversity: The role of stylistic context in harmonic expectation

Linda Adams

Harmonic expectation and surprise have been extensively studied in the context of Western art music. A resulting body of evidence suggests that these are important factors in listeners' musical experience and enjoyment. In addition, centuries of Western art music theory have resulted in an in-depth understanding of the musical techniques used by common practice composers to evoke expectation and surprise.

This thesis expands on this knowledge by investigating harmonic expectation and surprise within jazz and popular music. These styles have been neglected in the research due to an assumption that the common practice stimuli typically used in harmonic expectation experiments are representative of all Western tonal styles. However, due to the influence of blues and other factors, there are differences in tonal frameworks, narrative structures, harmonic languages, and chord functions in contemporary styles. Therefore, techniques to elicit surprise within common practice music may not have the same effect in jazz and popular music.

Results of this investigation suggest that common practice is not paradigmatic of jazz and popular music with respect to expectation and surprise. Techniques associated with surprise in common practice music, such as the traditional deceptive cadence to VIm, were found to be significantly weakened within jazz and popular music contexts, where surprise was found to be primarily elicited through chromatic techniques such as modal interchange. Results revealed a linear relationship between surprise and preference for pop and rock musicians, and an inverted-U relationship for jazz musicians. Pop music was found to elicit greater use of sensory processing strategies in listeners, in comparison to jazz.

These findings reinforce arguments that the tonal systems of common practice, jazz and popular music are distinct and unique. They provide the first comprehensive account of the musical techniques that elicit surprise in contemporary styles and establish an important initial link between music cognition and applied music theory. The results may be of note for those advocating for increased musical diversity and improvisation in the fields of musicology, music education, and music cognition.

Part 1

1. Introduction

Music, for many people, is a panacea. Music can calm us down, quieten our busy thoughts, and help us unwind. But while our bodies relax and our emotions are soothed in response to music, our brains, in contrast, may fire up, contextualising what we hear, making predictions and responding to changes, experiencing music not as a passive, relaxing activity, but as a thrilling game of prediction. This is the theory behind almost 70 years of research in musical expectation, beginning with musicologist Leonard B. Meyer's pioneering 1956 treatise, Emotion and Meaning in Music (Meyer, 1956).

In any game of prediction, we must have some knowledge of what is likely to occur; our predictions will be more accurate the more we know about the game. But how do we acquire enough knowledge to know what to expect when we listen to music? After all, music is enjoyed by all, not just by those with musical training and knowledge of music theory. Meyer suggested that anyone with long-term exposure to a musical style acquires knowledge of the statistical regularities of that style through passive absorption. These statistical regularities are then stored as "internalized probability systems" (Meyer, 1957, p. 414). It is through these systems that we contextualise music and thus make predictions. As Meyer puts it, "[t]he norms and deviants of a style upon which expectation and consequently meaning are based are to be found in the habit responses of listeners who have learned to understand these relationships" (Meyer, 1956, p. 61).

Events in music that we know to have low probability may thus catch us by surprise. This may even cause us to have an affective reaction. Meyer theorised that these surprising events could cause us to feel strong emotions when we listen to music. He summarises:

> the customary or expected progression of sounds can be considered as a norm . . . and alteration in the expected progression can be considered as a deviation. . . . deviations can be regarded as emotional or affective stimuli. (Meyer, 1956, p. 32)

Meyer's work was expanded by David Huron, who used Meyer's theory as a basis for the development of the ITPRA theory, a model of affective responses to musical surprise (Huron, 2006). Like Meyer, Huron maintains that music is learned implicitly, and he claims that we store knowledge of musical contexts in cognitive models known as "schemas", which he describes as "expectation 'set[s]'" (Huron, 2006, p. 204).

> [I]t is the learned schemas that provide the templates that enable the fast-track brain to make predictions, and in some cases, to be surprised. (Huron, 2006, p. 36)

Violation of these schemas may "provoke reaction responses" (Huron, 2006, p. 14). The physical manifestations of these reactions, e.g. goose bumps, chills, etc. have their roots in physiological fight, flight, or freeze responses to surprise.

Behavioural studies have verified several aspects of Meyer and Huron's theories. Researchers have found evidence that musical expectations may indeed be formed based on statistical analysis of the music we are exposed to throughout our lifetime (Castellano et al., 1984). Evidence has also been found that the meeting and thwarting of our expectations may contribute to our enjoyment of music (Shany et al., 2019) (Armitage & Eerola, 2020), and that harmonies that surprise us can elicit distinct physiological and cognitive reactions (Sloboda, 1991) (Janata, 1995), some of which may lead to affective responses (Steinbeis et al., 2006). It is the wider understanding of harmonic expectation in the context of the music that everyday listeners are exposed to that is the subject of this research.

1.1. Problem statement

Although research into harmonic expectation has been thorough and converging throughout the last several decades, there are issues that have yet to be addressed in depth. Meyer acknowledged at the outset of his study that there was very little knowledge of the exact musical structures that surprise listeners. He wrote:

> listeners and critics have generally been unable to pinpoint the particular musical process which evoked the affective response which they describe. (Meyer, 1956, p. 7)

Unfortunately, almost 70 years later, the situation remains largely the same. Although both Meyer and Huron identified many musical devices related to melody, harmony, timbre, and rhythm with the potential to elicit expectation and/or surprise, very few of these devices have been verified by behavioural or cognitive studies as achieving these effects, particularly in the case of unexpected harmony, the topic of this thesis.

The positionality of the author is shaped by a background as a jazz pianist and an educator in third level jazz and contemporary popular music education. It was an initial interest in the details of these musical devices, their cognitive effects on listeners, and the ways in which they could be used to inform music performance and education that sparked an interest in this research area. However, a preliminary survey of the literature revealed that such details were difficult to find. Musical techniques used in experiments were often not detailed, not notated, or described in overly broad terms. Moreover, representation of Western non-art styles such as jazz and popular music were rare.

There are two reasons for this dearth of specific information on the harmonic musical techniques associated with expectation and surprise. Firstly, most empirical research into harmonic expectation has been conducted within the research areas of neuroscience or experimental psychology, rather than within musicology and music theory. This means that the researchers who carry out these studies are understandably more interested in what the results of their studies tell us about the brain than what they tell us about music. Variation within experiments over time therefore tends to be within the experimental paradigms rather than the musical stimuli, and there has been a tendency to use a limited range of stimuli and to recycle those that are found to produce results. The consequence of this is that knowledge of the musical elements that elicit expectation and surprise have not been greatly expanded within the last several decades of research, despite greatly increased knowledge about how musical expectation and surprise work in the brain.

The second reason for a lack of progress in identifying musical structures related to expectation and surprise has been an undue focus on the music of the 18th and 19th century common practice period of European art music, hereafter referred to as common practice, or CP[1]. Correspondingly, there has been very little investigation into harmonic expectation and surprise in non-art styles, despite these being the most prevalent styles engaged with by general listeners[2]. It is likely that cognitive researchers in music have been influenced by art music theorists in making the assumption that there is harmonic transferability from CP music to other Western styles such as popular music and jazz. Both groups contend that since there are many similarities between CP harmony and the harmony of popular music and jazz, they can be

[1] The common practice (CP) period refers to the period within European art music spanning from the advent of the modern Western tonal system around 1650, until the beginning of the 20th century.

[2] The term "general listeners" is used in this thesis to differentiate trained and/or professional musicians from those without professional music experience or musical training.

described by the same patterns and rules. The examples below illustrate this thinking in music theory:

> Much of today's popular music is based on tonal harmony, just as Bach's music was, which means that both types have a good deal in common. First, both make use of a **tonal center**, a pitch class that provides a center of gravity. Second, both types of music make use almost exclusively of major and minor scales. Third, both use chords that are tertian in structure. (Kostka & Payne, 2009, p. x-xi)

> Jazz harmony is diatonic or major scale harmony found in the mainstream of classical music from 1600 to 1900. In other words, jazz harmony is classical harmony following the identical rules and conventions found in a Bach fugue, a Mozart sonata, a Brahms rhapsody. (Mehegan, 1984, p. 6)

This reductionist perspective has been critiqued by music scholars such as Gunther Schuller:

> It would, therefore, be easy to conclude, *as most studies of jazz* [emphasis added] have, that the harmony of jazz derives exclusively from European practices. . . . this conclusion seems to be another one of those over-simplifications in which historians indulge so readily when documentation is scanty. (Schuller, 1968, p. 39)

Within the area of music cognition, this has led to the assumption that experimental results derived using CP stimuli are applicable to all Western music contexts, and therefore research using contemporary popular styles is unnecessary. Researchers will often describe the excerpts and harmonic techniques used in their experiments as derived not from CP but from a broader category of "Western tonal music", and the common characteristics of the many musical styles under this Western tonal music umbrella will often be emphasised. This may be seen in the following examples:

> *Western tonal music* [emphasis added] corresponds to most musical styles of occidental everyday life (e.g., serious music from J. S. Bach to R. Wagner, pop music, jazz music, Latin music). (Bigand et al., 2005, p. 1350)

> *Western tonal music* [emphasis added] is "syntactic" in the sense that it employs perceptually discrete elements (such as tones or chords), which are

> combined in hierarchical ways to form musical sequences. (Bigand et al., 2014, pp. 1-2)
>
> [t]he full cadence structure is considered by many music theorists as one of the most basic, underlying structures of *Western tonal music* [emphasis added]. (Schmuckler & Boltz, 1994, p. 318)
>
> Thus it is possible to assume that the empirical probabilities in Bach's chorales are approximations of those in the whole [of] *Western tonal music* [emphasis added]. (Kim et al., 2011, p. 3)
>
> Neapolitan chords [have] become a popular stylistic element in *western tonal music* [emphasis added]. (Koelsch et al., 2002, p. 38)

The issue with these assumptions is that we may overlook the many important ways in which CP and other styles within Western tonal music differ. Although all Western styles have the same fundamental basis in terms of the diatonic note system used, they may also have many differences in the ways in which narrative is structured, and in their tonal frameworks, functions, and harmonic language. For example, although Neapolitan chords were a popular stylistic element during the late Baroque period, these chords are rarely found fulfilling the same function within the jazz repertoire. The full cadence may be an important underlying structure in Classical music but may be diminished in importance in contemporary rock. Root movements in popular music tend to prioritise fourths rather than the fifths that characterise movement in Bach's chorales, and therefore statistical regularities of the chorales may not approximate popular music. Neglect of styles outside of the 18th and 19th CP tradition extends even to styles within Western art music, such as those of the Romantic and 20th century periods. Music within these styles features harmonies that differ significantly from those of the late Baroque and Classical periods.

According to Meyer, style-based conventions are likely to be unique and non-transferable to other styles and contexts:

> [T]he same physical stimulus may call forth different tendencies in different stylistic contexts or in different situations within one and the same stylistic context. (Meyer, 1956, p. 30)

Meyer also acknowledges that chromaticism, commonly used as a CP harmonic technique to elicit surprise in experiment participants, may not be perceived as deviant within the context of a style where multiple modal or tonal systems are common, such as in Western popular music:

> However, not every alteration of a diatonic organisation results in a feeling of chromaticism, in a sense of deviation. Where several different and alternative modes of tonal organization are possible within a given musical style or style system or where such modes are themselves subject to transposition according to the rules of operation prevalent in the style, the alteration of one tonal group may well be interpreted by the listener as constituting a change or a transposition of mode rather than as being a chromatic passage. (Meyer, 1956, p. 217)

The lack of focus on contemporary popular styles in the research extends to the selection of participants in harmonic expectation experiments. Many studies in this area utilise the expertise of trained musicians, both to take advantage of their superior music processing abilities and to compare them with non-musician participants in order to assess the effects of musical training on music processing. The musicians participating in these experiments are most often classically trained conservatory students (Regnault et al, 2001), (Koelsch, Schmidt, & Kansok, 2002), (Steinbeis et al., 2006), (Bigand et al., 2005), (Poulin-Charronnat et al., 2006). Rarely are jazz, pop, rock, or improvising musicians studied, or practitioners within what musicologists refer to as the “vernacular”, which encompasses a broad range of styles practiced within diverse social groups (O’Flynn, 2006). Therefore, in the same way that some researchers and theorists assume that CP music is paradigmatic of all Western tonal music, there may be a belief that conservatory trained musicians may serve as representatives of all musicians.

The contributions of jazz, pop, rock musicians, musicians whose training occurred “on-the-job”, and those whose performance primarily involves improvisation, are invaluable to any research area that makes claims about musical expertise. Moreover, research has demonstrated significant effects of stylistic expertise and training in improvisation on music processing (Vuust et al., 2012), (Przysinda et al., 2017). This should be of no surprise given Meyer and Huron’s theories on the implicit learning of music: if exposure to music allows us to absorb the statistical regularities of a given style, then musicians with many years of training in different styles are likely to have schemas related to those styles. In addition, improvising musicians, whose primary skills involve anticipating and reacting to the sounds around them, are likely to have developed enhanced abilities to predict music through their work.

At the time of Meyer's research, Western art music may well have been the dominant musical influence among the general population, and thus his focus on this style was appropriate for the time. However, this is no longer the case. For many people in Western society, popular music makes up their primary musical experiences (North et al., 2004), (YouGov, 2011). Popular music has become more prevalent in third level music education (Coppes & Berkers, 2023), as has jazz, (Prouty, 2005), while degree programs that traditionally educated their students primarily through Western art music are increasingly broadening their curricula to include diverse styles of music (Myers, 2016). All of these developments mean that the dominance of western art styles is receding, and the tide is turning towards musical diversity.

Issues within the study of harmonic expectation reflect a larger problem: that of a disconnect between the areas of cognitive science and music theory/musicology. Links have been made between music cognition and speculative music theories such as Eugene Narmour's Implication-Realisation model (Krumhansl, 1995), and Fred Lerdahl and Ray Jackendoff's Generative Theory of Tonal Music (Bigand & Parncutt, 1999). However, the hierarchical Schenkerian basis of these theories further reinforces the focus on CP music, precluding the inclusion of more cyclical, non-hierarchical styles such as blues or rock, or styles incorporating improvisation. There has been little communication between the music cognition community and the more practical and applied side of music theory, and none between music cognition and jazz or popular music theory.

Greater communication between these communities would benefit the music theory, music education, and musicology communities. Over many decades, countless academic papers have been published with details of new discoveries of the effects of musical surprise on listeners, and these would no doubt be of great interest to practitioners of music. However, these papers are rarely written in the language of music, with few, if any details given about musical stimuli used, and as previously mentioned, few variations in stimuli across studies. Often, musical stimuli are described in extremely broad detail, but not published in notated form. Readers who are eager to find out about the musical techniques used to elicit these undoubtedly interesting effects are left to speculate. This means that, despite significant research into harmonic expectation, musicians and music educators are unable to benefit in practical ways from the findings of this research.

The music theory community would have much to offer to music cognition researchers in terms of appropriate contextual stimuli that would accurately reflect the real music that makes up so much of our listening experiences. While music cognition has clung to the well-defined and verified CP musical frameworks and techniques that have served them so well, a need for musical diversity, decolonisation, and a shift away from art music as musical archetype has been acknowledged (Jacoby et al., 2020). A first step in that process could be to explore non-CP styles that exist within the remit of Western tonal music, through communication with the practice-based music theory community. The harmonic systems of jazz and popular music are not derivative simplifications of the innovations of 18th and 19th century European composers, but, as will be outlined in this thesis, they are rich, organic, endlessly varied systems with unique characteristics and marked perceptual effects on listeners and are fully worthy of study in their own right. A more inclusive approach to harmonic expectation, where those in the cognitive sciences, music theory, and musicology can go beyond assumptions and pool their knowledge will result in a more complete understanding of human engagement with music.

The following three research questions are thus derived from the discussion above:

1) Are harmonic expectation and surprise mediated by style?
2) What are the specific harmonic techniques that elicit surprise in jazz and popular music?
3) Does stylistic expertise or experience in improvisation affect harmonic expectation and surprise in listeners?

1.2. Aims and objectives

The primary aim of this thesis is therefore to fill the knowledge gap left by the exclusion of contemporary popular styles and musicians in harmonic expectation research. This will be achieved by demonstrating that CP is not paradigmatic of all Western styles in terms of harmonic expectation, and by determining the specific harmonic techniques through which surprise is elicited in both jazz and popular music. This investigation will be carried out using a music-theoretic perspective and will include jazz, pop/rock, improvising, and self-taught musicians. Results will be presented in the language of musicians and music theorists. The findings of this thesis will therefore represent a step toward bridging the divide between cognitive science and music theory in music cognition.

The thesis is in two parts. Part 1, comprising Chapters 2 to 4, has two objectives. The first is to make the argument that CP harmony is not representative of either jazz or popular music.

Rather, the influence of blues on these styles has resulted in differences in narrative structures, tonal frameworks, functionality, and harmonic language, to the extent that harmonic expectation may be perceived differently. Therefore, investigations into harmonic expectation in jazz and popular music are warranted on their own merits. The second objective of this part is to determine the harmonic structures that may be associated with expectation and surprise within these styles in order to inform a series of experiments, following in Part 2. Part 1 may be further broken down as follows.

Chapter 2 consists of a survey of the literature on harmonic expectation within the areas of cognitive science and neuroscience. The objectives of this chapter are (1) to provide an understanding of the current state of the art vis-a-vis general harmonic expectation, (2) to enlighten the reader as to what is currently known about the mechanisms of harmonic expectation, (3) to critique the areas in the research where non-CP styles and musicians are overlooked or musical context is disregarded, and (4) to detail the effects of these omissions. This will be achieved through a critical survey of the scientific literature.

In Chapter 3, the musical sources of harmonic expectation and surprise in Western art music, from its Ancient Greek roots, through the Medieval, Baroque, and Classical periods, will be contextualised through the lens of contemporaneous music theory, through a review of historical music theory texts. The objectives of this chapter are to provide a deeper understanding of the musical techniques associated with harmonic expectation and surprise in CP, such as the deceptive cadence[3] and chromaticism. This will provide a basis with which to determine the ways that popular music and jazz deviate from CP norms, in Chapter 4.

Chapter 4 investigates harmonic expectation within popular music and jazz. It begins by tracing the roots of the commonly held perception that CP harmony is paradigmatic of all Western tonal styles. This perception may be rooted in the idea that popular music and jazz derive from a simple amalgamation of European CP harmony and African rhythm (Waterman, 1948). The chapter provides arguments to refute this claim by contrasting the functionality, tonal frameworks, narrative structures, and harmonic language of CP and blues. It describes the ways in which these forces combined in both jazz and popular music to produce unique harmonic worlds. Expectation and surprise within both of these styles are then investigated with reference to contemporary jazz and popular music theory to produce a model of

[3] The deceptive cadence is a chord progression consisting of a V chord leading to a chord other than the I (typically to VIm in CP).

expectation with which to inform the implementation of four experiments, described in Part 2.

Part 2, comprising Chapters 5 to 8, outlines these four behavioural experiments, which were carried out using a musically diverse cohort of trained and untrained participants. This section aims to investigate empirically whether harmonic expectation in contemporary styles differs from harmonic expectation in CP and to determine if stylistic training and/or improvisation is a factor in harmonic expectation. Musical techniques elucidated from Part 1 will be empirically verified as associated with harmonic expectation and surprise, and a music-theoretic model of harmonic expectation and surprise will be constructed for the benefit of both music cognition researchers and jazz and popular music theorists. Part 2 may be further broken down as follows.

Chapter 5 focuses on explicit expectations. It outlines the methodology, implementation, results, and discussion of a behavioural experiment designed to investigate the explicit expectations of a diverse cohort of musicians with different stylistic expertise and experience in improvisation. The objectives of this experiment are to (1) determine if stylistic or improvisation expertise mediates explicit expectations, (2) determine whether listeners perceive expectation on a spectrum, and (3) gather qualitative data on listeners' own perspectives on harmonic expectation and surprise.

Results reveal that both improvisation and stylistic expertise influence explicit expectations. Differences are revealed in terms of participants' schemas, their abilities to quantify music based on surprise, and their consistency. Listeners are shown to experience surprise as a gradated phenomenon, and they believe expectation and surprise to be important aspects of their own music listening experiences. The experiment validates the deceptive cadences of V-♭VI and V-Im in major keys as valid stimuli with which to elicit surprise.

Chapter 6 focuses on implicit expectations and preferences. It outlines the methodology, implementation, results, and discussion of a behavioural experiment designed to test stylistically diverse listeners' implicit expectations and preferences in response to a wide range of deceptive cadences. The objectives of this experiment are to determine if stylistic expertise mediates implicit expectations and/or preferences, and if more granular details on the gradated experiences of surprise and liking can be gathered.

Results reveal that implicit expectations are strongly influenced by voice-leading and sensory factors, particularly for pop/rock musicians and the most experienced musicians. Diatonicism appears to be a factor for the preferences of general listeners and chromaticism for jazz and pop/rock musicians, but this elicits further questions on confounds between chromaticism and deceptive resolution that require further investigation. Preferences are similarly mediated by stylistic expertise, with general listeners and pop/rock musicians revealing a linear relationship with surprise/complexity, and jazz musicians an inverted-U relationship.

Chapter 7 focuses on popular music. It outlines the methodology, implementation, results, and discussion of a third behavioural experiment. This experiment aimed to determine specific musical techniques that stylistically diverse musicians find surprising within the context of popular music, to investigate further questions on deceptive cadences and chromaticism, and to determine if these factors are mediated by stylistic/improvisational experience. Ecologically valid stimuli from the popular music repertoire were selected based on the results of the investigation in Chapter 4.

Results reveal that chromaticism is the primary factor in expectation and surprise in popular music. The traditional CP deceptive cadence does not appear to have a strong surprise effect in this style, although cadences to modal interchange deceptive chords are highly surprising to listeners. These chords are also surprising within a non-cadential context, but to a lesser extent. Stylistic/improvisational experience does not appear to be a factor in responses, but sensory aspects of the stimuli have a strong mediating effect, as does tonal context.

Chapter 8 focuses on jazz. The experiment detailed in this chapter is identical to that of Chapter 7 with the sole difference that musical techniques within jazz were investigated using ecologically valid stimuli from the jazz repertoire.

Results reveal that, as with the previous experiment, chromaticism is the strongest predictor of surprise within jazz. The effect of the VIm deceptive cadence is reduced, while modal interchange cadences and non-cadential chords are surprising. Jazz musicians demonstrate lower surprise overall to jazz stimuli. Other harmonic techniques, such as quartal harmonies, tritone substitutes and special function dominants all appear to elicit surprise results.

In Chapter 9, the experiment results are summarised, and conclusions and recommendations made.

1.3. Terminology

In order to ensure clarity, it will be helpful at this point to define some of the terms used throughout this thesis. Some of these terms may appear to be synonymous, but are intended to convey subtle variations in meaning, although they are all strongly linked:

- *Harmonic expectation:* This term refers to the process by which listeners expect the continuation of a harmonic sequence.
- *Prediction:* The intention of this term is to denote the process by which listeners form specific auditory images/percepts in response to cues or musical primes.
- *Anticipation:* Anticipation in this thesis refers to the process by which listeners await any musical element that they may or may not expect. This term is used primarily to refer to improvising musicians; these musicians may "anticipate" musical events, meaning that they are primed for both expected and unexpected events due to their musical experience.
- *Deceptive:* In relation to harmony, the intention of this term is to describe chords that are not the most expected continuation within the given context but are harmonically acceptable with reference to music theory. For example, a deceptive resolution might consist of a VIm chord following a V chord.
- *Unexpected:* Many researchers use this term to encompass all harmonic elements that are not the most expected in the given context. However, for clarity, in this thesis this term is used to refer only to chords that are not harmonically regular within any music theory. For example, an unexpected resolution might consist of a ♭VIaug chord following a V chord. Thus, in this thesis, deceptive and unexpected chords are mutually exclusive and can be considered separately.

In any discussion about the broader music of the 20th and 21st centuries, defining the scope of what is being discussed and the terminology that should be employed is imperative to avoid ambiguity and thus misinterpretation. Writers on popular music use a variety of terms to define the scope of their discussions, and the domains of these terms may sometimes overlap. According to Trevor de Clercq,

> [t]here is no good, concise term as of yet to refer to the broad array of contemporary commercially distributed musical styles in Western English-language popular music, even though there is general consensus that styles such as pop, rock, R&B, rap, and country comprise a family of related styles. (de Clercq, 2021, footnote 1 to para. 1.1)

Nicole Biamonte uses the term “popular music”, and refers to

> the constellation of genres and styles that has arisen around Anglophone pop and rock music in the latter half of the twentieth century, including rhythm & blues and heavy metal as well as genres with “pop” or “rock” in their names, but not country, hip-hop, industrial or electronic dance music. (Biamonte, 2017, p. 89)

Christopher Doll prefers to discard the pop moniker and simply refers to “rock” in his writings. He defines the scope of this label as referring to “North American and British popular music [spanning from] roughly 1950 to the present” (Doll, 2017, p. 2). He notes that “pop” is also a valid term but cautions that it dates back to at least the middle of the 19th century, a point also made by Mark Spicer in his discussion of the ever-evolving debate on popular music terminology. Spicer notes that this term has unfortunate links to concepts of authenticity and the lack thereof. However, he acknowledges the difficulty of distinguishing categorically between “pop” and “rock” and he himself comes to a compromise by employing the hyphenated term “pop-rock” (Spicer, 2017).

De Clercq’s own solution is to take a broader approach and find a compromise through the term “popular music”:

> Although the term “rock” has been used to refer to this larger family of styles by numerous authors . . . I prefer not to use the term ‘“rock” in this way due to the implied placement of rock music (in the narrower meaning) at the center of this musical family and the concomitant marginalization of other styles, such as country and R&B. Instead, I will use the term “popular music” (de Clercq, 2021, footnote 1 to para. 1.1)

In Part 1 of this thesis, the term “popular music” will be used, following de Clercq, in order to avoid excessive specificity in terms of style. The intention of this term is to cover non-art musics of the Anglosphere, including but not limited to pop, rock, soul, R&B, rap, easy listening, folk, reggae, and punk. Metal will be excluded as its harmonic frameworks are found to differ from mainstream popular music and warrant a separate investigation (Biamonte, 2017).

The term “jazz” encompasses a wide variety of styles, including many non-traditionally functional subgenres such as modalism and free jazz. An exhaustive analysis of all harmonic styles within jazz would be outside the scope of this thesis, and comparisons of expectation within the non-functional and non-tonal systems of post-bop jazz and popular music or CP music would not compare like for like. In order to ensure that comparisons between CP and jazz are balanced, analysis is limited to the era prior to the post-bop period, spanning roughly from the late 1910’s to 1959. This range will encompass both the swing and bebop eras, when jazz repertoire primarily consisted of functional harmony, and which is considered by many to be generally representative of tonal jazz. According to Henry Martin, “[t]he candidate for the central focus of tonal jazz theory is bebop, comparable in stature to the Classical era in common-practice European music” (Martin, 1996, p. 14).

Where both jazz and popular music are being referred to together, they will be termed jazz/popular music.

2. Harmonic Expectation in Cognitive Science

2.1. Introduction

The aim of this chapter is to critically survey the literature on harmonic expectation in behavioural science, cognitive science, and neuroscience, in order to (1) provide context and understanding of the mechanisms of harmonic expectation, and (2) determine areas within the research where musical diversity and contextual understanding may be overlooked. The chapter begins with a brief outline of explorations of general musical understanding, from the theories of the Ancient Greeks to the results of 20th century cognitive experiments. The ensuing behavioural, cognitive, and neuroscientific research on harmonic expectation that was built on this foundation of musical understanding is then outlined and discussed.

Key issues in this research area, such as critiques of experimental paradigms, the ongoing difficulties in disentangling the effects of sensory processing of sounds from cognitive processing of musical systems, and debates related to the validity of perceived emotional reactions to music, will be discussed.

The primary argument of this chapter is that there is a disconnect between cognitive science and applied music theory/musicology, causing a lack of musical diversity in harmonic stimuli and a disregard for the effect of tonal and functional context on chords. This disconnect has led to the assumption that experiment results may be generalised to all Western tonal music.

2.2. Musical meaning

Meyer and Huron have asserted that knowledge of a musical style results from implicit learning of the statistical regularities of that style. Evidence indeed suggests that listeners, both trained and untrained, apply meaning to music through a learned understanding of tonal relationships (Castellano et al., 1984), (Krumhansl, 1990). However, listeners have also been found to apply meaning to music based on their sensory responses to the psychoacoustic properties of sounds (Bigand et al., 2014) (Collins et al., 2014). Meyer and Huron themselves acknowledge the contributions that sensory factors may have. The dichotomy between the effects of learned cognitive factors and psychoacoustic factors on music processing has been a continuing conflict. This dichotomy can be traced back to the earliest investigations into how music works.

Early inquiries into musical meaning by Ancient Greek thinkers were concerned primarily with the fundamental psychoacoustic elements of sound and how these are combined. In the Pythagorean tradition of Ancient Greece in the 6th century BC, the relationship between music and number theory was paramount (Mathiesen, 2008). Music theorists of that time believed that the degree of relatedness of any combination of notes, that is, what we might experience as harmony, whether consonant or dissonant, was determined entirely by the relationships of the fundamental frequencies of the notes and the frequencies of their overtones. Therefore, music was meaningful through the relationships of tonal frequencies, and the ways in which these frequencies reflected natural laws.

The Pythagorean tradition was expanded by Boethius (c. 480 – 524AD) in the late Middle Ages. As Thomas Christensen writes:

> For Boethius, a faithful student of Platonic thought, it was number and proportion that were the “final” cause governing . . . harmony. The true philosopher of *ars musica*, the true musical *theoros*, was the one who understood this numerical basis of harmony. (Christensen, 2008, p. 3)

Jean-Philippe Rameau (1683 – 1764) later expanded on these Pythagorean principles of harmonic consonance to formulate his concept of Fundamental Bass. To simplify his argument, musical events are considered consonant when their component frequencies overlap, and dissonant when they do not (Rameau, 1722/1971). Rameau believed that dissonance and consonance are the drivers of musical motion, and thus the physical qualities of the component tones of chords and intervals are what give meaning to music. In this, Rameau was following a long line of music theorists from the Medieval Period through to the Baroque Era. These included Gioseffo Zarlino (1517 - 1590), who, in his treatise on consonant and dissonant musical intervals in madrigal settings, *Le Institutioni Harmoniche*, gave the first account of consonances/dissonances creating “happy/sad” effects:

> While the extremes of the fifth are invariable and always in the same ratio . . . the extremes of the thirds are placed differently within the fifth. . . . when the major third is below [consisting of the lower interval of the triad], the harmony is gay, and when it is above [consisting of the upper interval of the triad], the harmony is sad. So from these diverse positions of the thirds placed

> in counterpoint between the extremes of the fifth – or above the octave – comes harmonic variety. (Zarlino, 1558/1968, pp. 69-70)

In the 19th century, Hermann von Helmholtz elucidated another aspect of the musical meaning puzzle when he discovered and described the psychoacoustic effects of human perceptions of consonance and dissonance. For Helmholtz, these psychoacoustic effects were only part of the explanation. Physical properties of sound alone, the perception of which he called 'Konsonanz', were not sufficient to understand musical meaning. As he explains in *On the Sensations of Tone:*

> When we spoke previously, in the theory of consonance, of agreeable and disagreeable, we referred solely to the immediate impression made on the senses when an isolated combination of sounds strikes the ear, and paid no attention at all to artistic contrasts and means of expression; we thought only of sensuous pleasure, not of esthetic beauty. The two must be kept strictly apart, although the first is an important means for attaining the second.
>
> (Helmholtz, 1863/1912, p. 234)

Therefore, Konsonanz should not be used to explain sounds within a musical context, although it is a necessary part of music. Psychoacoustic study may explain how sounds within music are meaningful, but to fully understand the meaning of *musical sound*, an explanation of the perception of tonal relationships within musical contexts is required. However, little empirical evidence for the idea that listeners use more than just frequency information to understand music was presented until surprisingly recently. Although studies by psychoacoustic researchers such as Bregman (1990), Deutsch (1977), and Shepard (1964) made important advances in understanding how we process sound during the mid- to late 20th century, there remained a disconnect between this research and music theory. Scientists could explain how we process isolated sounds, but once those sounds were embedded within real-life music, the situation became more opaque.

Investigating musical context is not a simple matter. In psychoacoustics experiments, the constituent parts of a musical sound must be isolated, eliminating confounding factors. However, if ecological validity is to be preserved, then experimental material must be presented as it would appear in "real-life". Musicians and music theorists will contend that isolating musical factors such as melody, harmony, rhythm, and timbre destroys the integrity of music, and thus ecological validity is not possible when parts are isolated. This conflict between ecological validity and experimental integrity remains a problem within music cognition.

Some of the first steps into empirically understanding musical meaning were undertaken by Carol Krumhansl in a series of experiments carried out during the 1970s and 1980s. In the first of these experiments, Krumhansl (1979) presented listeners with tone pairs and asked them to rate the relatedness of the tones to each other. Crucially however, listeners were first primed with a tonal context, specifically a C major scale or chord. This contrasts with previous psychoacoustic studies of musical processing, where sounds were typically presented devoid of harmonic context. Krumhansl's approach therefore represented an important advance in the study of music processing. In her results, she found some of the first evidence that listeners process musical sounds in sophisticated ways based on intuitive knowledge of music-theoretic rules. For example, multidimensional scaling of listeners' relatedness ratings revealed a hierarchical 3-layer structure. This structure can be thought of as a model for listeners' mental representations of the notes they had been presented with. In this model, the root, 3^{rd} and 5^{th} notes of the major key were found to cluster together at the bottom level of the hierarchy, i.e., the most stable level. Above these were found the rest of the scale tones, i.e., the 2^{nd}, 4^{th}, 6^{th} and 7^{th}, and then on the highest, most unstable level were the non-scale tones, i.e., the $\flat 2^{nd}$, $\flat 3^{rd}$, $\flat 5^{th}$, $\flat 6^{th}$ and $\flat 7^{th}$. Krumhansl also found asymmetries in listeners' ratings, e.g., the tone pair of D to D♯ was rated significantly less related than the tone pair of D♯ to D, even though psychoacoustically they are identical in relative terms, providing evidence that listeners were contextualising these tones with reference to a tonal context, and not just on their physical properties.

These results are important for three reasons. Firstly, they are the first empirical evidence showing that listeners experienced in musical traditions process sounds in relation to that learned system. Secondly, they demonstrate that listeners have internalised hierarchies of stability that coincide directly with the rules of music theory, suggesting an empirical basis for music theory. And thirdly, they demonstrate that it is possible to investigate complex musical systems by breaking them down into their constituent parts; well-founded and interesting data may be discovered even without full ecological validity.

The hierarchical 3-layer mental representation found by Krumhansl was subsequently verified in a later study by Krumhansl and Shepard (1979). A similar paradigm was used: listeners were primed with a major key context, but this time they were asked to rate tones based on how well they completed a prime major scale. This type of paradigm is known as a probe-tone paradigm and would become a popular method for investigating melodic expectation. Here, major chord tones were again found to be the most preferred, followed by scale tones and then non-diatonic notes. However, there was an important innovation in this study. The researchers used hierarchical clustering on the results and found three divisions within the participants based on their levels of musical training. Musically experienced listeners were found to follow the hierarchical schema found in Krumhansl's 1979 experiment, suggesting that learned processes based on tonal context were strongly influencing their perceptions. In contrast, the ratings of less experienced listeners suggested that they were influenced primarily by the psychoacoustic factor of pitch height, although they did follow the hierarchical model to some extent. Less experienced listeners gave higher completion ratings to tones closer in pitch to the last note of the prime scale, in comparison to trained musicians who prioritised melodic suitability. These results are notable as they show that the influence of tonal context is not universal, but rather may be dependent on musical experience.

Following these investigations into tone perception, Krumhansl and colleagues next investigated the ways in which listeners understand the relationships between chords within a key (Krumhansl et al., 1982). In this set of experiments, the researchers demonstrated that musically experienced listeners perceive triads in major and minor keys in a similar manner to the way in which they perceive notes. As with notes, triads are perceptually categorised within hierarchies of stability. The researchers found that listeners perceive the major I, V and IV triads as the most stable, with VIm and IIm chords following, and the IIIm and VIIdim chords as the least stable. These results empirically verify principles of music theory related to chord hierarchies (Mulholland & Hojnacki, 2013). In addition, ratings of goodness-of-fit between related and unrelated chord pairs showed that listeners may have strong expectations for diatonic continuation once a key context has been established.

Further investigations by Krumhansl formed the basis of her influential 1990 book *The Cognitive Foundations of Musical Pitch* (Krumhansl, 1990). Through experiments on chord hierarchy, Krumhansl was able to outline a definitive hierarchy of listeners' perceptions of the saliency of all major and minor triads with reference to the major key. These are outlined in the table below:

Chord	C Major Context	C Minor Context
C Major	6.66 (I)	5.30
C♯/D♭ Major	4.71	4.11
D Major	4.60	3.83
D♯/E♭ Major	4.31	4.14 (III)
E Major	4.64	3.99
F Major	5.59 (IV)	4.41
F♯/G♭ Major	4.36	3.92
G Major	5.33 (V)	4.38 (V)
G♯/A♭ Major	5.01	4.45 (VI)
A Major	4.64	3.69
A♯/B♭ Major	4.73	4.22
B Major	4.67	3.85
C Minor	3.75	5.90 (i)
C♯/D♭ Minor	2.59	3.08
D Minor	3.12 (ii)	3.25
D♯/E♭ Minor	2.18	3.50
E Minor	2.76 (iii)	3.33
F Minor	3.19	4.60 (iv)
F♯/G♭ Minor	2.13	2.98
G Minor	2.68	3.48
G♯/A♭ Minor	2.61	3.53
A Minor	3.62 (vi)	3.78
A♯/B♭ Minor	2.56	3.13
B Minor	2.76	3.14
C Diminished	3.27	3.93
C♯/D♭ Diminished	2.70	2.84
D Diminished	2.59	3.43 (ii°)
D♯/E♭ Diminished	2.79	3.42
E Diminished	2.64	3.51
F Diminished	2.54	3.41
F♯/G♭ Diminished	3.25	3.91
G Diminished	2.58	3.16
G♯/A♭ Diminished	2.36	3.17
A Diminished	3.35	4.10
A♯/B♭ Diminished	2.38	3.10
B Diminished	2.64 (vii°)	3.18 (vii°)

Fig. 1: Table of perceptual chord hierarchies in major and minor contexts
(Source: Krumhansl, 1990, pp. 171-172)

In summary, evidence suggests that listeners are consistent in how they perceive musical relationships within the Western major/minor tonal system. Listeners apply meaning to musical events through the lens of these tonal relationships. They categorise notes and chords based on hierarchies, as proposed by music theory. Hierarchies of tones and chords are stored as cognitive frameworks, or schemata, for each individual major/minor key. If a piece of music fits into an established major/minor tonal schema, that schema will be activated so that meaning can be applied. Listeners adapt quickly to changing musical contexts as a piece of music evolves, discarding old tonal schemata as they become obsolete, and replacing them with new, more appropriate frameworks.

This foundational understanding of how listeners apply meaning to musical sounds gave researchers a framework within which to begin to study expectation and surprise.

2.3. A survey of harmonic expectation

Some of the first evidence of harmonic expectation was found in a study by Bharucha and Stoeckig (1986). In this study, listeners were primed with a context chord and their reaction times (RTs) to a related/unrelated target chord were measured. This was an important advance in the research methodology in harmonic expectation, as RT tests allowed researchers to gather data on listeners' immediate, implicit expectations. Previously, probe tone tests that allowed listeners time to determine their answers measured only listeners' explicit reactions, confounding the influence of musical training. RTs in Bharucha and Stoeckig's study were found to be faster in response to related than unrelated chords, suggesting that listeners expected the related chords, but not the unrelated ones. The authors concluded that the results demonstrated in listeners

> an overall increased sensitivity (faster and more accurate responses) to related targets relative to unrelated targets, and a bias in favor of judging a related target to be the more stable . . . This bias enhances the observed facilitation of the more stable or consonant target (Bharucha & Stoeckig, 1986, pp. 409-410)

With these results Bharucha and Stoeckig established an effective experimental paradigm for testing harmonic expectation and provided initial validation of Meyer's theory of expectation.

Schmuckler (1989) also used a probe tone method to test listeners' expectations for melodic and harmonic events at different points within a section of a Schumann lied. Schmuckler found that listeners' melodic expectations correlated strongly with Krumhansl's key-profiles, and their harmonic expectations conformed to Piston's Table of Root Progressions (Piston, 1978), a table outlining the most common chord progressions in CP music, according to theorist Walter Piston. These results suggest that listeners' expectations are informed by their schemata, which reflect music-theoretic norms of the given musical culture and style. It is worth noting that the participants in Schmuckler's study were highly trained musicians, who likely were more familiar than most general listeners with the stylistic norms of the late Classical style which formed the basis of the experimental stimuli.

In addition to the facilitation of expected harmony, results for inhibition of unexpected harmony have been found, demonstrating that musically trained listeners are not only primed for related chords, but a processing cost is applied to unexpected chords. Tillman, Janata, et al. (2003) found inhibition costs for both non-diatonic unexpected chords and, notably, diatonic chords following a closed cadence. This shows that listeners contextualise not just the tonality of chords and their belongingness to a particular tonal centre, but also their function within progressions.

Results of a follow-on study by the same researchers demonstrated a hierarchy of inhibition/facilitation (Tillmann et al., 2008). Only the tonic I chord was found to be facilitated, while RTs to the dominant V chord were the same as the baseline, and the subdominant IV and other non-related chords were inhibited. In a similar study on cadences using excerpts from Mozart sonatas (Sears et al, 2018), researchers found that for all listeners, authentic cadences were the most expected, followed by half cadences. Least expected were deceptive and evaded cadences. This further corroborates music theory, verifying that closed, open and interrupted cadences indeed fulfil, on a cognitive level, the functions that music theorists ascribe to them.

In addition to behavioural evidence for the effects of harmonic expectation and surprise, researchers, through fMRI (*functional magnetic resonance imaging*), EEG (*electroencephalography*), MEG (magnetoencephalography) and PET (*positron emission* tomography) studies, have found evidence of *event-related potentials* (ERPs)[4] in response to unexpected harmonies.

Many of these studies used an experimental paradigm featuring a Neapolitan 6^{th} (N^6) chord. The N^6 chord contains two non-diatonic notes in the form of a minor 2^{nd} and a minor 6^{th}. In one condition, the N^6 was placed following the chord of I and preceding a V chord, as is typical of its use. In the other, the chord is placed in an unusual position at the end of a cadence, following a V chord, making it an unexpected resolution. Koelsch et al. (2000) used this paradigm and found that an event-related potential (ERP) they termed an ERAN, was elicited in listeners in response to the N^6 chord. This ERP is the primary musical expectation-related brain response found in neuroscience. In Koelsch et al.'s study, the strength of the ERAN was much greater in the unexpected condition than in the expected. When the N^6 chords were replaced with dissonant tone clusters with no music-theoretic logic or function, the elicited ERANs were even more distinct, suggesting that the amplitude of the ERAN relates to the level of unexpectedness of the

[4] An event-related potential (ERP) is a measurable brain response that occurs in response to a stimulus. ERPs are representative of "specific sensory, cognitive, and motor events" (Luck, 2005, p. 4)

sound. This study provides evidence that surprise reactions to deviant harmony occur in measurable ways in the brain.

Further studies have used the same Neapolitan paradigm to discover that the ERAN can be elicited in response to harmonically deviant chords even when listeners were specifically instructed to ignore the stimuli (Koelsch et al., 2001), or asked to complete concurrent attention-demanding tasks (Loui et al., 2005). This is notable as it suggests that the effects of deceptive harmony are strong enough to affect listeners even when they are not paying attention. It has been found in listeners under sedation, although with attenuated amplitude (Heinke et al., 2004), and in children as young as 2 ½ years old (Jentschke, 2007). Evidence has also been found that ERPs are stronger in musicians in comparison to general listeners (Steinbeis et al., 2006), (Besson & Faita, 1995).

2.4. Sensory/cognitive debate

Researchers are divided on how the results of many of these studies should be interpreted. Many believe that results represent evidence of cognitive processing of musical information. That is, prime stimuli within the experiments activate listeners mental schemas of tonalities, and subsequent goodness-of-fit judgements are based on the contextualisation of target stimuli within these cognitive tonal schemas. Others contend that results instead primarily demonstrate listeners' sensory processing of the psychoacoustic qualities of the musical sounds, such as the frequencies of the fundamental pitch and upper partials of the tones, which combine to produce the sensation of timbre. That is, listeners' results are based on their judgements of how well the target stimulus fit within the spectral context of the prime stimulus. The issue is further complicated by the fact that harmony that is unrelated stylistically is often also unrelated psychoacoustically, given that psychoacoustic factors played such an important part in the development of early musical frameworks, such as the Ancient Greek system. The debate over whether listeners use primarily tonal or timbral information to process music has persisted through the decades and the issue remains contentious to this day.

Researchers have made compelling arguments for both sensory and cognitive effects in harmonic expectation. In Bharucha and Stoeckig's 1986 study described above, the authors point out that it could be argued that the facilitation of related harmony found in their results was enabled by the fact that frequency components of both the prime chords and the target chords overlap, and thus faster processing times can be accounted for by a psychoacoustic explanation. In later experiments, these harmonic components were removed from the experiment stimuli. It was found that priming effects still held, and RTs for harmonically related chords were again faster than those for non-related chords. However, Richard Parncutt has subsequently argued that these deleted harmonic components may have been perceptually restored as "virtual pitches" (Parncutt, 1989), meaning that the participants may have been responding to these sensory factors after all.

The phenomenon of virtual pitch cues was first theorised by Terhardt (Terhardt, 1974), who described a system where spectral cues present in a sound signal may evoke other pitch cues that may not be explicitly present. Huron and Parncutt (1993) created a model following Terhardt's pitch perception model that factored in virtual pitch perception, short-term memory decay and pitch saliencies, i.e. the probability of noticing a pitch. They found that the model could account for Krumhansl's key profiles purely through psychoacoustic priming. This finding challenges the theory that listeners are primed for harmonically related stimuli because of the activation of tonal schemata acquired through exposure to a musical culture.

Attempts have been made to disentangle sensory and cognitive priming using variations of the experimental priming paradigm. Using harmonic stimuli whose psychoacoustic similarity and harmonic relatedness were in opposition to each other, e.g. the chords of C and D, which are harmonically related in the key of G major but contain no pitches in common, researchers have found evidence of cognitive priming (Bharucha & Stoeckig, 1987), giving weight to the cognitive argument. Tekman and Bharucha (1998) found that when the duration of the prime chord is less than 50ms, sensory priming appears to occur, but at longer durations, cognitive priming occurs. In the words of the authors, "expectations . . . are driven by psychoacoustic similarity at very short SOAs [stimulus onset asynchronies] and by implicit knowledge thereafter" (Tekman & Bharucha, 1998, p. 259).

Further evidence of cognitive priming was found by Bigand and Pineau (1997). In this study, the researchers used longer chord progressions and held the final two chords, inclusive of the target chord, constant in both the expected and unexpected conditions. In this way, the researchers were able to extricate cognitive effects from sensory since, from a sensory point of view, the stimuli were identical in both conditions. It was found that participants judged the expected progression as more complete and its final chord more belonging. This shows that they were contextualising the final two chords within the overall key, and therefore were likely to be using cognitive rather than sensory processes.

A meta-analysis of musical priming (Bigand et al., 2014) found that many results, including several of those described above, can be accounted for using Marc Leman's Auditory Short-Term Memory model (Leman, 2000), a model that approximates listeners' sensory processing of musical information. This suggests that priming effects may be completely accounted for by processes related to auditory short-term memory and so may not be a result of larger-scale syntactic processing.

Evidence for both sensory and cognitive processes have also been found within neuroscience. A brain response termed the N5 by neuroscientists has been found that appears to reflect cognitive musical processes (Poulin-Charronnat et al., 2006). According to Koelsch et al., the N5 represents "processing of [musical] meaning information" (Koelsch et al., 2008, p. 1). This interpretation is further validated by a later study that found that the N5 was not elicited when listeners were asked to pay attention to a concurrent task, that is, when they were unable to use cognitive processing (Koelsch, Gunter, et al., 2005).

Neurological evidence of sensory priming has also been found. A complex of two brain responses comprising what neuroscientists have termed the N1 and P2 has been found to relate to musical predictability (Schafer & Marcus, 1973), and is generally regarded to be a manifestation of sensory bottom-up processing (Hantz et al., 1997). P2 amplitudes are enhanced in those with musical training (Baumann et al., 2008).

Evidence for both cognitive and sensory priming in musical expectation and a lack of consensus as to which process is primary means that this question remains open for further investigation within the field of music cognition.

2.5. Alternative experimental paradigms

Further investigation into harmonic expectation has been undertaken using the methodology of divided attention paradigms. Berent and Perfetti (1993) found that musically trained listeners' reaction times to audible clicks were slower when a modulation co-occurred, in comparison to reaction times to clicks before and after a modulation. Similar results have been found when attention was divided between two musical elements, specifically melody and harmony. Loui and Wessel (2007) asked musicians to make judgements regarding the contour of a melody and found that when the accompanying harmony was theoretically unexpected, contour reaction times were slower. These results provide further evidence that unexpected harmony incurs inhibited facilitation and processing costs, as found by Tillman, Janata, et al. (2003) and Tillmann et al. (2008).

Many early harmonic expectation experiments used reaction time paradigms with a mistuning discriminator (Tillmann et al., 1998), (Justus & Bharucha, 2001), (Tillmann, Janata, & Bharucha, 2003). In this paradigm, the dependent variable being investigated is the participant's RT in response to an in-tune or out-of-tune target chord. The independent variable is the harmonic expectedness of the target chord. A potential issue with using a mistuning discriminator task on priming tests, as pointed out by Bigand et al. (2001), is that a confound may arise between the dissonance of the out-of-tune target and the inherent dissonance of the unrelated target chords. This confound may cause results that appear to support the idea of priming but may instead demonstrate listeners' confounding of two separate types of dissonance. In order to avoid this confound, Bigand et al. instead used a temporal asynchrony detection task and found similar results to previous tuning discriminator studies, with listeners found to be primed by tonal context to expect related chords, demonstrating the robustness of harmonic expectation effects when tuning effects are controlled for. Results showing inhibited/facilitated processing based on chord expectedness have also been found using timbre discrimination (Tillmann et al., 2006) and phoneme discrimination tasks (Bigand et al., 2001).

2.6. Schematic vs. veridical expectations

One important question arising from research into harmonic expectation involves repeated exposure. In contrast to other forms of art and entertainment, enjoyment of a piece of music does not necessarily tend to deteriorate as a result of repeated exposure, but rather may increase (Pereira et al., 2011), meaning that listeners enjoy listening to the same piece of music multiple times, over long periods. If listeners are familiar with a piece of music, however, how can their expectations be violated? Researchers divide musical expectations into two categories: schematic expectations, i.e. those generated through implicit knowledge of the typical harmonic, melodic, rhythmic and timbral structures of a musical culture; and veridical expectations, i.e. those specific to a given familiar piece of music (Huron, 2006). Theorists have considered what may happen when these two types of expectation contradict each other. Meyer proposed that one reason we can rehear the same piece many times and still be surprised by it is that listeners enter into an *aesthetic illusion*, whereby they "pretend" they are hearing the music for the first time (Meyer, 1961).

Another theory proposed to explain competing veridical and schematic expectations is Fodor's theory of modular input systems (Fodor, 1983). In such a system, different schemata may be cognitively separated from each other. Jackendoff expands on this, theorising that the musical parser that analyses music as we listen to it may be ignorant of veridical knowledge and always processes a piece of music as if it were hearing it for the first time (Jackendoff, 1992). Our musical parser may be modular, and isolated from long-term memory; it only has the absorbed rules of musical grammar at its disposal to develop an analysis. This would allow schematic expectations to override veridical ones and allow enjoyment of a piece of music with repeated listening.

The question of veridical versus schematic expectations was investigated by Justus and Bharucha (2001) in a series of experiments. Participants in one condition were given the opportunity to familiarise themselves with the musical experimental stimuli, ensuring that they had specific veridical expectations. The trials themselves consisted of typical in-tune/out-of-tune RT tests. It was found that although processing was generally faster overall where listeners had previously heard the progressions, unrelated chords were still processed slower than related chords. This demonstrates that schematic priming occurs even when it may contradict veridical expectations. Tillman and Bigand (2010) found similar results in a timbre discrimination task. Despite prolonged exposure to unexpected target chords, reaction times were persistently longer for these chords in comparison to expected chords. These results show that schematic expectations appear to occur implicitly and automatically and are not affected by expectations related to specific pieces. The results also suggest a certain modularity for schematic and veridical expectations, supporting Fodor's theory.

Schematic and veridical expectations have also been investigated through neuroscientific studies. Evidence for distinct and separate neural correlates for veridical and schematic knowledge has been found by Miranda and Ullman (2007), who discovered that ERAN components, previously found by Koelsch et al. (2000) in response to N^6 chords, were found for violations of schematic knowledge only, while violations of veridical knowledge did not elicit these ERPs.

The amplitudes of ERANs elicited by unexpected chords have been found not to diminish significantly with repeated exposure in a short term context (Guo & Koelsch, 2016). ERANs have been found to be robust over long periods: when listeners were subjected to repeated exposure to deceptive harmony for approximately two hours, ERANs were elicited for the full duration of time, although amplitudes reduced significantly. This shows that listeners can become familiarised with schematically deviant progressions, but the unexpectedness of these progressions is not easily erased (Koelsch & Jentschke, 2008). Guo and Koelsch (2015), have also found that the peak latencies of ERANs, i.e. the time it took for them to reach their peak amplitude following the stimulus, were found to occur earlier when participants were told to expect a deceptive cadence than when they were given no information. This suggests that veridical expectations may mediate the speed of schematic processing, although not its extent.

2.7. Studies using popular music

A small number of studies have investigated tonal hierarchies and, to some extent, expectation within popular music. These studies are particularly important within the literature as their results reflect the processes of general listeners in response to the music that they hear in their everyday lives (North et al., 2004), and that represents their preferences (YouGov, 2011). Thus, these studies portray a more realistic image of contemporary music listening than studies that use exclusively CP stimuli.

Craton and colleagues tested listeners on their perceptions of tonal hierarchies in mainstream popular music (Craton et al., 2016). They found that general listeners, i.e. those with no musical training, had preferences for chromatic chords typically found in contemporary popular music, but atypical in CP music, in comparison with chords atypical of both styles. For example, the ♭VII7 chord commonly found in rock and jazz was found to have similar liking ratings to the diatonic IV and V chords. This chord is not tested in any previous studies of CP harmony as it is not considered a valid CP chord, yet listeners found it to be as salient as the most common diatonic major chords. The ♭III and ♭VI chords, commonly found in contemporary popular music, were also judged as more liked than even some diatonic chords, such as IIm and IIIm.

Hughes (2011) has found evidence for distinct harmonic cognitive schemata activated when listeners are exposed to different musical styles. When experiment participants were primed with an excerpt from either a classical or rock recording, they had distinct sets of ratings for target chord pairs following the primes. The classical context led to higher expectation levels for progressions containing I and V. The rock context led to similar ratings between progressions containing I, IV and V, suggesting that listeners have higher expectations for IV chords when primed with a rock context. Thus, an argument can be made for a distinct rock music cognitive schema which is activated when listeners are exposed to a rock style. Vuvan and Hughes (2019) followed up this study and presented listeners with either a V-I cadence or a ♭VII-I cadence subsequent to either a classical or rock context. Previous results of Hughes were validated, with listeners demonstrating higher expectations for V-I in the classical context but showing no significant difference in the rock context.

Applying their methodology to tonal hierarchies, Vuvan and Hughes (2021) found that tone profiles elicited from participants following a rock stylistic cue differ from those found by Krumhansl and Kessler (1982). Instead, the hierarchies reflected the results of statistical analysis of a rock corpus drawn from Rolling Stone magazine's list of the '500 Greatest Songs of All Time' carried out by de Clercq and Temperley (2011). Given that Krumhansl and Kessler's original tone profile has been considered the basis of tonal hierarchy for around forty years, this discovery is significant.

Miles et al. (2017) performed a statistical analysis on the same McGill Billboard corpus investigated by Temperley and de Clercq. They found that, statistically, the surprising chords that contributed the most to preference (as measured by chart placement) were the II (significantly), the Im, IIIm, ♭IIIma, IVm, and IVm. However, many questions arise from these results. Why were so many diatonic chords surprising? Many of these chords are commonly found in the corpus, and so it cannot be their rarity that contributes to the surprise they elicited. Perhaps the chords preceding these diatonics acted as dominant chords eliciting deceptive resolutions, but unfortunately the authors do not reveal this. They do acknowledge, however, that:

> many of the chords that appear to contribute significantly to the difference in surprise between Q1 and Q4 are diatonic chords. Therefore, the contribution to this difference by some of the chords may be due to the prevalence of their extensions, rather than tonality based on their root or third notes. (Miles et al., 2017, p. 6)

These results provide support for Huron's concept of "cognitive firewalls" (Huron, 2006, p. 414) between internalised musical models, whereby listeners apply different schemata based on context. That is, listeners familiar with different musical styles will have unique sets of expectations for those styles. A harmonic schema for a particular style is activated when a listener hears stylistic cues for that style. These schemata are distinct and separate, and listeners may be adept at transferring between them when necessary. Further, even general listeners may have the ability to ensure that the relevant schema is applied in the specific context in which it is appropriate.

Although the number of studies that account for non-CP Western styles is limited, those that have been undertaken show the benefits of broadening the musical scope of experimental stimuli. However, what is lacking in these results is a comprehensive accounts of the structures and techniques that specifically elicit surprise within popular music.

2.8. Musical images

Studies have been conducted to try to determine if listeners' expectations can themselves be identified as mental images represented by electrical brain responses. Janata (1995) conducted a neuro-imaging study using prime progressions and surprising harmonic targets. It was found that an ERP was elicited in the period of silence between the offset of the prime progression and the onset of the target chord, during which time participants were asked to imagine the best possible resolution to the prime progression. The amplitudes and locations of these ERPs were similar to those found in response to the chords of the prime progression. This suggests that listeners were responding in similar ways to an imagined chord as they would to a heard chord, further reflecting the validity of harmonic expectations. In a follow-up study, Janata (2001) asked musically experienced participants to listen to short melodies. The melodies were then replayed with the final few notes missing, and the participants were asked to mentally continue them. ERP components were found in response to listeners' mental continuations of the melodies, suggesting that these ERPs may reflect musical imagining. Janata and Paroo (2006), in a later study, found that listeners' mental representations of the final notes of major scales were functionally identical, in terms of task responses, to their expectancies for those notes, giving support to the idea that expectations manifest as musical images.

Zatorre et al. (1996) measured cerebral blood flow (CBF) in participants as they imagined music and as they listened to it. They found similar patterns of CBF changes in both conditions, suggesting that both hearing and imagining music share functional similarities in the brain. They conclude that this is evidence that "hearing in the figurative mind's ear utilizes similar neuronal processes as hearing via the actual ear" (Zatorre et al., 1996, p. 42). When general listeners were asked in an experiment by Halpern (1989) to imagine given tunes and produce the first notes, either by singing, or on a hidden keyboard, they showed very little variability across trials. This suggests that the pitch of imagined sounds is stable and consistent and persists over time.

Hubbard and Stoeckig (1988) asked listeners to imagine a note or chord a whole tone above a prime. They found that when listeners were asked to imagine specific chords, they had faster reaction times and accuracy in response to harmonically related chords, suggesting that listeners were able to accurately imagine the required chords, and that chords function the same way in the imagination as they do in reality. According to the authors, there may be "shared mechanisms in the processing of musical images and percepts" (Hubbard & Stoeckig, 1988, p. 656). The ability of researchers to pinpoint musical images in the brain as tangible entities lends weight to the argument that expectation and prediction are core components of music processing.

2.9. Prediction, preferences, and emotion

It is clear from a review of the research related to harmonic expectation that listeners have specific expectations and marked cognitive responses to unexpected harmony. But these findings are only relevant to us as listeners if they influence how we interact with and enjoy music. It is important to ask whether these factors affect preferences for and emotional reactions to music, as theorised by Meyer and Huron.

According to psychologist Daniel Berlyne, the pleasure we get from an aesthetic stimulus, i.e. what Berlyne refers to as its "hedonic value" (Berlyne, 1971, p. 81), depends on the level of arousal it elicits in us. Berlyne suggested that levels of arousal in response to external stimuli are determined by interactions between three types of variables:

1) Psychophysical variables, which are related to sensory preferences.
2) Ecological variables, related to associative preferences such as those elicited when a stimulus triggers a positive memory.
3) Collative variables, which Berlyne described as "such properties of stimulus patterns as novelty, *surprisingness* [emphasis added], complexity, ambiguity, and puzzlingness" (Berlyne, 1971, p. 69).

Berlyne's theory holds that collative variables are the most significant factors in aesthetic preference. He models his theory through an adaptation of the Wundt curve, created by Wilhelm Wundt in 1874 to explain human reactions to stimulus intensity. In Berlyne's adapted curve, "the horizontal axis represents not merely stimulus intensity but arousal potential, which includes intensity but also other stimulus properties, including . . . collative properties" (Berlyne, 1971, p. 90). This figure became known as Berlyne's "inverted-U" curve.

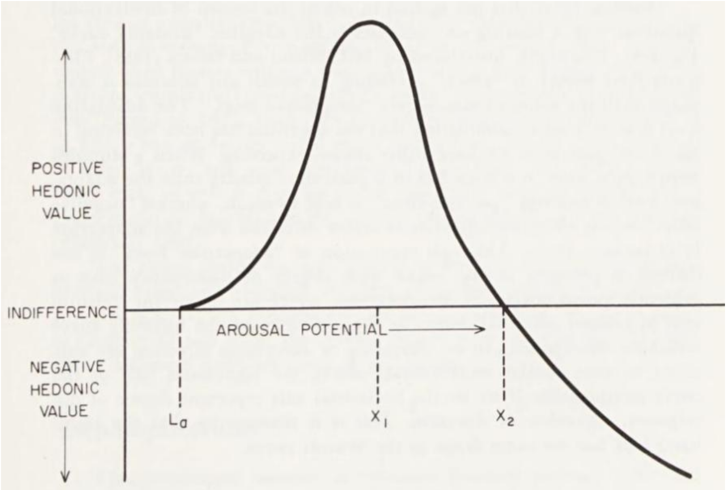

Fig. 2: Berlyne's inverted-U curve (Source: Berlyne, 1971, p. 89)

Thus, as factors such as novelty, complexity, and surprisingness increase, hedonic value increases, until a zenith is reached, at which point hedonic value steadily decreases. In terms of harmonic expectation, this suggests that while a complete lack of deception is not likely to elicit positive reactions from listeners, there exists a peak amount of deception that listeners will enjoy. Beyond this point, enjoyment is likely to drop.

Other experimental results, however, have shown that the inverted-U curve may not be a sufficiently sophisticated model to account for aesthetic preferences. For example, research by Zajonc has highlighted a 'mere exposure' effect, whereby increased exposure to a stimulus increases liking towards it (Zajonc, 1968). This appears to contradict Berlyne's inverted-U theory, which suggests that arousal potential with respect to the collative variable of novelty will be inhibited at a certain point. However, Chmiel and Schubert (2017) argue that these theories are not necessarily mutually exclusive since it cannot be conclusively demonstrated that liking rating as a result of exposure never declines, and as such is not merely the positive slope of a curve-shaped graph. Within music, experiments involving both novel and self-selected familiar musical stimuli have shown varying results, some supportive of Berlyne's theory, and others in opposition.

Preference for harmonic complexity has been found to be mediated by musical experience. In a study by Smith and Melara (1990), expert musicians were found to prefer more complex chord progressions, while general listeners and intermediate level musicians' preferences decreased linearly as harmonic complexity increased. Similar results were found for musicians and general listeners, with increasingly complex jazz and bluegrass improvisations used as test stimuli (Orr & Ohlsson, 2005). In tests involving chord progressions, the preferences of improvising musicians have been found to follow the inverted-U curve, with the highest preferences for medium-complexity progressions in contrast to general listeners, who preferred low complexity progressions (Przysinda et al., 2017). Contrasting results have been found, however, by Loui and Wessel who tested musicians' and general listeners' preferences for unexpected chords and found no difference in their ratings (Loui & Wessel, 2007).

Evidence has been found that listeners who experienced more surprise when listening to a musical excerpt had greater enjoyment when listening to it (Shany et al., 2019). Further evidence that musical surprise increases preference has been found in an experiment measuring listeners' ratings of pleasantness in response to excerpts from 745 songs from the Billboard charts (Cheung et al., 2019). Excerpts were statistically analysed to determine the surprise levels of their chords, and researchers found a correlation between surprise levels and pleasantness ratings. Armitage and Eerola (2020) found similar results of increased preference in tandem with increased surprise. This finding was mediated, however, by a drop in preference in reaction to excessive surprise, which supports Berlyne's inverted-U theory, and suggests that the strongest preferences are for a moderate level of surprise.

Evidence of emotional reactions to surprise have been found, although these results are tempered by ongoing discussions around whether the sensations elicited are valid emotions or a kind of representative approximation of an emotion. Meyer took a cognitivist position; he believed that emotional responses to music were too undifferentiated to properly quantify or classify and that exploration of physiological responses to music was not a worthwhile endeavour (Meyer, 1956). Meyer is supported in his opinion by Kivy, according to whom "there are no behavioral symptoms of listeners actually experiencing [emotions] when attending to music" (Kivy, 1990, p. 151). However, more recent studies have demonstrated physiological, neurological and behavioural responses to music that are consistent with accepted definitions of definitive emotional reactions (Juslin et al., 2011).

Sloboda (1991) asked listeners to self-select music that has elicited in them particular physiological responses, such as "chills", a lump in the throat, or a racing heart. Musical analysis of these segments shows that they contain, among other features, "new or unprepared harmony", and "melodic appoggiaturas". Both of these musical features are related to expectation: unprepared harmony by its nature violates listeners' expectations for diatonic continuation, while appoggiaturas violate expectations for strong chord tones, rather than tensions, to fall on downbeats.

Physiological effects, including increased inter-heartbeat interval and electrodermal activity in response to expected, deceptive and unexpected cadences have also been found

(Steinbeis et al., 2006). Notably, these physiological results appeared to be the same for musicians and general listeners, although ERP measurements taken in parallel demonstrated differences. Neurological evidence of emotional responses to self-selected music have also been found (Blood & Zatorre, 2001). Heightened activity in brain regions associated with reward, emotion, and arousal, such as the amygdala, was discovered at points where listeners reported feeling "chills" in response to self-selected musical pieces. Increased activity in the form of dopamine release has also been found during the moments leading up to points of heightened response in self-selected music (Salimpoor et al., 2011).

2.10. Cross-cultural studies

Many scholars have reflected critically on the lack of non-Western perspectives in the field of music cognition (Jacoby et al., 2020) (Stevens, 2012). Huron points out a disconnect between cognitive science and ethnomusicology:

> Regrettably, most cognitive scientists are ill-equipped to do remote field work, and few ethnomusicologists know how to do an experiment. This situation must change rapidly if we are to have much hope of glimpsing the range of possible musical minds. (Huron, 2008, p. 457)

Tillman et al. have noted a lack of diversity in the field:

> Most research has been conducted on musical material from the Western tonal system, thus questioning its relevance for the processing of other musical systems. While some data have overcome this ethnocentric bias and have provided some data for the perception of music from other cultures . . . there are still too few data on musical expectations per se and no data yet on musical expectations in contemporary musical pieces. (Tillmannet al., 2014, p. 111)

The few cross-cultural studies that have been completed demonstrate consistently that listeners with different musical backgrounds have different musical schemata, suggesting that diversity is a factor that should be considered in all studies. For example, researchers have studied the musical preferences of people raised in the Tsimane culture of Bolivia, who have limited exposure to Western music. They found that these listeners showed no preference for chords that are considered in the Western system to be consonant, in comparison to dissonant chords (McDermott et al., 2016).

In one of the very few studies that did not use harmonic stimuli derived from Western art music, Castellano et al. found that when North Indian listeners were asked to contextualise Indian classical music, they ordered tones in a hierarchy consistent with Indian classical theory (Castellano et al., 1984). Their orderings reflected the underlying *thaat*, or parent scale on which the music was based. However, Western listeners unfamiliar with Indian classical music gave precedence to the tones that occurred most frequently in the prime context. Their overall hierarchical orderings did not reflect the underlying *thaat*. This suggests that the two groups were applying meaning based on two very different schemata. The familiar listeners were working from a knowledge of the underlying relationships in the music, gleaned from exposure over a long period of time. The unfamiliar listeners were basing their understanding of the music on the statistical distribution of tones in the excerpts they had been immediately exposed to, as well as Gestalt principles such as proximity and good continuation.

Notably, Castellano et al. compared the hierarchical ratings of the unfamiliar Western listeners with Western major and harmonic minor scale hierarchies and found that there was little correlation between the two. They conclude that this demonstrates that Western listeners were not basing their expectations on Western musical statistics, as may be expected. This is important to highlight, as it demonstrates that listeners do not appear to apply their familiar schemata in contexts that they know to be inappropriate, but rather, will rely on psychoacoustic clues for contextualisation in unfamiliar musical situations.

Similar results have been found in a study of Balinese music (Kessler et al., 1984). In this experiment, the researchers compared three groups of listeners: Western listeners unfamiliar with Balinese music, Balinese music conservatory students, and Balinese listeners unfamiliar with Western music. A probe tone paradigm was used, where listeners were asked to rate the goodness-of-fit of single tones played at the end of either a Western major or natural minor scale, or a Balinese slendro or pelog scale. Although there were participants in all three groups who appeared to base their goodness-of-fit ratings primarily on psychoacoustic factors such as pitch height, the authors conclude that listeners in all groups demonstrated an internalisation of their own cultural musical schemata.

2.11. Limitations of previous studies

This literature review has detailed a long history of investigation into musical meaning and harmonic expectation. Critical issues in the area have been outlined, such as the discussions around the best method of empirically testing harmonic expectation and the critical refining of paradigms. Although questions remain, researchers may now have a reasonable amount of confidence that the typical paradigms used, i.e. probe tone paradigms and reaction time tests in response to various types of discriminators, are not at risk of errors due to sensory processing issues or confounding of dissonance. But however confident we may be that experiment participants are being tested on what we intend to test them on, the full picture of how harmonic expectation works remains obscured. There are two primary reasons for this lack of clarity: a lack of musical diversity in experimental stimuli, and a lack of musical diversity in experiment participants.

2.11.1. Musical diversity in experiment participants

Given that cross-cultural studies have shown that listeners from different musical cultures have different schemata, it is likely that listeners trained or highly experienced in different styles within Western music may have different schemata, and thus different expectations. Few studies have investigated harmonic expectation using jazz, pop, or improvising musicians, but results in related areas have suggested that these musicians will likely have different experiences of harmonic expectation in comparison to the conservatory trained musicians usually studied. For example, several studies have demonstrated that diverse musicians have distinct neural responses to deviant musical elements. Vuust et al. (2012) investigated mismatch negativities (MMN)[5] in jazz musicians, classical musicians, band musicians and general listeners in response to a variety of deviant auditory features, including deviant pitches, rhythms, and intensities. They found that jazz musicians had larger MMNs in response to the experimental stimuli in comparison with the other musicians. This suggests that jazz musicians may have heightened sensitivity to unpredictable sounds. The researchers comment that “[t]hese results suggest that the style/genre of music that professional musicians are engaged with influences, at least partially, early auditory skills” (Vuust et al., 2012, p. 144)

In another ERP study, researchers compared the MMN and P3a potentials of jazz, classical and rock musicians (Tervaniemi et al, 2016). Musical excerpts with deviants in tuning, timbre, rhythm, melodic transposition, and melodic contour were presented to musicians from all three styles. ERP results showed that jazz musicians were particularly sensitive to transposition in

[5] The MMN is a brain response found in musicians and general listeners that reflects prediction errors in auditory processing. It is thought to reflect sensory, rather than cognitive, processing (Näätänen et al., 2007).

comparison to the other groups. Although rock musicians had larger initial MMN responses in reaction to modulations, jazz musicians' subsequent P3a responses were larger and appeared earlier than those of the other musicians. Since the P3a has been linked with the process of "sound evaluation which leads to attention shift" (Tervaniemi et al., 2016, p. 7); this may suggest that jazz musicians were more sensitive to the harmonic deviations than others.

In addition to having heightened reactions to unexpected non-harmonic stimuli, jazz musicians may also be unique in terms of their predictive processing. Hansen et al. (2016) investigated how jazz musicians compared to classical musicians in response to high-entropy music, i.e. music containing a lot of uncertainty, and low-entropy music, i.e. containing little uncertainty. The researchers used Charlie Parker solos as experimental stimuli, as these contained segments considered low-entropy in a jazz context but high-entropy in a classical context, and vice-versa. The intention of the researchers was to separate out the effect of specialised musical expertise on predictive processing. They found that when asked to rate the uncertainty of unfinished segments of solos, jazz musicians estimated entropy values in a similar manner to a model trained on bebop vocabulary. This suggests that specialised expertise leads to enhanced predictive processing.

Jazz musicians and classical musicians may even differ in their action-planning responses to deceptive harmony. For example, when pianists were asked to imitate silent videos of chord progressions, jazz musicians had faster reactions to incongruent chords in comparison with classical musicians (Bianco et al., 2018). Although both groups showed neural responses to the incongruent chords, jazz musicians very quickly overcame their cognitive conflict to reprogram their planned actions. These results suggest that jazz musicians were better able to flexibly adapt to incongruent harmony, even in situations where the harmony is not audible.

Scholars have highlighted the important role that expectation and anticipation play in the practices of improvising musicians. MacDonald, Wilson, and Miell note that improvisation is created through "moment-by-moment responses to immediate musical contexts", (MacDonald et al., 2011, p. 246) and that improvising musicians "must form expectations about what other players may do in any emergent musical situation" (MacDonald et al., 2011, p. 242). Franziska Schroeder and Iain Campbell highlight that "[i]mprovisation and indeterminacy seem to be aligned terms, both being associated with an acceptance of contingency and an openness to the unexpected" (Schroeder & Campbell, 2021, p. 359). Schroeder, in a ethnographic study of Brazilian improvising musicians, observed that "[m]any improvisers talked about a 'natural' or 'organic' way of making music, saying that it is essential to let yourself be surprised" (Schroeder, 2019, p. 18). Vijay Iyer, discussing Huron's work, draws a link between prediction and improvisation, stating:

> Expectation is a capacity that guides our understanding of real-world, real-time events in a way that helps us make efficacious, life-sustaining actions, to "predict the future" and "take advantage of opportunities." This view would seem completely compatible with, and indeed nearly identical with, our working understanding of improvisation. (Iyer, 2016, p. 83)

Improvisation is a highly skilled technique that involves multiple complex and interconnected neural processes, including fine motor control, analysis of auditory feedback, and error correction (Pressing, 2000). Creative activities such as improvisation require sophisticated cognitive interplay between different areas of the brain, particularly between those areas involving idea generation, and those involving executive control, relevancy and applicability to the current task (Vergara et al., 2021).

Kenny and Gellrich developed a model of improvisation that includes three levels of anticipation: short-term anticipation of events within an interval of 1-3 seconds; medium-term anticipation of phrase-length events; long-term anticipation, or "[p]rojection of long-term plans for the . . . improvisation" (Kenny & Gellrich, 2002, p. 124). Sawyer draws attention to the importance of unpredictability in improvisation, pointing out that "[t]he word 'improvisation' comes from the Latin root improvisus, meaning 'unforeseen' or 'unexpected'"(Sawyer, 1999, p. 193). He considers unpredictability to be the most salient characteristic of a group improvisation, noting that performers must listen and respond to each other's unpredictable performance. Thus, we can infer that anticipation of unpredictable events is a constant factor in any improvising musician's performance and practice. Indeed, Biasutti and Frezza (2009) found, in an analysis of musicians' questionnaire responses, that improvising musicians themselves rate the ability to anticipate musical events as the most important ability employed during improvised performance.

Improvisation has been shown to cause profound changes in musicians and general listeners. Improvisation in areas such as dance and comedy has been linked to higher creativity (Fink & Woschnjak, 2011) (Kudrowitz, 2010). Young children enrolled in a musical improvisation programme in primary school demonstrated increased creative thinking as a result of participating in the programme (Koutsoupidou & Hargreaves, 2009). Classical musicians were found to have increased scores on divergent thinking tasks after just one 20-minute free improvisation session (Lewis & Lovatt, 2013). MacDonald and Wilson, in a review of the literature on the effectiveness of improvisation within the context of music therapy, noted multiple positive effects for particular populations, including “the amelioration of neurological damage, improvements in mental health conditions, [and] reductions in stress and anxiety” (MacDonald & Wilson, 2014, p. 11). Taken together, these data demonstrate that the practice of improvisation can have a significant impact on creativity, communication, problem solving, and imagination.

Theorised differences in music processing between improvising and non-improvising musicians have been borne out by research. Przysinda et al. (2017) have suggested that jazz musicians’ preferences for harmonic complexity may be related to the fact that they are often trained in improvisation. In a comparison of improvising musicians, non-improvising musicians, and general listeners, improvising musicians were found to have larger P3b ERP components in response to deviant harmonic stimuli, in comparison to the other participants. According to the authors, improvisers may have “increased perceptual sensitivity . . . followed by higher engagement . . . followed by a faster return to baseline after the occurrence of unexpected events” (Przysinda et al., 2017, p 51). P3b component amplitudes were found to be correlated with general musical training and were not found for general listeners. Given that P3bs have been previously linked to cognitive workload, this suggests a greater engagement with deviant musical material for improvising musicians.

Taken together, these results show that there are marked differences in how improvising and non-improvising musicians process music, and that quantifiable changes in the brain occur in those who improvise. Many musicologists have noted the axiomatic link between improvisation and prediction, and indeed initial support for this link has been found in the studies described above.

2.11.2. Issues from an applied music theory perspective

In this section, the musical stimuli used in the studies described above are critiqued with reference to musical diversity, repetition, and consideration for musical context. Issues with these stimuli further reflect the necessity of integration between music theory and cognitive science and highlight the issues that can arise when insufficient consideration is given to the background and context of harmonic techniques. An argument is made that the results of these studies cannot be considered universal within Western tonal music contexts, but rather are specific only to CP contexts.

Many researchers cite the work of Krumhansl and colleagues in the 1970s and 1980s as the definitive perspective on tonal hierarchies in Western music. Krumhansl's early experiments utilised the major and harmonic minor scales as priming material. The use of the major scale was justified on the strength of its being, according to Krumhansl, "[t]he most common scale used in traditional Western music" (Krumhansl, 1979, p. 347). This is certainly true but an undue focus on the major scale overlooks the many other scales and contexts that serve as tonal frameworks within the span of Western tonal music.

For example, blues and blues-derived music exists within a tonal framework that does not correspond to the major scale. The tonic chord in blues is a dominant 7, containing a ♭7, in comparison to the major triad/7th found in major, e.g., Muddy Waters' "Got My Mojo Working" (1957), B.B King's "Lucille" (1968), Billie Holiday's "Fine and Mellow" (1944), Nina Simone's "Revolution" (1969). Melodies are generally pentatonic, containing notes that deviate from the major scale, and a minor third is commonly used in the major key. Rather than functioning as a chromatic passing note, or suggesting a modulation to the parallel minor, as would be typical in CP music, this note does not undermine the major key tonality. Examples include Aretha Franklin's "Chain of Fools" (1967), Stevie Wonder's "Living for the City" (1973), Lauryn Hill's "Superstar" (1998), Led Zeppelin's "When the Levee Breaks" (1971), and Laura Nyro's "You've Really Got a Hold on Me" (1971).

Modal contexts that do not fit within the major/harmonic minor tonal frameworks are also very common in jazz/popular music (Moore, 1992). For example, Freddie Hubbard's "Little Sunflower" (1967), Carla Bley's "Ad Infinitum" (1977), Joe Satriani's "Flying in a Blue Dream" (1989), Bjork's "Army of Me" (1995), Fleetwood Mac's "Rhiannon" (1975), Nine Inch Nails' "We're in this Together" (1999), and David Bowie's "Rebel Rebel" (1974) all have modal tonalities.

In Krumhansl et al.'s study (1982), the harmonic minor scale is used as a minor key prime context, with the justification that "chords in minor keys . . . use a raised seventh scale note" (Krumhansl et al., 1982, p. 26). However, the use of harmonic minor may not accurately reflect norms within all Western tonal styles. For example, in a corpus analysis of approximately 780 songs within the popular music repertoire, Moore (1992) categorised around 280 songs as being within the natural minor mode, while only 16 were found to be in the harmonic minor mode.

Evidence exists within Krumhansl and colleagues' early results suggesting that listeners may have been influenced by contemporary musical norms in their responses. Notably, when Krumhansl and Kessler mapped the relationships of chords to keys in their study, they found that listeners considered a dominant 7th target chord to be perceptually "halfway" between two different keys: the key of the chord, and the key in which the chord would be a V7 (Krumhansl & Kessler, 1982). That is, listeners considered a G7 to be perceptually "halfway" between the key of G and the key of C. Krumhansl and Kessler noted that this position was at the same distance as the B diminished triad and thus determined that this is confirmation that "the leading tone triad, VII [can be interpreted] as the dominant seventh chord with a missing root" (Krumhansl & Kessler, 1982, p. 350). However, it may alternatively be the case that the chord was interpreted by some listeners as a I chord in the key of G within a "blues-based schema", activated when the G7 was heard, where the tonic is a dominant 7th structure.

Krumhansl (1990) also found that when primed with a major key context, listeners reported the IV chord to have higher salience than the V chord, which would appear to contradict CP music-theoretic reports that V is the most common chord after I. Krumhansl explained this anomaly by pointing out that the harmonic prime used in the experiment consisted of a cycle of fifths pattern ending on a I chord; the IV chord would continue this pattern and thus may explain its high rating. However, this may be also explained with reference to norms in popular music; in blues and blues-derived rock music, the IV chord is more often found than the V (de Clercq & Temperley, 2011); this factor may have influenced listeners' ratings. This is supported by the results of Hughes (2011), who found that when primed with a rock context, listeners rated the IV as highly salient along with the I and V.

Krumhansl and Kessler (1982) pioneered the use of chord progressions as experimental stimuli, with a view to increasing ecological validity. Walter Piston's *Harmony* (Piston, 1978) was used as a music theory reference with which to construct these progressions. Many researchers have since used this template based on *Harmony* to develop material or models for their own experiments (Bharucha, 1987), (Bharucha & Olney, 1989), (Schmuckler, 1989). Although this is an important step towards ecological validity, Piston's view of harmony explicitly reflects only the norms of 18th and 19th century European art music, and therefore contemporary styles and their influence on listeners are overlooked again. As Piston states in his Introduction to the first edition of *Harmony*:

> [T]he aim of this book is to present as concisely as possible the harmonic common practice of composers of the eighteenth and nineteenth century. (Piston, 1978, p. xx)

Piston's methodology is based on a table of what he refers to as usual root progressions, as seen below. It is this set of rules that researchers in music cognition have used to construct chord progressions. However, Cross and Rohrmeier point out that Piston's table "seems to be grounded in subjective judgment since there is no mention or reference to any construction method" (Rohrmeier & Cross, 2008, para. I)

I is followed by IV or V, sometimes VI, less often II or III.
II is followed by V, sometimes IV or VI, less often I or III.
III is followed by VI, sometimes IV, less often I, II, or V.
IV is followed by V, sometimes I or II, less often III or VI.
V is followed by I, sometimes IV or VI, less often II or III.
VI is followed by II or V, sometimes III or IV, less often I.
VII is followed by III, sometimes I.

Fig. 3: Piston's Table of Usual Root Progressions
(Source: Piston, 1978, p. 21)

Theorists have noted stark differences between the typical root movements of CP music and popular music. Ken Stephenson notes that typical root-movement in popular music is "diametrically opposed to that of CP movement" (Stephenson, 2002, p. 104). A fundamental difference in harmonic movement between rock and classical music can be seen in the primary cadence of the blues: V-IV-I, which can be found in almost every blues form since the beginning of the 20th century. This directly reverses the traditional authentic cadence of CP music. As Philip Tagg notes:

> [C]onventional harmony can only see V as 'dominant' leading to I and cannot entertain the notion that V can be directly followed by IV, as in the I-V-IV-IV loops. According to those norms, IV can, if no parallel fifths or octaves are involved, proceed to V (and thence to I) but V 'cannot' go to IV, and thence possibly also to I. 'Thence to one' is an important observation because the most common incoming and turnaround chord in ionian, dorian and mixolydian loops is, at least in rock-related contexts, IV or, failing that, another chord whose root note is situated flatward of the tonic in the circle of fifths. Under such circumstances movement to the target tonic proceeds in a clockwise direction. Indeed, plagal cadences are probably more rule than exception in those musical styles. (Tagg, 2014, pp. 423-424)

Rock music is based on a language that emphasises retrogressive movement around the cycle of fifths rather than, or at least equal to, the "progressive" root movement found in CP music, according to popular music theorists such as Nobile (2016). That is, progressions in rock tend to ascend in fifths where CP progressions tend to descend in fifths. As well as differences in fourth/fifth movements, corpus analysis of popular music by de Clercq and Temperley (2011) has revealed differences in movement in seconds and thirds. For example, within popular music, movement by descending seconds is common. However, this is rarely found in CP music; ascending steps in seconds are more commonly found. In terms of pre- and post-tonic chords, i.e. those preceding and following I, de Clercq and Temperley found that the most common for both was the IV, followed by V, followed by the blues/Mixolydian chord ♭VII. They note that this suggests more of a "hierarchy of preference for certain harmonies over other" (de Clercq & Temperley, 2011, p. 61) in place of rules of functional progressions.

Root	Instances	Proportion of total	Song instances
I	3,058	0.328	99
bII	46	0.005	5
II	336	0.036	39
bIII	240	0.026	18
III	174	0.019	23
IV	2,104	0.226	90
#IV	23	0.003	4
V	1,516	0.163	88
bVI	372	0.040	21
VI	674	0.072	39
bVII	748	0.081	37
VII	38	0.004	7

Fig. 4: Chord frequencies in Billboard Corpus
(Source: de Clercq & Temperley, 2011, p. 60)

In summary, according to Temperley, the corpus analysis revealed "an equal frequency of 'classical' harmonic motions (descending fifths and thirds, ascending seconds) and 'anti-classical' ones (ascending fifths and thirds, descending seconds)" (Temperley, 2018, p. 41).

A subsequent second corpus analysis by Temperley and de Clercq (2013) revealed differences between prevalent chord structures in popular music in comparison to CP music. In their analysis, the authors found that the statistical distribution of the chords did not match tonal hierarchies described by Krumhansl (1979). For example, Temperley and de Clercq found that the IV chord was more common in the corpus than the V chord. As noted previously, Krumhansl explained this result as an artefact of her experimental paradigm, rather than as the possible influence of popular music.

Temperley and de Clercq's corpus analysis also revealed that ♭VII was one of the most common chords in popular music; this chord rarely appears in 18th and 19th century art music, although it may be found in late Romantic and 20th century art music. Vuvan and Hughes note that traditional music theorists consider the ♭VII rare:

> Clendinning and Marvin (2011) suggest that ♭VII should only be used as a secondary dominant of ♭III and make no mention of its potential resolution to I. Likewise, Gauldin (2004) refers to the ♭VII-I progression as 'comparatively rare' in classical music (Vuvan & Hughes, 2019, p. 2)

Other chords that would be considered chromatic in CP include ♭IIIma and ♭VIma. These chords can be thought of as having modal or blues origins. Corpus analysis by Craton et al., (2021) has found that these chords are common within the popular music corpus. The results of corpus analyses of popular music have thus revealed stark differences between the harmonic languages of CP and popular music, as well as differences between their typical root movements and progressions.

As well as composed chord progressions based on Piston's Table of Usual Root Progressions, harmonic expectation researchers have also used reductions of Bach chorales, an example of which is notated below, as experimental stimuli. The use of these chorales originated with Bigand and Pineau (1997). Although these progressions have more ecological validity than single chord prime-target paradigms or specifically composed chord progressions, they give limited information from a music theory perspective. The most commonly used method of exploring harmonic expectancy using Bach chorales has been to hold the final two chords constant in two separate versions of the short progression, but in some cases manipulate the prime context such as to transpose it to the dominant key. In this way, the final dominant-tonic cadence in the original key was altered to a tonic-subdominant progression, while the chords themselves, and therefore their sensory information, were held constant. Multiple subsequent studies followed suit and used the same paradigm (Tillmann et al., 1998), (Regnault et al., 2001), (Bigand et al., 2003), (Tillmann, Janata, & Bharucha, 2003), (Tillmann, Janata, et al., 2003), (Bigand et al., 2005), (Poulin-Charronnat et al., 2006), (Tillmann et al., 2006).

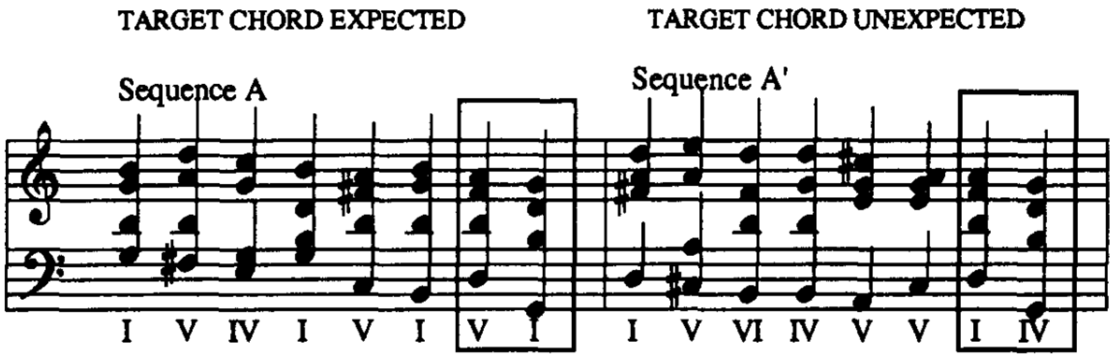

Fig. 5: Experimental stimulus based on Bach chorales (Source: Bigand & Pineau, 1997, p. 1101)

This is an effective method of exploring listeners' reactions to V-I versus I-IV while avoiding any confounding sensory influences. However, though the results of these experiments may lead to interesting results from a cognitive point of view in that listeners' reaction times may differ significantly, from a music theory perspective the results may have limited value. Music theory would hold that in tonal music a tonic functioning I chord has the effect of "closing" a progression, in that it provides a resolution and a sense of finality. In contrast, a dominant functioning V chord leaves a progression "open" since it creates a sense of anticipation, and expectation of a I chord. A IV chord, having a subdominant function, will also give the sense of an "open" or unfinished progression. Thus, a confound may arise between the effect of fulfilled expectation and the effect of closure. That is, the increased reaction times of listeners to the manipulated progression may be less a result of a difference between how listeners perceive I chords and IV chords, and more a result of listeners hearing a progression that concludes idiomatically versus an open progression that stops abruptly. This example of the use of musical stimuli in ways that do not reflect their actual usage is evidence of the problems that arise when sufficient music-theoretic or musicological consideration is not given to harmonic stimuli. Indeed, the results of a later study using a variation of this paradigm revealed that the perception of a target chord was only facilitated if that chord provided harmonic closure to a phrase, suggesting that a confound between surprise and lack of closure had occurred (Bigand et al., 2005).

Koelsch et al. (2000) used a methodology that was more likely to measure listeners' reactions to both expected and unexpected chords. They used a N^6 chord in both a congruent and incongruent location, notated below, and found that listeners' reaction times were longer in the incongruent condition than they were in the congruent.

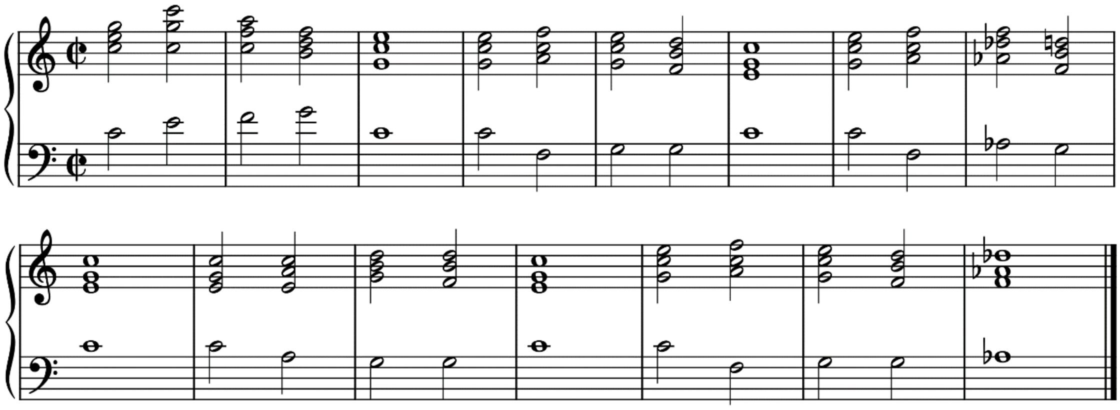

Fig. 6: Experiment stimulus used by Koelsch et al., re-notated
(Source: Koelsch et al., 2000, p. 522)

This Neapolitan excerpt has been used in many harmonic expectation studies since then (Maess et al., 2001), (Koelsch et al., 2001), (Koelsch, Schmidt, et al., 2002), (Koelsch et al., 2003), (Heinke et al., 2004), (Koelsch, Fritz, et al., 2005), (Leino et al., 2007) (Koelsch & Jentschke, 2010), (Loui & Wessel, 2007) (Przysinda et al., 2017).

This excerpt has been very useful as a means of thwarting expectations and has allowed researchers to determine multiple brain responses associated with musical expectation. However, ecological validity may be lacking in the use of this paradigm, for two reasons. Firstly, although the N^6 chord is commonly found in music of the 18th and 19th century, in the vast majority of cases it is found within a minor key context (Kostka & Payne, 2009). The use of this chord within a major key context, such as it is used in these studies, reflects a deviation from the stylistic norm before any experimental conditions have even been applied. Secondly, the use of the N^6 chord in the given context is vanishingly rare within popular music or jazz, which means that this chord is reflective only of CP, and not Western tonal music in general. The use of the N^6 in experimental contexts is based to some extent on its function as a subdominant chord; in its “correct” condition it functions as a pre-dominant approach to a V chord, while in its “incorrect” condition it functions as a tonic, following a dominant V chord. In jazz, chords built on the ♭II are most often found as tritone substitutes of the V chord and therefore have a dominant function, as an approach to I. In other cases, chords built on ♭II may be modal mixture chords, such as in the well known “Lady Bird”[6] turnaround. In this case, the ♭II does not have a dominant function, but nonetheless serves as an approach to a I chord. In neither case does the

[6] The Lady Bird turnaround is a two-bar progression consisting of the I, ♭III, ♭VI, ♭II, whose chord qualities may vary. It is so called because it first appeared in the Tadd Dameron tune “Lady Bird” (1948).

function or movement of the ♭II chord match its use as a subdominant in the "correct" condition of the experimental paradigm.

Secondary dominants have also been used by researchers to investigate harmonic expectation. These chords were used as part of progressions, examples of which are notated below, in a study by Koelsch and Jentschke (2010).

Fig. 7: Experimental stimulus using N^6 chords
(Source: Koelsch & Jentschke, 2010, p. 2252)

Secondary dominants are dominant functioning chords that elicit expected resolution down a fifth to a diatonic chord. This means that they can be used to create deceptive resolutions, through resolution to a chord other than the expected diatonic down a fifth. The thwarting of expectations through the deceptive resolution of secondary dominants is a much-discussed topic in jazz theory (Nettles & Graf, 1997). However, the dominant functions of these chords were not explored in the harmonic expectations studies in which they were used. This may be seen first through the voicings of the secondary dominant chords; they did not contain 7ths as chord tones and thus did not contain a tritone, which jazz theory would hold is an essential feature of a secondary dominant functioning chord. In addition, the chords were treated as resolutions rather than tensions; listeners were tested on their reaction times to the secondary dominants following a primary dominant (Koelsch & Jentschke, 2010), rather than to expected or deceptive resolutions following the secondary dominants. Although the paradigm used is not incorrect, it does not accurately reflect the idiomatic use of secondary dominants.

Other studies have used a paradigm whereby the last chord of a sequence is transposed up or down a semitone (Tillmann, Janata, & Bharucha, 2003), or where the V and/or I chords are raised a semitone in order to investigate global and local context effects (Tillmann et al., 1998). In this case, resolution to an unexpected chord following a dominant function is tested, but harmonically these progressions are similar to Neapolitan resolutions, and, given that they incorporate only two possible deceptive resolutions, are limited in terms of the conclusions that can be drawn with respect to music theory.

This is not to say that all stimuli in harmonic expectation experiments are ecologically invalid or musically inappropriate. Researchers have made efforts to include ecologically valid examples of CP music, including Koelsch and Mulder (2002) and Koelsch et al. (2008), who used excerpts from pianos sonatas by Beethoven, Haydn, Mozart, and Schubert. Steinbeis et al. (2006) and Gold et al (2019) have used ecologically valid Bach chorales. However, although these stimuli are examples of real-life music and therefore all chords are contextually appropriate, they serve to reinforce the focus on a narrow range of music within the CP period. Not only is non-CP music overlooked, but the myriad of styles within CP, including the folk-influenced nationalism of Dvořák and Grieg, and the adventurous chromaticism of Wagner and Strauss are similarly passed over.

To summarise, the examples above demonstrate a lack of concern for musicological validity, which causes two issues. The first is that if target chords do not reflect their usage in real life musical examples, then it is difficult to justify that the results are representative of real-life musical listening. This occurs both when CP chords are used non-idiomatically, and when it is presumed that CP techniques function in the same way within non-CP contexts, if they are found at all. The second issue is that the results elucidate little about the actual musical techniques used by composers, either within CP or non-CP styles, to elicit expectation and surprise in real-life musical contexts. Granted, this is not likely to be the main priority for the cognitive scientists conducting this research, but consultation with the music theory and musicology communities could allow for more accurate and representative stimuli, through which experimental results may be generalised to real-life examples.

2.12. Conclusions

The aim of this chapter was to (1) provide context and understanding of the mechanisms of harmonic expectation, and (2) determine areas within the research where musical diversity and contextual understanding may be overlooked.

The literature review revealed that listeners interpret music through schemas consisting of hierarchies of stability in the musical system. Sensory processes are more influential for general listeners and responses below 50ms, and cognitive processes more influential for musicians and later responses. Expectation has been found to be an important part of music listening for both musicians and general listeners, and listeners have strong expectations for specific harmonic structures to follow others. Further evidence of the importance of expectation and prediction in music listening is provided by the results of neuroscientific studies that found measurable brain responses in listeners in reaction to unexpected harmony, in terms of both sensory and cognitive processes. Studies have also found strong links between musical surprise and music preference, enjoyment, and appreciation, highlighting the relevance of this topic to listeners.

Despite elucidating many aspects of human responses to music with respect to expectation and surprise, the results described in the literature review yield little information about music itself. Research tells us that listeners contextualise tones and chords in particular hierarchies based on a major or harmonic minor key prime, but we do not know how these notes and chords would be contextualised given a non-CP prime such as a modal or blues context. Listeners appear to be surprised by N^6 chords, but they are presented in a contextually inaccurate way, and these chords are found only rarely, if at all, in jazz or popular music. Expectation is on a gradient, as demonstrated by responses to authentic, half, deceptive, and evaded cadences. However, these are CP structures, and may not function in the same way, or at all, in jazz/popular music. Secondary dominants are found to be surprising, but these have been only tested as major triads, rather than the 7^{th} chord secondary dominants typically found in jazz. In addition, the potential deceptive resolutions of secondary dominants have not been investigated. Given the vast number of chromatic chords used by composers in jazz/popular music, and indeed in later periods of Western art music, there remains the potential for a world of harmonic deception to be explored.

To summarise, an undue focus on CP stimuli and conservatory trained musicians in harmonic expectation research is problematic for four reasons. The first is that the perspectives of expert musicians with training and experience in non-CP styles such as jazz and popular music are overlooked, and thus the potentially important effects of stylistic training on harmonic expectation remain unknown. The second is that improvising musicians are overlooked, with the result that the effect of training within a style where anticipation and reaction to unexpected events is of paramount importance is unknown. The third is that there is little knowledge of the specific musical techniques that elicit expectation and surprise in contemporary styles such as jazz and popular music, which is to the detriment of music theory and musicology. Finally, the narrow range of stimuli used means that there is a lack of diversity even within the realm of Western art music, with art styles of the late 19th and 20th centuries neglected.

The next two chapters investigate harmonic expectation from the perspectives of historical CP music theory and contemporary jazz and popular music theory in order to attempt to gain a fuller understanding of how musical expectation and surprise work in context, and to expand our knowledge of the range of musical techniques with the potential to elicit expectation and surprise.

3. A History of Harmonic Expectation

3.1. Introduction

The aim of this chapter is to identify the techniques eliciting harmonic expectation in common practice (CP) through a survey of music-theoretic texts. This survey will prepare the groundwork for a music-theoretic analysis of how these techniques evolved and changed throughout the late 19th and 20th centuries within jazz and popular music, which will follow in the next chapter.

Both the CP survey comprising this chapter, and the jazz/popular music survey comprising the next chapter, aim to investigate how musical elements exist within a context, and how their meanings are derived from how they function within that context. The previous chapter demonstrated that by isolating musical elements and not paying due regard to their contexts, we risk changing their meaning. In addition, by ignoring the rich diversity of musical techniques used by composers, songwriters, and musicians to generate surprise and expectation, and focusing only on a narrow range of elements, we risk missing out on a wider perspective (Tervaniemi, 2023), (Demorest, 1995), (Thompson, 2009). Therefore, in order to gain a complete picture of how harmonic expectation works, great care must be taken to understand and maintain the meaning of musical elements associated with surprise and expectation. To do this, we must have a full account of their place within the broader context of music theory, and of the variety of ways they are used by musical creators, and we must fully understand all of the possibilities available within them. This will lead to a better understanding of the contextual factors that should be taken into account when these elements are used in music cognition experiments.

The survey begins with music from the Medieval mode of practice and continues through the shift to diatonic tonal frameworks in the Baroque period, through to the classical and early Romantic periods. The survey does not explore expectation within the art music styles of the 20th century, as this is not typically used in harmonic expectation experiments and is not the subject of this thesis, which focuses on jazz and popular music. It is not the purpose of this chapter to provide a comprehensive account of the sprawling history of Western art music, nor would this be relevant to the aims of the research. Rather, the purpose of this chapter is to focus on and identify the techniques used to create harmonic expectation and surprise within CP and to trace their development over time, in order to compare the differences between these elements as they occur in CP, jazz, and popular music and thus determine how expectation and surprise may function differently between styles. This will lend weight to the case that the results of expectation studies that use CP stimuli are not paradigmatic of all Western tonal styles.

In order to achieve this the account focuses on cadence, chromaticism and modal mixture. These techniques, and their justification for inclusion, are outlined below.

Cadences are generally accepted by music theorists to be a primary method used to elicit expectations and surprise listeners (Rameau, 1722/1971) (Schoenberg, 1922/1978), and are frequently used in music cognition experiments to investigate harmonic expectation (Sears et al., 2018). Studies that have included deceptive cadences in their experimental stimuli (Seger et al., 2013) (Sears et al., 2018) have found converging evidence that listeners have specific expectations for V7 chords to resolve via a perfect cadence, as propounded by music theorists, but the range of cadences studied has been narrow. This review will demonstrate that music theorists throughout history allowed for a far broader range of deceptive cadences than are described in current accounts of music theory. Cadences are included in this review due to the overwhelming agreement from theorists, musicians, and music cognition researchers that they are a significant source of expectation, and in the case of deceptive cadences, surprise.

Various types of **chromaticism** will also be explored in this review. Music theorists agree that chromaticism can be a source of surprise (Cohn, 2012), (Clough, 1957), and there have been many accounts of composers using chromaticism for dramatic effect and to evoke tension (Shir-Cliff et al., 1965), (Aldwell et al., 2011). This view is to some extent supported empirically by Krumhansl's studies (Krumhansl, 1990), which found that listeners expect melodic continuation within the diatonic context to which they are initially exposed. Several studies have found that specific chromatic chords, such as the N^6, elicit surprise in listeners, particularly when found in an unusual location within a progression (Koelsch et al., 2000), (Koelsch, 2005), although Chapter 2 revealed the use of the N^6 in experimental contexts to be generally non-idiomatic. However, this review will demonstrate that there are multiple methods of using chromaticism to elicit surprise, many of which are unexplored in music cognition due to the narrow focus on Neapolitan chords in the literature. These include secondary dominants, augmented 6th ($^{+}$6) chords, and chromatic mediants.

Modal mixture is another method explored in this review**.** Modal mixture is a type of chromaticism, whereby harmonies from parallel keys/modes are inserted into the current key, thus interrupting the expected diatonic context. The literature on the relationship between modal mixture and expectation and surprise is limited. It has been referred to as an expressive source of tension, drama, and conflict (Aldwell et al., 2011), and, following Krumhansl's findings, modal mixture chords that violate expectations for diatonic continuation are likely to be perceived as surprising. However, no studies on harmonic expectation and surprise have to date investigated the effects of modal mixture on listeners. These chords are commonly found throughout classical, jazz, and popular music, and so they are idiomatic of all three contexts. Modal mixture was used during the pre-CP modal era but given the differences in context, a pre-CP review is not necessary. Thus, modal mixture is not investigated in this review until it appears in its CP form during the Baroque period.

In this chapter, the following questions will be asked:

1) How did elements associated with surprise and expectation arise in CP?
2) How have these elements developed throughout the history of CP, particularly within a harmonic context?
3) How have music theorists throughout history conceptualised these elements?

In each case, the purpose is to reveal a broad range of musical elements which operate to create surprise in the listener in order to develop a better understanding of how expectation and surprise function within CP.

3.2. The evolution of cadence and chromaticism

3.2.1. Pre-history

Expectation in CP music is inherently linked to musical tension (Tillmann, 2014), (Tillmann et al., 2014), (Meyer, 1956) (Huron, 2006). This link is manifested in several different ways. According to Lehne et al., "musical tension is strongly linked to processes such as expectancy build-up, violation or fulfilment of expectancies, to the anticipation of resolution after a breach of expectancy, and to the eventual resolution of such a breach" (Lehne et al., 2013, p. 171). Therefore, in order to uncover the origins of expectations and surprise in music, we must find the first iterations of tension and release.

It has been suggested that the earliest expressions of tension and release in Western music may have come about in parallel with the development of rhyming schemes in pre-historic Russian and European folk song (Nikolsky, 2015). A rhyming scheme in song creates an intonational hierarchy in the following way: the stress pattern resulting from the rhyme confers a greater emphasis on the rhymed words. This gives tones associated with rhyming words the perception of stability following a sequence of less stable tones, precipitating a hierarchical musical system where fixed/stable tones are contrasted with variable/unstable tones.

Nikolsky contends that this phenomenon of stability and instability may have led to the development of mode-based music among prehistoric people on the European continent during the Magdalenian period. Modes in these early systems contained up to five fixed pitches. Later, as further notes were introduced to the scales, they followed a set pattern whereby tones adjacent to stable tones, such as the root, became supportive, and tones adjacent to supportive tones became stable. From this pattern arose a harmonic axis of stability consisting of non-adjacent stable tones surrounded by harmonic instability, creating the foundations of Western scale patterns and the roots of their perceptually hierarchical nature, as discovered by Krumhansl (1979).

Tensional hierarchies may also be found in Ancient Greek music, another direct progenitor of Western tonal music. The Pythagoreans considered any sequential interval that could not be represented as a ratio using the numbers 1 to 4 as a dissonance (Tenney, 1988). However, rather than use these dissonances to deliberately create tension and release, the Greeks aimed to avoid dissonance completely. This is because music of this time was considered a reflection of nature in perfect balance; tension represented a lack of balance and so must be rejected. The Pythagoreans, considered the prominent thinkers of the time, were interested in how music mimicked the outer world, and were not concerned with music for its own sake or for its aesthetic value. Instead, they sought to discover music's harmonious reflection of number, the ultimate reality. As tension did not exist within this harmonious reality, it should not exist within music.

These ideas of hierarchical tetrachord-based scale systems, and the fundamental concept of consonance and dissonance was passed on by the Greeks to the ecclesiastical musical systems of the Middle Ages. Thus, although the Greeks did not significantly utilise tension and release within their own music, they laid the groundwork for two important frameworks for creating tension in later periods: a hierarchical musical system, and the contrasting duality of consonance and dissonance. These frameworks were to become fundamental in allowing composers of later periods to engage listeners through the manipulation of their expectations, through tension and release.

3.2.2. Medieval

3.2.2.1. The origins of the cadence

The ultimate expression of tension and release within common practice music is the perfect authentic cadence. The concept of cadence and formalised music closure began to cohere during the Middle Ages. It has been theorised that the initial use of cadence within music was derived from grammatical doctrines of punctuation, which themselves had their origins in Ancient Greek rhetoric, and were originally used to formalise chanting of the liturgy. These rules outlined different types of pauses or rests to be taken between sections in a text. John of Affligem, a prominent music theorist of the time, draws a link between punctuation and melody in his treatise *De Musica,* written c1100. Caleb Mutch translates:

> Similarly, when a melody rests in a suspended manner (*per suspensionem*) a fourth or a fifth from the final note, it is a colon. When [the melody] is led back to the final note in the middle, it is a comma. When it arrives on the final note at the end, it is a period. As in this antiphon: . . . "Moreover Peter" (colon) "was being kept in jail," (comma) "and prayer was being made" (colon) "on his behalf without ceasing" (comma) "by the church to God" (period). (Mutch, 2015, p. 51)

According to Mutch, this development is particularly important in identifying several different types of musical closure, and therefore several different types of cadence, which will later give composers multiple methods of manipulating expectations through cadences.

> It is by drawing upon the grammatical doctrine of punctuation, the *positurae* or *distinctiones*, that John first identifies the phenomenon of a musical event sounding complete on a lower level, while simultaneously being incomplete on a higher level. This kind of perceptual experience developed to great effect in later polyphonic music and underpins such familiar phenomena as the half cadence of tonal music. (Mutch, 2015, p. 56)

The concept of cadence was thus established, but the question then arises of how to initiate closure in terms of musical material. Fortunately, this could be easily achieved through the tensional hierarchical patterns of the ecclesiastical modes of the period, derived from the Greek modes, which featured marked distinctions between stable and unstable tones. For example, each of the ecclesiastical modes contains a *final (mese)* and a *reciting (dominant)* tone. Both are considered points of stability. Below in the hierarchy are the *mediant* and *participant*, considered to be supporting tones to the final and reciting tone. Thus, a piece was concluded when there was an ultimate resolution to the final, usually by stepwise motion. According to Fuller Maitland, "[h]ere are the first signs of the sense of Tonality . . . but they are only rudimentary as yet" (Fuller Maitland, 1907a, p. 222)

The first polyphony in Western art music arose around the 10th century with the practice of organum, or harmonised chant. Initially chants were harmonised with a single line a fourth or fifth away from the primary line, and later with contrapuntal lines, giving rise to dyadic structures between the upper and lower parts. These dyads had the potential to incorporate dissonance and tension, but the list of allowable intervals between parts was proscriptive, and only intervals considered consonant could be used. Thus, although consonance could be used to indicate resolution, the deliberate use of dissonance to precipitate that resolution was still to come.

Guido of Arezzo in his early 11th century treatise *Micrologus* makes one of the earliest known references to a polyphonic closing gesture, or precursor to a cadence, which he refers to as an "*occursus*" (Guido, c.1026/1978, p. 78). He stipulates that the resolution to a unison between two voices must be preceded by whole tones in both the cantus firmus (main melody) and the organum (harmony). He gives an example of a chant where resolution to the final (D) is preceded by a whole tone on either side (C and E):

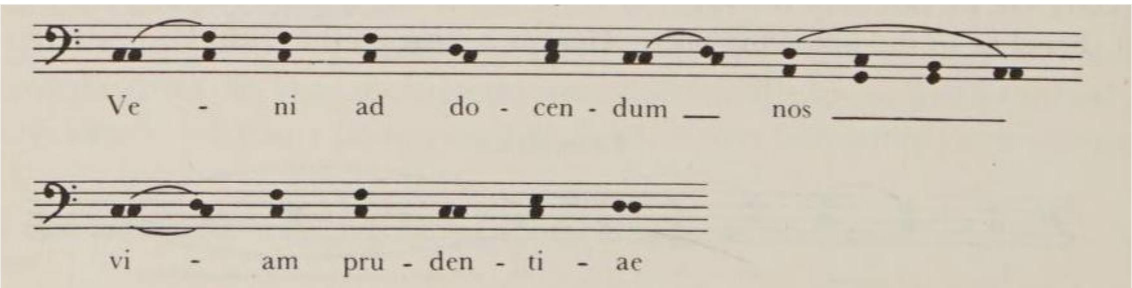

Fig. 8: Example of an occursus from Guido of Arezzo's Micrologus
(Source: Guido, c.1026/1978, p. 80)

It is important to note that Guido deliberately makes a case for avoiding resolution by half step, stating that "this convergence on the final [*occursus*] is preferably by a tone, less so by a ditone, and never by a semiditone" (Guido, c.1026/1978, p. 78).

This avoidance of chromatic approaches in cadences, which would become an integral feature of the later cadences of the Classical Period, persisted throughout most of the Medieval Period. Carl Dahlhaus, writing from a 20th century perspective, notes that "[a]s late as the 13th century, the half step was still experienced as a problematic interval not easily understood, as the irrational remainder between the perfect fourth and the ditone" (Dahlhaus, 1968/1990, pp. 86-87).

Dahlhaus emphasises the lack of leading tone function or expectation in the early Medieval concept of cadence, demonstrating that cadence at this point in history was a single-unit entity, in contrast to the dualistic tension/release- based structure it would later become.

> no "tendency" was perceived of the lower tone toward the upper, or of the upper toward the lower. The second tone was not taken to be the "goal" of the first. Instead, the half step was avoided in clausulas [closes] because it lacked clarity as an interval. (Dahlhaus, 1968/1990, p. 87)

In the music of England in the 12th and 13th centuries, the first 3rd and 6th intervals began to appear. This innovation spread to the rest of Europe through the influence of English composers such as John Dunstable. With this increase in available intervals, a need arose for classification, and simultaneous intervals began to be described with varying degrees of consonance. Distinctions were made between perfect, imperfect and intermediate consonances, demonstrating that the perceptual effects of dissonance were becoming an important concern for composers and theorists of the time. James Tenney quotes Anonymous VII, in the first recorded description of distinct intervallic qualities in 1220:

> Let it be observed that the unison, semiditone, ditone, diatessaron, diapente, and diapason are more essential than the other intervals *[species]*, for all discant forms one of these consonances *[consonantiarum]* with its tenor. It should be noted that the unison and the diapason are perfect consonances, the ditone and the semiditone imperfect, and the diatessaron and the diapente intermediate. (Tenney, 1988, p. 22)

As the 13th century progressed and the range of intervals allowed in composition expanded, composers became more liberal in terms of how they approached cadences. Around 1250, acceptable cadences which included semitone approaches became standardised in their use among composers. In the examples below, Donald Jay Grout illustrates three common cadences of this period, two of which feature chromatic resolution.

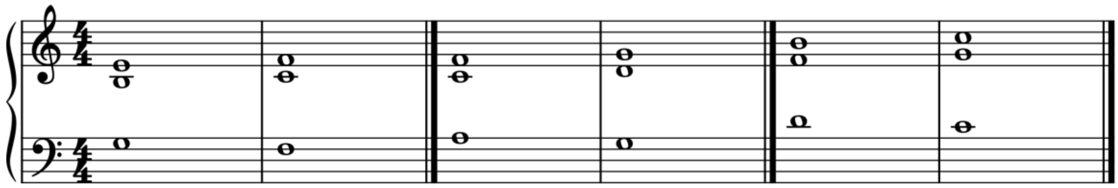

Fig. 9: Examples of 13th century cadences, re-notated
(Source: Grout, 1978 p. 109)

It is important to bear in mind when discussing music of this period that listeners did not likely perceive music in the vertical, harmonic way that modern listeners do. In music of the time, the linear nature of the music was of primary importance. Therefore, we should not yet consider the cadence in terms of a specific dissonance giving rise to an anticipated resolution, but rather as contemporaneous listeners would have heard them - as a cantus firmus simply terminating on the final, with additional harmonisation. This termination and its antecedent would eventually evolve into the most fundamental element of music in the 18th and 19th centuries, but several stages of development yet remained.

3.2.2.2. Ars Nova and musica ficta

The Ars Nova period of the 14th century was a key stage in the history of musical expectation. At this point, strict rules around composition stipulated that different types of consonances must alternate, and that only perfect consonances may begin or end a piece. This resulted in the creation of a hierarchy of harmonic consonance, the origins of which had been hinted at in the writings of 13th century theorists. These dyadic progressions became firmly established, and theorists began to speak in terms of anticipation, although it is unlikely that this related to harmonic anticipation as much as structural. As translated and quoted by Sarah Fuller, Johannes Boen wrote in his treatise *Musica* in 1357:

> It is established thus insofar as a *cantus* that is judged imperfect through thirds and sixths, despite its inharmonious quality, attracts and allures the ears toward the following fifth and octave. This is so that thirds and sixths, who are their . . . heralds and maidservants may announce the perfection of the *cantus* in fifth or octave, a perfection the sweeter for being long expected. (Boen, 1357, as quoted by Fuller, 1992, pp. 229-230)

Theorists were also beginning at this point to quantify these adjacent pairs of dissonant and consonant intervals as single dualistic units, that is, as rudimentary cadences involving tension and resolution. According to Jacques of Liege, writing in the 1320s (quoted by Fuller), “[c]adence

. . . refers to a certain arrangement or natural inclination of an imperfect concord to a more perfect one" (Jacques of Liege, c1320, as quoted by Fuller, 1992, p. 230). Thus, the concept of cadence and its burgeoning links to expectation were beginning to cohere.

It was also during the Ars Nova period that the first precursors to chromaticism began to arise, in tandem with cadences. During the Middle Ages, a division existed between *musica vera* (true music), and *musica ficta* (false music). Musica vera consisted of notes included in the gamut, a collection of overlapping hexachords which encompassed all available tones. Musica ficta refers to the unnotated practice of chromatically altering a melody by substituting notes not included in the gamut. Musica ficta was utilised for two purposes. Primarily, ficta was necessary in order to avoid prohibited dissonances such as augmented or diminished perfect intervals, either within or between voices. It was also used to ensure a perfect major consonance at the end of a piece. This primary purpose of musica ficta, that is, the avoidance of dissonance, was known as *causa necessitates*.

Ficta causa necessitates was behind what John Fuller Maitland refers to as "one of the most striking characteristics of Medieval music" (Fuller Maitland, 1907b, p. 332), i.e. the tradition of ending a phrase on a major sonority, regardless of its mode. This became known as the Tierce de Picardie, or Picardy 3rd, and remained popular throughout the Medieval period into the Renaissance and beyond.

The other purpose of musica ficta was known as *causa pulchiritudinis*, that is, ficta for aesthetic effect, and it is through this that scope for surprise through interruption of the diatonic context arose. Under causa pulchiritudinis, a performer could alter notes in order to add colour through unexpected intervals, according to their own taste. Brothers quotes Seay's translation of Anonymous II in *Tractatus de Discantu*, "false music has been invented for two reasons, namely, because of necessity and because of beauty in melody itself" (Anonymous II, c1300/1978, as quoted by Brothers, 1997, p. 1). Brothers interprets Anonymous II's use of the word "beauty" here as "a way of valuing departure from such systematic ordering [of the gamut]". He continues: "discant must be composed mainly of consonances . . . but deviation from this foundation is possible and it may be beautiful, since it makes the consonances more delightful" (Brothers, 1997, p. 4). Indeed, the theorist Marchetto of Padua preferred the term *musica colorata* to describe ficta, which speaks to its colouristic effect (Woodley, 2006).

Thus, during the Ars Nova period, the concepts of dissonance and chromaticism, such as it could be interpreted within a modal system, were beginning to be appreciated as means of respectively eliciting expectation for a satisfying resolution, and generating colour, interest, and surprise.

3.2.3. Renaissance

3.2.3.1. Chromaticism in the High Renaissance

Over time, ficta causa necessitates evolved into a tightly controlled system of chromaticism, which was demonstrated at its best during the Renaissance by composers such as Josquin de Pres and Giovanni di Palestrina. Strict rules governed how a dissonance must be prepared, how it must be resolved, how long it may last, and on what beat it may be placed. Composers of the time abided faithfully by these rules. Although *ficta causa pulchritudinis* occurred, chromaticism was used primarily to avoid awkward intervals between voices rather than for colourful effect.

A preference began to arise during this period for chromatic resolution at cadential points. Composers began to use ficta to ensure resolution by semitone in at least one voice, and preferably two voices in three-part writing. Dyadic semitone cadences had occurred during the Medieval Period but were not mandated. Here, however, a rule emerged whereby approaches to a unison cadence must make up a minor third, thereby ensuring both a half step and whole step in the resolution. Approaches to an octave cadence were required to make up a major 6th, for the same reason. This led to the first examples of triadic leading-tone cadences, examples of which are shown below.

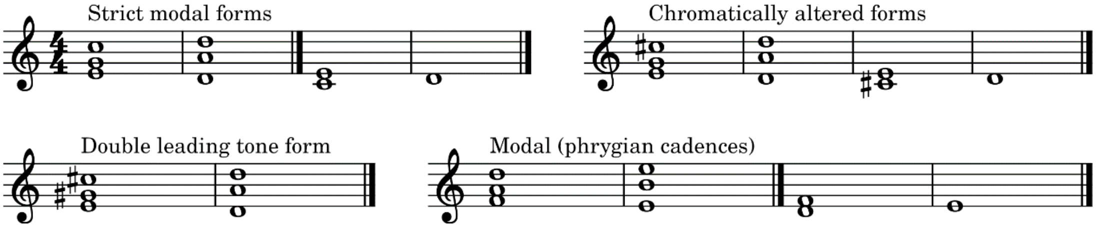

Fig. 10: Examples of Renaissance leading-tone cadences, re-notated
(Source: Grout, 1978, p. 140)

Other cadential variations became popular during this period. For example, in one variation, an escape tone is used as part of the approach to the final. This pattern was known as the Landini cadence and became popular through its use by composers such as Machaud.

Fig. 11: Variations on the Landini Cadence, re-notated.
(Source: Grout, 1978, p. 125)

Composers of the Renaissance Burgundian School, including Guillame Dufay and Gilles Binchois, popularised a proto-authentic cadence during the 15th century. This was achieved through crossing the lower two voices, resulting in essentially an early V-I resolution. Examples by these composers, which also feature the Landini ornament, are shown below:

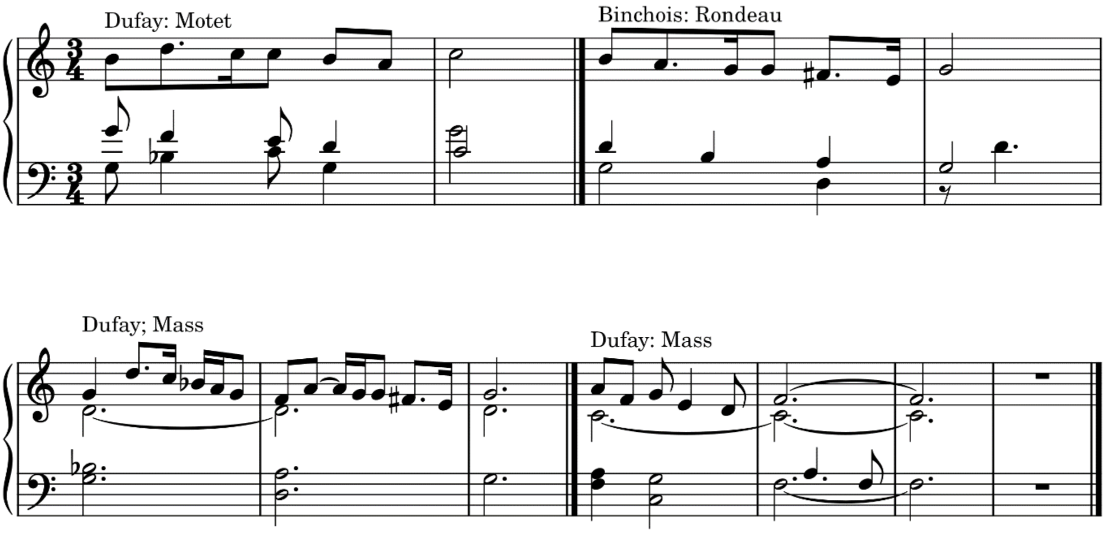

Fig. 12: Examples of Burgundian cadences, re-notated
(Source: Grout, 1978, p. 165)

This proto-V-I, in combination with a growing preference for leading tone resolution, paved the way for the CP authentic cadence as we know it.

3.2.3.2. The systematisation of cadences

In the early 16th century, scholars at the University of Cologne codified common musical practice into the earliest music textbooks (DeFord, 2015), and a nascent but cohesive theory of musical closure was outlined (Mutch, 2015). In c.1505, Johann Cochlaeus, a prominent scholar at Cologne, published a treatise, *Musica*, in which he gave details of various techniques for constructing a cadence in three voices. Scholars began to distinguish between final closing gestures which terminated a piece, and intermediate ones that terminated only a phrase. Final cadences of the time were known as *clausula vera*, and always involved descending stepwise movement to the final, while there were several different types of intermediate closes. *Clausula media* were intermediate cadences terminating on the mediant of the mode, while *clausula ficta* referred to a cadence on any other note (Blom, 1954).

Although closing gestures described in these texts were cadential in the sense that they concluded a phrase or piece, it is important once again to note that they still existed within a contrapuntal modal system whereby individual voices containing tensions were resolved through stepwise motion. Theorists of the time discussed multi-part polyphony, but the overall harmonic perspective was still dyadic, rather than triadic, and any sense of momentum or anticipation of resolution was considered to be purely linear. Thus, these closes, although they may have much in common with classical cadences, were not perceived in the same way as classical cadences would come to be. Although a handful of forward-thinking theorists were beginning to conceptualise closure as related to anticipation, as will be described below, this was not the prevailing perspective of the time. However, these discussions demonstrate that the concept of cadence was an important and wide-ranging one that warranted extensive discourse in the emergent music theory literature.

Cadences received further treatment in Thomas Morley's 1597 treatise *A Plain and Easy Introduction to Practical Music* (Morley, 1597). Morley distinguished between "cadences", which implied a harmonic closing sonority, and "closes", which referred to a melodic resolution to the final. Morley's treatise includes an extensive list of over 100 examples of common cadences of the time, giving a comprehensive depiction of cadential practices of the 16th century.

Morley outlines two perfect cadences, or *clausula vera,* similar to those found in the music of Machaud, signalling that these formulas have been robust enough to persist through several centuries. He then goes on to elaborate on what he refers to as "false closes…being devised to shun a final end and go on with some other purpose" (Morley, 1597, p. 144), a clear description of a functionally deceptive cadence. Indeed, several of the cadences in Morley's treatise, notated below, are clear precursors to the Classical deceptive cadence, with ascending stepwise movement in the bass voice.

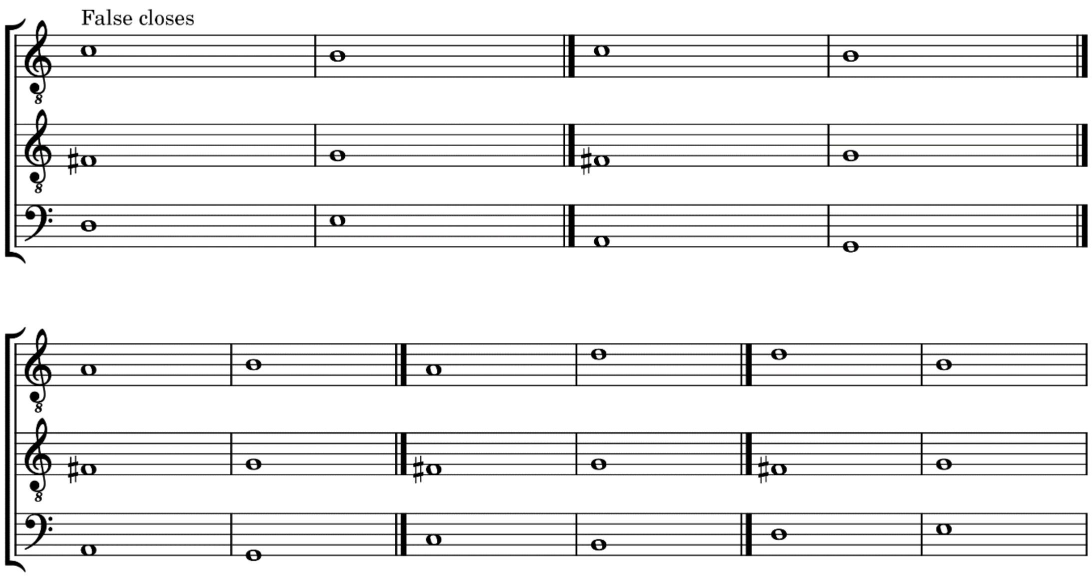

Fig. 13: Deceptive cadences from Morley, simplified and re-notated
(Source: Morley, 1597, p. 144)

Morley also included several plagal cadences in his list, which previously had been somewhat neglected in theoretical works, although used extensively in composition (Long, 2022). The Renaissance plagal cadence was derived from the *clausula vera* occurring in the Phrygian mode, with a harmonic variation resulting in a descending bass movement down a perfect fourth (Long, 2022). The plagal cadence stands out among Renaissance cadences in an important way. Scholars argue that it is unique in that it does not specifically feature any melodic pattern, for example in the way that a clausula vera cannot take place without a stepwise movement to the final. Therefore, this cadence came to signify closure even without the contrapuntal necessities required of other cadences. Thus, it became an important precursor of closure achieved only by bass, or harmonic, movement, without the need for a simultaneous melodic resolution (Long, 2022).

One of the first writers to suggest that a cadence may be used to defy the expectations of the listener is the Italian music theorist Joseph Zarlino. In his 1558 treatise *Le Istitutioni*

Harmoniche, Zarlino defines an "evaded cadence" as one in which "the voices give the impression of leading to a perfect cadence, and turn instead in a different direction" (Zarlino, 1558/1968, p. 151). Thus, as Christensen writes, "a composer can avoid having some two-part counterpoint cadence on the expected octave or unison by substituting a third, fifth, or sixth at the resolution" (Christensen, 1993, p. 122).

This is an important acknowledgement that mid-16th century thinkers were beginning to notice the perceptual effects that arose from the sonorities of a cadence.

3.2.3.3. The era of surprise

In the final decades of the Renaissance, a movement arose which aimed to more accurately convey the emotions in a text and heighten the attention of listeners at important points. This movement is sometimes referred to as *musica reservata*, although scholars are divided on this term (Dunning, 2001). Composers of this style, such as Orlande de Lassus and Nicola Vincentino, used chromaticism, adventurous harmonies, ornamentations and other techniques to vividly portray the strong emotions found in the texts they set to music. The strict conventions of the High Renaissance regarding dissonance and tension were duly abandoned. Zarlino, writing of musica reservata in Le Istitutioni Harmoniche, advocates for the use of chromaticism as a means of providing colour and contrast but is careful to caution against its excessive use. Feldman quotes Zarlino: "so that when [the text] denotes harshness, hardness, cruelty, bitterness, and other similar things, the harmony may be similar to it, namely rather hard and harsh . . . but not to the degree that it would offend" (Feldman, 1995, p. 175).

Since 3rds and 6ths had at this point become ingrained into harmonic vocabulary, more and more triadic structures were being formed. Composers such as de Rore utilised these structures to create striking pseudo-harmonic progressions. An evocative dissonant technique used by composers of the time was the cross-relation, whereby an altered version of a note in one voice is heard against the unaltered version of that note in another voice. Cross-relations were often used as a form of word painting; their rarity making them sound "strange and abnormal" (Schulenberg 2008, p. 32).

This new expressionism flourished in the first part of the 17th century through composers such as Monteverdi, de Rore, and Gesualdo, in a movement known as *stile moderno,* or *seconda prattica*. Within this movement, composers were not constrained by the rules of the older *prima prattica* of Palestrina*,* a style which nonetheless continued within church music for many decades. In seconda prattica, dissonance had free rein. No longer did dissonances have to be prepared and resolved, but instead could be highlighted as features in their own right. In an important advance for chromaticism, composers began to deliberately introduce clashes for aesthetic affect, rather than either as a by-product of contrapuntal lines, or as brief points of tension in-between consonances. However, this advance was short lived, due to dramatic changes on the horizon in the overall modal foundation on which Western music stood.

3.2.4. Baroque

3.2.4.1. Perceptual hierarchies

Perhaps the most important change that occurred in Western music history is the development of the major/minor tonal system, or CP system, which would eventually replace the modal system that had been used for centuries prior in Europe. Cadence and chromaticism, the elements primarily associated with expectation, would need to be entirely reframed within this new system.

As the Renaissance transitioned into the Baroque, composers began to rely more regularly on just two modes, Ionian[7] and Dorian[8] (Horsley, 1967, p. viii). Zarlino had already observed in 1558 that the modes could be classified into two groups, depending on whether they had a major or minor 3rd, demonstrating the duality of the 3rd even in the 16th century. This minor/major 3rd division was soon to replace the authentic/plagal division that had previously been the norm. The earliest theoretical presentation of the new major/minor tonal system can be found in French theorist Charles Masson's treatise *Nouveau Traite des Regles Pour la Composition de la Musique* of 1699 (Masson, 1699/1967), at which point the system was firmly established. In it, Masson maintains that only two of the Renaissance ecclesiastical modes (Ionian and Dorian) were necessary. According to Verba's translation, Masson claims that these two modes "contain everything which Antiquity has taught" (Masson, 1699, as quoted by Verba, 1978, p. 468).

As well as a reduction of the ecclesiastical modes to a bipartite system containing only major and minor, there was a dramatic change in how composers thought about the structure of their music, from a linear melodic perspective to a more horizontal chordal basis. One feature that accelerated this way of thinking about music was the growing popularity of the *basso*

[7] The Ionian mode corresponds exactly to the major scale.
[8] Dorian is a major scale with a flattened 3rd and flattened 7th.

continuo. Through the implementation of a fundamental bass note on which all the other notes rested, music became gradually more vertical and less linear. According to Grout:

> The basic sound ideal of the Renaissance was a polyphony of independent voices; the sound ideal of the Baroque was a firm bass and a florid treble, held together by unobtrusive harmony. . . . [It] was still a blending of different melodic lines, but the lines all had to fit into the regulative framework of a series of harmonic chord progressions explicitly defined and sounded by the continuo: it was, in short, a harmonically governed counterpoint, whose melodies were subordinated to the harmonic scheme. Within the harmonies thus defined, composers eventually were able to use dissonance quite freely, just because the underlying harmonies were so clear. (Grout, 1978, pp. 300 - 302)

In terms of cadences, resolution by semitone in the upper voice and fifth in the lower, which had begun to replace whole tone resolution during the Renaissance, became fully codified. As a result, dominant to tonic functionality began to appear in cadences. In 1613, English composer Thomas Campion described cadences purely in terms of their bass movement (Campion, 1671) which suggests that as early as the beginning of the 17th century, linear contrapuntal movement was no longer the only cadential force, and harmony was on its way to becoming the impetus behind musical momentum.

In the mid-17th century, theorists began to think of cadences increasingly in terms of a perceptual hierarchy, differentiating between those that achieve a sense of finality and those that elicit surprise or further anticipation. French theorist La Voye Mignot, in his 1656 treatise *Traité de musique,* was among the first to describe cadences hierarchically in these terms, differentiating as he did between three types of cadence, perfect (parfait), broken (rompue), and waiting (attendante) (La Voye-Mignot, 1565/1972). La Voye Mignot's terminology reflects a more perceptual way of thinking, and he confers on the perfect cadence a higher position in the hierarchy than the others by way of its sense of finality. He categorises the broken cadence by its bass movement of the dominant either ascending to VI or descending to III. In his "waiting" cadence, corresponding to a contemporary half cadence, the tonic ascends a fifth to the dominant. The terminology of "waiting" shows that La Voye Mignot was conscious of the anticipatory effects elicited by the dominant chord.

Fig. 14: 17th century cadences from La Voye Mignot, re-notated
(Source: La Voye-Mignot, 1565/1972, pp. 75-76)

In 1676, theorist Wolfgang Printz published *Phrynis Mitilenaeus*, which contained a detailed and comprehensive description of cadences found in German music of the mid-Baroque (Printz, 1676). Printz divides cadences into an elaborate hierarchy of groups and subgroups, the highest level of which is a distinction between those that come to rest (clausula perfecta), and those that do not (clausula imperfecta). What is notable in Printz's treatise is the new way in which he categorises closure, and his method of structuring cadences hierarchically in terms of closure. Printz takes what Mutch calls a "more listener-oriented perspective which focuses on the perceived quality of restfulness or closure in a cadence" (Mutch, 2015, p. 176). Printz takes into account the overall emergent property of resolution from the intervallic structures that make up cadences; this is an important advance towards functional tonal harmony, and an important acknowledgement of the perceptual effects of closure.

Within the category of imperfecta, Printz discriminates between cadences whose root movements are in fifths (totalis), and those with other root movements (dissecta). Many cadences that would become integral to CP harmony are described by Printz in the imperfecta category. Within the totalis category, Printz describes a *desiderans* cadence, which is analogous to La Voye Mignot's *cadence attendante*, or waiting cadence. Printz's terminology of *perfecta desiderans*, meaning desiring, clearly suggests dominant functionality giving rise to a desire to hear a resolution. Printz's treatise is an important link between the cadential formulae of modal harmony and CP tonal closing gestures. It is also an important example of the strengthening links between chord functionality and expectation.

3.2.4.2. A new foundation

Through both the transition towards harmonic functionality and an emphasis on vertical chordal structures, well-defined techniques within this system to elicit, meet, and defy listeners' harmonic expectations could arise. These techniques, such as the use of chromaticism, dissonance, cadences, and modulation had all appeared during the previous centuries of musical progression, but they lacked a propulsive framework in which they could be used to manipulate listeners' expectations. The stage was thus set for expectation and surprise to become a driving force within music.

However, one inevitable effect of the transition to a new form of tonality was a brief initial lull in the use of dissonance, chromaticism, and other unexpected musical elements. To put this in terms of expectation and surprise, listeners were already struggling to anticipate the progression of tonal music in its most basic form, and thus any attempt to manipulate their expectations could result in a lack of coherence, rendering the music potentially unpleasant to listen to. However, rather than being to the detriment of surprise and expectation as musical features, this was ultimately to be an advantage. The impending major/minor tonal system would be a cohesive and stable musical foundation for listeners, thus allowing them to form specific expectations for composers to play with. Hugo Leichtentritt summarises the effect of this on elements associated with surprise and expectation:

> Towards 1700, abrupt modulations, juxtapositions of distantly related chords, deceptive cadences, etc., were used with much greater moderation than in 1600. They came to be employed only occasionally, for the purpose of underscoring emotional expression or of adding force to a climax. Whereas, after 1600, chromaticism had become the rule with Italian specialists in harmony, it was used only as an exception after 1700. (Leichtentritt, 1935, pp. 209-210)

Another important advance around the 17th century was a change in how theorists interpreted dissonance. Previously, dissonant intervals had been conceived of as an interruption in an otherwise consonant progression. With the new way of thinking of harmony from the bass up, in contrast to linearly, theorists of the 17th century began to conceptualise dissonance as an essential part of a harmonic progression. Dissonance became, in the words of Christensen "neither a disruption nor a darkening of some consonant chord progression; rather, it was an artful and even necessary means of defining that progression" (Christensen, 1993, p. 64).

And so, with the practical consolidation of the major/minor tonal system at the end of the 17th century, the 18th century began with an explosion of creativity atop this new foundation. Chromaticism flourished, composers began to use dissonance more frequently, and modulations reached new heights of creativity. Once listeners could be relied upon to have thoroughly absorbed the regularities of the new musical system, composers could begin to test their boundaries. As the 18th century dawned, composers had at hand a fully formed musical system within which to elicit listeners' expectations, and several tools with which to manipulate them.

3.2.4.3. Chromaticism in the Baroque

Chromaticism advanced significantly within this period, with many Baroque composers using chromatic chords for dramatic effect and to colour their pieces. Among these were Neapolitan (N^6) chords and Augmented 6th ($^+6$) chords. The Neapolitan chord, so called because of its use by Neapolitan composers of Italian opera such as Alessandro Scarlatti and Giovanni Pergolesi, is a chromatic chord built on the flattened supertonic. The majority of N^6 chords are found in minor keys (Kostka & Payne, 2009). It is generally found in first (6-3) inversion, hence the designation of 6, but has been found in root position in the early 17th century, leading some scholars to believe it is derived from the modal Phrygian (Ellis, 2016). It is generally followed by a V chord and functions as a dominant preparation, primarily appearing in cadences. It can also be found as a modulatory device.

In an investigation of N^6 chords in the music of Bach, Lewis (1939) found several distinct uses of the chord by the composer. Firstly, Bach used the N^6 as a cadential chord, for example in the opening phrase of the "Agnes Dei" from his *Mass in B Minor, BWV 232*. This is the traditional use of the chord; here it would be considered a subdominant functioning chord, approaching the dominant and therefore setting up a potential cadence. Bach also uses the N^6 as a modulatory chord. However, the most common way in which Bach uses N^6 chords is as what Lewis refers to as an "altered second class chord" (Lewis, 1939, p. 39), such as in the opening bars of the chorale *Ach Gott von Himmel Sieh Darein, BWV 153/1*. These are situations where neither a cadence nor a modulation is taking place, but an N^6 chord is used for expressive colour within a progression. From this we can conclude that there are multiple methods of using N^6

chords, with varying effects, and that its primary use, at least within the repertoire of Bach, is as a colour chord within a minor key.

Other chromatic chords, such as secondary dominants, i.e. major triads (later dominant 7th chords) built on diatonic roots and resolving down a perfect 5th, served to introduce chromaticism within the early years of the CP era. Clough makes the argument that these evolved from a practice within Renaissance seconda prattica of altering notes to create pseudo-leading tones (Clough, 1957). In this technique, the composer raised the 3rd of a diatonic minor chord to create a leading tone in the "key" of the resolution chord, thereby creating a non-diatonic major triad. The use of voice-leading made the alteration subtle enough that the overall sense of tonality was not endangered (Clough, 1957) and thus these chords survived the transition into tonality. Within CP, voice-leading became less essential and these chords could function on their own merits.

Chromaticism was also introduced in Baroque music through the use of modal mixture, whereby elements from one mode are introduced in a piece primarily composed within another. Modal mixture had been relatively common in the modal context of the Medieval and Renaissance Periods and was generally used to convey moods associated with given modes. According to Aldwell et al., modal mixture "provides not only variety but often the potential for dramatic juxtaposition and, even, conflict" (Aldwell et al., 2011, p. 436). Christopher Gage (2019) has demonstrated that modal mixture arises in the music of Bach, Pachelbel and Scheidt through practices of linear chromaticism, demonstrating the linear origins of what will later become a popular colouristic technique.

During the Baroque period, by far the most common modal mixture element was the Picardy 3rd. Evidence for its popularity can be found in the fact that in his first book of *The Well-Tempered Clavier*, Bach ends all of his minor key preludes on a Picardy 3rd. With the move to CP harmony and the relaxation of cadential rules, this technique began to lose its function as a means of avoiding the dissonance of a minor third on a cadence and became more expressive and colourful. Peter Kivy writes of its new role in the Baroque:

> The picardy third is absolute music's happy ending. Furthermore, I hypothesise that in gaining this expressive property of happiness or contentment, the picardy third augmented its power as the perfect, most stable cadential chord, being both the most emotionally consonant chord, so to speak, as well as the most musically consonant. (Kivy, 1999, p. 289)

Although the majority of modal mixture chords found are tonic, Bach uses chords such as the IVm and IIø throughout the major key, particularly in his chorales and keyboard works, for example in his chorale *Herzliebster Jesu, was hast du*, *BWV 1093*.

Another chromatic sonority found in the Baroque period is the augmented 6th ($^{+}$6) chord. The augmented 6th arises from the interval between the lowest note of the IVm chord in 1st inversion, and sharpened root in the highest, which functions as a passing tone between the IV and the V. This essentially leads to what would be thought of in contemporary terms as a ♭VI7 (Ger^{+}6/It^{+}6), or ♭VI7♯11 chord (Fr^{+}6). It is believed to have arisen through linear voice-leading and is still considered by some to be a linear structure, rather than a chordal one. This sonority was first introduced in the 17th century, although Mark Ellis has traced its derivations back to the Medieval Period. During the 17th century, the augmented 6th functioned as a rare but potent word-painting chord. According to Ellis, “very often, specific texts ‘triggered’ the chord, which must, at least initially, have been regarded as a terrible dissonance” (Ellis, 2016, p. 40).

3.2.4.4. Rameau and Western common practice

From the beginning of the 18th century onwards, as the CP system flourished, there were major changes in how theorists thought about cadences and chromaticism within the new emerging framework. The innovative conceptualisations of cadences by La Voye Mignot and Printz decades earlier became standardised as theorists began to think in terms of perception, hierarchies, and chordal structures, and began to allow for a wider diversity of deceptive cadences. These changes reflected the more purposeful, functional nature of the new CP system. The role of the cadence was being expanded from simply signifying a point of rest, and was becoming increasingly associated with large scale form, expectation, surprise and goal-direction. According to Dahlhaus,

> [t]he change in quality between the penultimate chord and the final chord, perceived tonally, no longer lies in the antithesis of imperfect and perfect consonances but in the contrast between the chord of the 7th and the triad. This change is experienced not merely as a juxtaposition but as a logical sequence in which the second chord forms the goal of the first. (Dahlhaus, 1980, p. 179)

Although many theorists around the turn of the 18th century had published works attempting to codify the new system, it was not until 1722, when Rameau published his landmark *Traité de l'harmonie*, that the first unifying CP theory was outlined, and triads and their movements were fully described. Rameau was the first theorist to link dissonance and expectation in terms of chords and triads within a major/minor key context, as progressions of the "fundamental bass", and the first to establish the basic concept for today's functional analysis. According to Lester,

> Rameau reached back to an ancient explanation of motion in contrapuntal theory – the need for a dissonance to resolve to a consonance . . . to explain how chords connected to one another. Essentially, Rameau elevated the role of dissonance . . . as the prime motivator of harmonic motion, the force that mechanically propelled one harmony to the next . . . Rameau believed that the factor motivating a chord to progress in a directed fashion to another chord is the presence of dissonance. (Lester, 2008, p. 761)

Rameau was particularly cognizant of the perceptual effects of cadences, describing the perfect cadence of V7 resolving to I in terms of harmonic expectation, in *Traité de l'harmonie*, "[t]he perfect cadence is a certain way of ending a strain which is so satisfying that we desire nothing further after it" (Rameau, 1722/1971, p. 63). He describes the importance of the bass movement of a perfect fifth in the perfect cadence thus, "[p]eople who are at all sensitive to harmony can never hear the conclusion of any piece whatsoever without feeling compelled to make the bass proceed by the interval of a descending fifth" (Rameau, 1722/1971, p. xliv).

He also describes the tension and release of the cadence as resulting from the voice-leading of both the 3rd of the V chord, which "we never hear . . . without feeling . . . that either the tonic note or its octave should follow immediately" (Rameau, 1722/1971, p. 65), and the dissonant tritone formed by the combination of the 3rd, which he refers to as the major dissonance, and 7th, or minor dissonance. Thus, Rameau clearly invokes expectation as a motivating force underlying the cadence.

Rameau's fundamental theory, based as it was on the concept that the perfect fifth is "the first interval in harmony" (Rameau, 1722/1971, p. 124), and thus root movement in fifths is the only means of resolving dissonance, was challenged by the idea of the deceptive cadence from V to VI. He bypasses this inconsistency, however, by redefining the VI in this context as a 2nd inversion I chord with a 6th. According to Christensen, "[s]ince all other aspects of the voice leading remain unaltered, and the substitution is only of a consonant interval, Rameau can claim that the *cadence rompue* is still a variety of the *cadence parfaite* granted by license" (Christensen, 1993, p. 116).

This leads Rameau to an important insight regarding the perception of surprise. Since the bass movement is "by licence" moving a whole tone, "[t]his causes an interruption which rather disturbs the ear, for at the very moment when the desired conclusion, a perfect cadence, seems inevitable, the ear is surprised by the interruption" (Rameau, 1971, p. 124). Here, Rameau is describing an early and important example of, as Markus Neuwirth puts it, "one of the most important procedures adopted in the classical style . . . the strategic delay of structural closure", (Neuwirth, 2015, p. 117) which has the function of both "playing with listeners' expectations and stretching the temporal dimensions of a given composition." (Neuwirth, 2015, pp. 117-118)

With this important work, Rameau laid the foundations of the cadence as it will be used throughout the Classical period, where it will become one of the most integral aspects of music, determining form, harmony, and narrative.

3.2.5. Classical

3.2.5.1. The Classical cadence

Much of the transition among theorists from conceptualising cadences in contrapuntal terms to chordal harmonic terms was influenced by Rameau's concept of fundamental bass. Rameau's concept pulled the focus of music theory towards the lower lines and away from the tenor and thus firmly established the transition to a vertical system based on chords. Rather than describing cadences in terms of movement of individual voices, theorists began to think of the sonorities involved as chordal units, which were perceived as a whole. In his 1739 treatise *Cririscher Musicus*, the German theorist Johann Scheibe, as quoted and translated by Neuwirth, defines a deceptive cadence in the new horizontal terms as occurring "when one alters the final note at the end of a phrase and turns to a completely different and *unexpected chord* [emphasis added]" (Scheibe 1739, quoted by Neuwirth, 2015, p. 120).

This new focus is also evident in the work of German theorist Johann Friedrich Daube, who gives examples of multiple forms of deceptive resolution in his publication of 1756, *General-Bass in drey Accorden*. Daube's innovation was to include deceptive cadences to secondary dominant chords, reflecting contemporary practices of composers of the day (Wallace, 1983).

Fig. 15: Deceptive cadences from Daube, re-notated, interpretation of figured bass
(Source: Daube, 1756, p. 68)

Theorists were conscious of the wide variety of deceptive resolutions being utilised by composers of the time and began to describe more diversity of deceptions and interruptions in their writings on cadences. The German theorist Heinrich Koch, in his *Introductory Essay on Music Composition* (Koch, c1787/1983), written in three volumes in 1782, 1787, and 1793, distinguishes between deceptive melodic cadences and deceptive harmonic cadences, and describes the harmonic variety thus:

> the deceptive cadence is produced by the bass [in contrast to the upper part] when (1) another degree takes the place of the keynote as the closing tone of the cadence . . . or when (2) the cadential note is accompanied by a dissonant interval which necessitates another unessential bass note (Koch, c1787/1983, pp. 50-51)

Koch provides examples where VI takes the place of the keynote in the bass, and where a dissonant interval is avoided by movement of the V chord to a ♯V diminished chord. He notes that these techniques "thus deceive . . . the ear in its expectation of the closing tone" (Koch, c1787/1983, p. 50).

Daniel Gottlob Türk, in his 1789 treatise *Klavierschule*, published a comprehensive collection of deceptive cadences, which he refers to as *cadenza d'inganno* (Türk, 1789/1982). Türk here connects deceptive cadences with the perception of surprise and advocates performance techniques to reinforce this effect:

> [t]he so-called deceptive cadences . . . also require a greater or lesser degree of loudness, according to whether it is more or less unexpected . . . the unexpected harmony must be played with force in order that it surprise more. (Türk, 1789/1982, p. 341)

Türk's list of deceptive cadences is greatly expanded from Koch's. Like Daube, he includes several secondary dominants as resolutions: V/V, V/VI, V/IV and V/II. He also includes resolution to the IVm, VIIdim7, and ♭VIma.

Fig. 15: Deceptive cadences from Türk, re-notated, interpretation of figured bass (Source: Türk, 1789/1982, p. 341)

Albrechtsberger, in his 1790 treatise *Gründliche Anweisung zur Composition* differentiates between the interrupted cadence and the deceptive cadence. Albrechtsberger describes the interrupted cadences as occurring when, "after proper preparation for a *perfect* chord, the expected conclusion is replaced by another chord" (Albrechtsberger, 1790/1855, p. 64)

He goes on to give examples of a V chord moving to a V/II in 3rd inversion, and a V diminished chord. Albrechtsberger acknowledges that the deceptive cadence is a subtype of the interrupted cadence, but "includes many amplifications" (Albrechtsberger, 1790/1855, p. 64). He speaks about the deceptive cadence in terms of surprise and expectation: "When a composition, consisting of a well-ordered succession of regularly connected chords, concludes in a foreign key, the hearer is surprised, disturbed and deceived in his pre-conceived ideas"(Albrechtsberger, 1790/1855, p. 64).

However, for Albrechtsberger, the primary characteristic of a deceptive cadence is that it precipitates a change of key; his conception of a deceptive cadence is as a modulatory technique. He provides a comprehensive list of examples of possible methods of modulating using a deceptive cadence to every possible chromatic note, from the minor 2nd to the major 7th. Although at first glance this would appear to approximate the contemporary method of dominant chord modulation (Nettles, 2007a), Albrechtsberger's method differs in that the dominant chord included is not that of the original key, but instead the key of the modulation. His method involves the use of a cadence to reinforce the new tonal centre; a way of thinking that harks back to the earlier days of the transition to CP.

Antonin Reicha, in his 1824 treatise *Traité de Haute Composition Musicale* states that the cadence rompue can be performed on any note of the scale, diatonic or chromatic (Reicha, 1824). He provides an exhaustive list of examples of deceptive cadences which "break" between the fifth and every possible chromatic note, in both major and minor keys.

Fig. 16: Deceptive cadences from Reicha, re-notated
(Source: Reicha, 1824, p. 64)

The idea that a deceptive cadence can occur on any note, diatonic or chromatic, is echoed almost a century later by Heinrich Schenker, who stated in his work *Harmony*, first published in 1906,

> [f]inally, also, the deceptive cadence allows for various modifications; for, in a broad sense, any step progression, not merely V–IV or V–VI, may be heard as a deceptive cadence, provided that it prevents the fulfilment of an expected full close. (Schenker, 1906/1954, pp. 226-227)

It is clear from these examples that many theorists of the classical period allowed for a wide range of deceptive cadences, from resolutions to VIm and IIIm to resolutions to secondary dominants, modulatory cadences, and finally to the allowance of resolution to any root.

3.2.5.2. The cadence as structural marker

As the Classical Period progressed, the cadence began to take on a more prominent role within the CP forms used by composers. As these forms became more structured and symmetrical, composers began to use the cadence to outline larger global structures. According to Mutch, "the regular occurrence of cadences were a particularly crucial means by which compositional comprehensibility was communicated" (Mutch, 2015, p. 260). E. Markham Lee points out the ubiquity of cadences in the establishment of form in the Classical Period, "with Haydn, and more especially with Mozart, the desire for absolute clearness of form was so great that their Cadences are somewhat wearisome to modern ears." (Markham Lee, 1905, p. 69).

Deceptive cadences and other types of non-authentic cadences also began to play important roles in defining structure, particularly in the case of prolonging forms, and introducing cadential passages. According to Neuwirth,

> music from the second half of the eighteenth century may be described as goal-directed . . . If we accept such goal-directedness as one of the basic premises for the analysis of classical music, it is uncontroversial to claim, following Leonard B. Meyer, that one of the most important procedures adopted in the classical style was the strategic delay of structural closure. (Neuwirth, 2015, p. 117)

Caplin, in his work *Classical Form*, describes a technique that arose during the Classical Period, which he refers to as cadential extension. In this technique, a promised perfect authentic cadence "fails to materialize, thus motivating the appearance of . . . an imperfect authentic cadence, a deceptive cadence, an evaded cadence, or an abandoned cadence" (Caplin, 1998, p. 101). This is exemplified in the fourth movement of Beethoven's *Piano Sonata no. 12 in A♭ major, Op. 26.*

A popular cadence used for this purpose is the evaded cadence. According to Janet Schmalfeldt, this technique was used for several different purposes, including "for motivating text repetitions, for highlighting the soloist's secondary-key cadential area within the aria and the concerto, in general for extending and invigorating secondary-key materials, and for generating varied reprises as well as extensive codas" (Schmalfeldt, 1992, p. 1).

Primary among these functions is the extension of form to generate cadential sections. In this technique, the V chord is heard, but instead of the final tonic following, the composer will "back up" to repeat the preceding motif, thus "evading the cadence". This may happen more than once. Schmalfeldt maintains that this technique differs from other types of repetition in that it contains

> special features of the technique that distinguish it from all other types of repetition — its capacity to withhold resolution precisely where the cadence reaches its highest degree of tension, its potential for creating surprise through thwarted expectation, and for disrupting the rhetoric of closure, with the result that what is repeated becomes imperative, and thus emphatically dramatic. (Schmalfeldt, 1992, p. 6)

Markham Lee writes about how, during the late Baroque and Classical periods, the deceptive cadence also contributed to the evolution of cadential sections such as codas and codettas. He gives the example of such use by Bach:

> the hearer in both cases anticipates a perfect ending, in both cases Bach delights the ear and keeps the listener in suspense for a moment by the delaying of the final chord and the insertion of the *Inganno*. The result is this: a little piece is tacked on to the movement, which gives greater point to the final Cadence when it actually comes, and also provides room for a little further treatment of previously heard material. Here is the embryo Coda, the germ of the mighty appendix which Beethoven so fully developed. . . . So great a factor has the Coda become today, that we are apt to forget that its origin was a humble one, an accident suggested by the Interrupted Cadence. (Markham Lee, 1905, pp. 71-72)

Hence, over the course of several hundred years, the cadence is raised from its humble beginnings as a mere punctuation mark and becomes a foundational element of form and structure in Classical music, while maintaining its ability to signal closure and to surprise.

3.2.5.3. Modal mixture and chromaticism in the Classical Era

Chromaticism also underwent dramatic changes in the transition from the Baroque modal systems to the new tonal framework. In the Classical period, a preoccupation with order and symmetry led to tighter strictures around chromaticism in comparison to the Baroque period. Chromaticism was now required to function within strict forms, without upsetting the balance and narrative that underlay these forms. The effect of this constriction can be seen in the differing functions of chromatic chords between the Baroque and Classical eras. For example, as harmonic structure began to crystallise, the function of the $^{+}6$ chord began to cohere as cadential. Given its origins as an ascending structure voice-leading upwards from IV to V, and the heavy emphasis on the dominant as a structural marker in classical form, classical composers began to use the $^{+}6$ more regularly as a "signpost", designed to draw attention to the dominant chord.

Despite the popularity of the $^{+}6$ as a chromatic cadential device, the Baroque use of the chord as a colouristic sonority did not completely fade during the Classical period. It can be found in the music of Beethoven and Mozart in situations where the composers clearly intended to startle the audience, for example in the opening of Beethoven's *Piano Sonata no. 24 in F♯ major*, Op. 78. Towards the end of the Classical period, composers began to connect this chord to the similarly chromatic N^6 chord (Ellis, 2016) but it was not until the 19th century that its full chromatic capabilities and its potential to induce tonal ambiguity and create or confound expectations were explored. In the early Romantic era, its original function as a colouristic chord was fully revived, and its role as a pre-dominant chromatic approach chord weakened. For example, a common technique of Beethoven was to approach the $^{+}6$ directly from the tonic or dominant, such as in the famous opening to his *Symphony no. 5 in C minor, Op. 67*, which no doubt would have been more unexpected to listeners than a voice-leading approach from IV. Romantic composers also began to use the augmented 6^{th} as a pivot chord to modulate chromatically. According to Ellis, Tchaikovsky in 1871 wrote conclusively that "the augmented chord of the sixth resolves to the tonic triad" (Ellis, 2016, p. 6), evidencing the rarity at that point of its original function. Ellis points out that "despite theoretical attempts to classify the augmented sixth as an 'approach chord' to V or I6/4 there are many contexts in which this is patently not justifiable" (Ellis, 2016, p. 6).

Modal mixture, which had developed during the Renaissance and Baroque primarily as a voice-leading technique, began to be used more regularly and with more variations by Classical composers as a method of introducing colour. Modal mixture at this point abandoned its voice-leading roots and became primarily centred on borrowed chords. Isolated chordal sonorities from the parallel minor key were transplanted into a major key piece, in order to introduce colour and variation. In the major key, parallel minor harmonies were introduced through the use of chords containing the ♭3 and ♭6 tones.

In the Classical Period, modal mixture chords from the Baroque and Renaissance began to be used more regularly. For example, the Renaissance Picardy 3rd can be heard dramatically ending the finale of Mozart's opera *Don Giovanni, K527*. Other modal mixture chromatic chords such as the ♭VI, which may be heard in the final bars of Mozart's *Piano Quartet no. 1, K478* and ♭III also came into use during the Classical and Early Romantic periods, although these are far rarer than the traditional IVm and IIø. Aldwell et al. note that the use of ♭VI as a modal mixture variation on a deceptive cadence "greatly increases the tonal contrast and, consequently, the deceptive affect" (Aldwell et al., 2011, p. 441). Chords from the parallel harmonic minor, such as IIdim7 and VIIdim7 are also found throughout the Classical repertoire.

3.2.5.4. Transition to the Romantic

As the Classical period transitioned into the Romantic, chromaticism expanded, and composers found many more ways to introduce colourful and ambiguous modal mixture harmonies into their music. The ♭VI and ♭III chords began to appear more regularly, particularly in the music of Schumann, Schubert, and Verdi and even the ♭VII chord began to appear. Schoenberg (1922/1978) writes that music of the Late Romantic moved towards a foundation of essentially 12 chromatic chords, justified through the use of modal mixture, rather than a strict delineation of major and minor.

During the late 19th century, another method of undermining tonality and introducing chromaticism involved using chromatic mediant relationships, a type of "coloristic chord succession", (Kostka & Payne, 2009, p. 461). Earlier uses of this kind of harmonic movement can be found in the music of Mozart and Haydn, who utilised the technique for the purposes of modulation. It can also be found in Baroque music, according to David Kopp, to introduce an "unexpected new tonic" (Kopp, 2002, p. 18). This kind of modulation was based on the idea of common tone relationships between triads of the same quality, i.e. a I chord could move to any non-diatonic major or minor triad that contained a common tone. The resulting root movement tended to be in 3rds, e.g. C major to E major or Ab major. Romantic composers greatly expanded on this idea to break new harmonic ground, using mediant relationships and common tones to introduce colourful and ambiguous harmonies, such as in the opening of the final movement of Mahler's *Symphony no. 9*, and to initiate distant modulations, such as in the Schubert song *Der Musensohn, D764*. Kopp speaks to the difficulty of pinning down these relationships and thus highlights their perceptual ambiguity:

> Third relations are multifarious: they may be chromatic or diatonic; they may preserve or alter mode; they may involve major or minor thirds; they may or may not invoke a relative mode; they may or may not interact directly with fifth relations. Third-related chords may be seen as functional, non-functional, or altered forms of functional harmonies. (Kopp, 2002, p. 8)

By the time of the Romantic Period, the strict Classical schemas that held tonal harmony together were beginning to disintegrate, and with them the simple ways of generating surprise through straightforward deceptive resolutions and conventional chromatic chords. The decline of the cadence as both a structural feature and a tool for eliciting surprise is summarised by Mutch:

> In the later nineteenth century . . . regularly recurring cadences are far less necessary. Indeed, long stretches of Wagner's music, and even compositions by Brahms, seem at times to thematize the avoidance of usual cadential progressions. Musical practice was moving away from the traditional cadential formulas (Mutch, 2015, p. 260)

Examples of the disintegration of traditional classical cadential structures can be found in the transformation of one of the most fundamental structures of the Classical period, the sentence, within which an antecedent phrase ending in a half cadence is distinctly separated from a consequent phrase ending in a full cadence. Cubero notes the tendency of Romantic composers to manipulate this structure by eliminating the marked delineation between phrases and instead blending the antecedent phrase into the consequent. This is achieved through transforming the traditionally phrase-ending V chord of the antecedent half-cadence into a progressive dominant with expected resolution to I. Cubero gives the example of a Fanny Mendelssohn song "Ferne", Op. 9. No. 2, notated below as Cubero's voice-leading sketch, which, through the use of a IV chord to end the antecedent, pushes the V into the consequent and thus to resolution to I. Cubero notes that this has the effect of leaving listeners "waiting to experience the medial half cadence and the closing perfect authentic cadence of a traditional period. The absence of cadential signposts causes us to wander along with the protagonist through a defamiliarized soundscape" (Cubero, 2021, para. 33)

(b) Voice-leading sketch

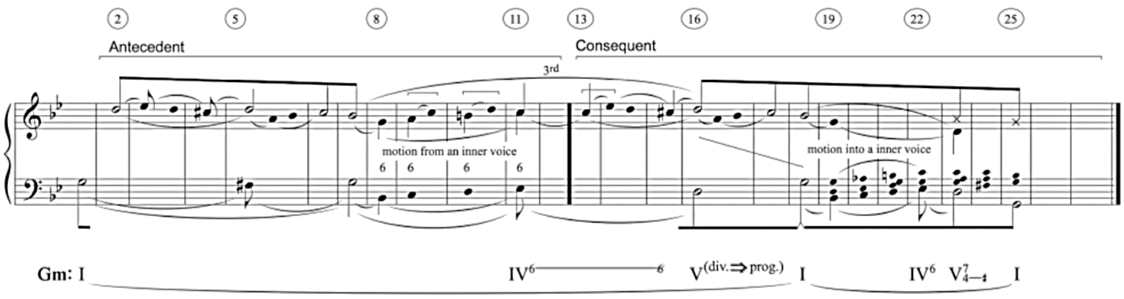

Fig. 17: Voice-leading sketch of Mendelssohn's "Ferne" Op. 9 no. 2
(Source: Cubero, 2021, Example 15)

William Caplin notes several ways in which cadence and closure were manipulated by Romantic composers to create the "boundlessness" that Grout has described as characterising Romantic music (Grout, 1978, p. 539). Caplin points out that in contrast to the goal-oriented use of themes in the Classical period, Romantic composers "began to favor a more *circular* mode of organization [where] the melodic-motivic material of the opening basic idea, rather than becoming fully liquidated [i.e. broken down], returns at the end to provide the melodic content of the cadential idea itself" (Caplin, 2018, p. 9). He notes also the tendency of Romantic composers to use successive root position harmonies, such as in the middle section of *Chopin's Nocturne in G Minor, Op. 37, no. 1*, notated below. Caplin maintains that this practice serves to "blur the fundamental distinctions among prolongational, sequential, and cadential progressions that are so essential to classical harmony in its relation to form" (Caplin, 2018, p. 6).

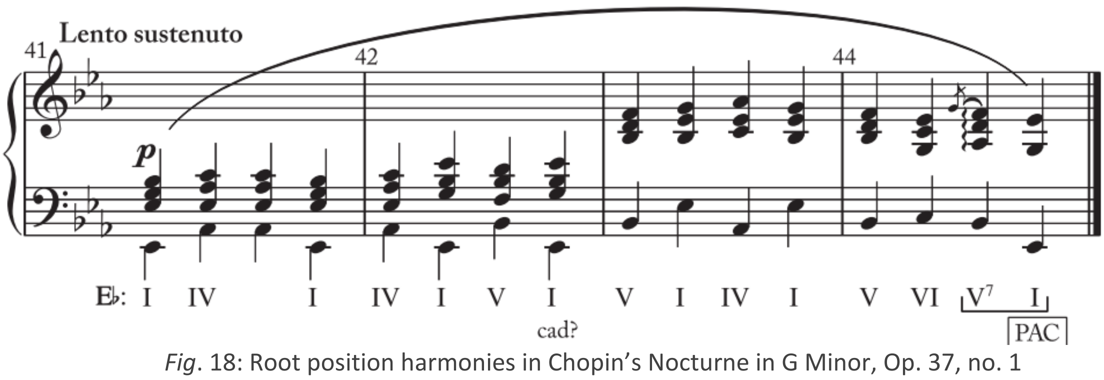

Fig. 18: Root position harmonies in Chopin's Nocturne in G Minor, Op. 37, no. 1
(Source: Caplin, 2018, p. 7)

Overall, the Romantic Period is characterised by an impulse among composers to experiment with the manipulation of expectations by tweaking the fundamental structures and language of music. The simple methods of using deceptive cadences and popular chromatic chords within a predictable framework became old-fashioned, and composers looked to other means, such as unfamiliar modes and scales, to generate surprise. Later, within many styles of the 20th century, the thwarting of expectations through dissembling of familiar structures was to become part of the purpose of music.

3.3. Conclusions

The discussion above identified the links between tension and release, stability and instability, and expectation and surprise, which have characterised CP from its beginnings. At various times, prevailing trends have been either to suppress instability and surprise, such as in the music of Ancient Greece and the early Middle Ages, to carefully control it, as in the Classical Period, or to embrace it without limits, such as in musica reservata, stile moderna, and in the late 19th century. Whether tension, instability, and surprise have been suppressed or encouraged, throughout the history of Western art music prior to the 20th century, the techniques at their heart have been cadence, chromaticism, and modal mixture.

The cadence, the most fundamental element used to elicit tension and expectation, has its roots in the earliest Western music, and has been carefully curated, developed, and analysed by composers and theorists. The importance of the cadence is reflected in the vast amount of words that have been written on it by theorists. The volume of different kinds of cadences categorised by theorists, such as the compendiums of Printz, Rameau, Daube, Koch, Türk, Albrechstburger, and Reicha further reflect its importance, as well as demonstrating the wide range of deceptive resolutions available to composers. The cadence's links with expectation and surprise have been discussed by theorists throughout its history. These links became thoroughly solidified with the advent of the goal-directed CP diatonic major/minor system, where functional harmony became the impetus behind musical momentum. Expectation, via the cadence, became part of the overall musical structure, delaying closure, underlying cadential sections, and serving as a controlling force behind the narrative of a piece.

Chromaticism has long been associated with colour, expressionism, drama, and surprise, from ficta causa pulchiritudinis of the Medieval period to the chromatic mediants of the Romantic. Prior to the advent of the CP system, these elements were linear and could exist within multiple modal frameworks, but after CP, they were recontextualised as chordal entities within a thoroughly grounded binary major/minor framework, which allowed them to be carefully controlled by composers in order to have maximum effect.

The objectives of this chapter were to provide a deeper understanding of the musical techniques used in harmonic expectation experiments, their sources and contexts, and to discover other techniques associated with harmonic expectation and surprise in CP. Through this investigation, three findings have arisen that may be useful for the current study of harmonic expectation, and to inform a comparison with expectation and surprise in popular music and jazz.

The first of these is the finding that composers and theorists throughout history conceived of surprise as a gradated, rather than binary, phenomenon. They were aware that a spectrum of unexpectedness was available to them and used surprising harmony as part of a continuum. This finding may be relevant to current studies of harmonic expectation and surprise in that we may learn more by designing experiments around the idea of a continuum of surprise, rather than as a binary effect.

Although this review has demonstrated that composers used multiple harmonic structures to achieve deceptive cadences, contemporary accounts of deceptive cadences do not reflect this gradated phenomenon, but rather present the deceptive cadence as a single chordal progression containing a V-VIm chord (Aldwell et al., 2011), (Kostka & Payne, 2009). Mainstream contemporary theorists thus reduce the multiple gradients of surprise used by composers to a single chord progression. This simplified account of deceptive harmony related to cadences has resulted in the use of binary deceptive experimental stimuli in studies of harmonic expectation and has overlooked the true meaning of surprise in CP music.

The second finding is that there is a wide diversity of surprising elements within the categories of cadences and chromaticism, and the subcategory of modal mixture, used throughout Western musical history. These include a variety of deceptive cadences used in the Baroque and early Classical periods and a wide range of chromatic chords used by late Classical and Romantic composers. However, studies in harmonic expectation tend to utilise only a very narrow range of deceptive elements; the N^6 chord is the singular focus in many cases. A widening of the range of elements used in harmonic expectation experiments can be achieved through consultation with the music theory and musicological communities and will provide elucidation not just of how the brain processes expectation and surprise, but of the effects of different kinds of harmony on listeners. The range of elements discovered in this review, comprising secondary dominants, modal mixture, $^{+}6$ chords, N^6 chords, and chromatic mediants will serve as useful in the following chapter when expectation and surprise in CP are compared with that of popular music and jazz.

The third finding relates to musical context. This review found that composers throughout the history of CP were extremely careful about the use of chromaticism and took great care to ensure contextuality was considered. Additionally, the review found that cadence, from the Classical Period onward, was not just an isolated musical technique, but served as a building block for entire compositions. This reinforces the idea that we must be acutely aware of context within music cognition studies and do everything we can to maintain the intended context behind a surprising chord, lest we unintentionally change its meaning, something which could be achieved through the cooperation of the cognitive science and music theory communities.

In the following chapter, the focus moves from late 19th century Europe to America. The development of 20th century musical culture, with roots in both European CP music and the music of African American communities, will be explored with reference to expectation and surprise.

4. The harmony of jazz and popular music

4.1. Introduction

The objective of this chapter is to highlight non-CP influences, particularly those of African American music, on the tonal frameworks and harmony of jazz and popular music in order to challenge the commonly held perception that common practice harmony is paradigmatic of all Western tonal styles.

There are two reasons why this perception needs to be challenged with respect to the study of harmonic expectation. The first is that tonal frameworks, narrative structures, harmonic language, and functionality in popular music and jazz may differ from those of CP to such an extent that the perceptual effects of expectation and surprise differ between these styles. The second reason is that CP may not be the primary style of general listeners' musical schemas. Schemas are created based on statistical learning of the music to which we are exposed, and European art music may not be the culturally dominant music that it once was. Assuming that CP serves as the paradigm of Western tonal music may result in erroneous generalisations, and so a full understanding of how general listeners process music will require the questioning of assumptions regarding the dominance of Western art music.

This chapter will outline the ways in which language, narrative, and musical meaning within early popular American styles deviated from CP norms through the influence of African American music and other social, cultural, and musical influences. It will trace the development of popular music and jazz from their origins and investigate new harmonic structures that arose within them. The perspectives of contemporary jazz and popular music theorists will be discussed. The chapter aims to develop an understanding of how expectation and surprise may arise within these styles.

The chapter begins with a brief investigation of the common claim that popular music and jazz derive from a simple amalgamation of European CP harmony and African rhythm, details of which may be found in Waterman (1948). In refutation of this claim, the harmonic and tonal origins of jazz and popular music in Africa are discussed, and the effects these influences had on harmonic development in America are outlined.

The chapter is then divided into four sections. In the first, functionality, tonal frameworks, narrative structures, and harmonic language within the blues at the origins of contemporary popular music are described and contrasted with their equivalents in CP music. In the second, the same characteristics are described within popular music, with reference to how this style was influenced by blues, and in the third, the same characteristics are described within jazz. In the final section, these reviews are consolidated into conclusions about how expectation in surprise differ between jazz/popular music and CP, and several techniques likely to elicit expectation and surprise in jazz/popular music are outlined.

It is not the aim of this chapter or thesis to determine the harmonic roots of blues, jazz, or popular music within Africa or to investigate harmony in African music. Nor is it the aim to claim that any differences between CP and jazz/popular music are derived solely from non-Western sources or minimise the important contribution of African rhythm to Western music, or the contribution of Western harmony to jazz/popular music. The objective is only to make the case that African influences on jazz/popular music were not limited to rhythmic, expressive, or formal call-and-response characteristics, but had profound effects on the narrative, structural, functional, and thus perceptual aspects of tonality and harmony within both jazz and popular music. In addition, other factors such as the influences of folk music, non-functional 20th century European art music, instrumental practices, commercialisation, and creative evolution served to further widen the gap between CP harmony and that of jazz and popular music in the 20th century.

All musical examples in this chapter were analysed from primary sources, i.e. transcriptions of original recordings and/or analysis of original sheet music. Details of all songs and links to their primary sources may be found in the song catalogue in Appendix C.

4.2. Roots of the problem

The perception of common practice harmony as paradigmatic with respect to jazz/popular music disregards the influence of blues on these styles. The blues is widely regarded as the foundation for nearly all later American popular forms. According to *Grove Music Online*, blues has “formed an integral part of jazz, R&B, rock” (Wald, 2012, para. 1)**.** David Evans notes that “[b]lues has had a history of its own, but it has also had a profound influence upon other types of popular music in the 20th century” (Evans, 2008, p. 37). Evans lists jazz, folk, ragtime, country music, rock and roll, and gospel music as being influenced by blues. LeRoi Jones states that “[b]lues is the parent of all legitimate jazz” (Jones, 1970, p. 17). In his introduction to the *All Music Guide to the Blues*, Cub Koda notes that blues is “interwoven into the fabric of rock and popular music” (Koda, 2003, p. vii).

Looking closer, we find that most accounts of blues influence on later styles focus almost exclusively on rhythmic and expressive influences, and on the widespread adoption of the 12-bar form. Accounts of tonal and harmonic influences of blues on jazz and popular music are few and far between. When tonal and harmonic influences rooted in the blues are acknowledged, they are largely limited to discussion of "blue notes". For example, the *Encyclopedia Brittanica* entry on blues notes the primary influence of the 12-bar form on popular music: "the simple but expressive forms of the blues became by the 1960s one of the most important influences on the development of popular music" (Zelazko, 2024, para. 1). Friedlander comments on the influence of blues rhythm, expressionism and form on rock and roll: "The syncopated rhythms, raw vocal emotionalism, and work-chant "call and response" are all part of the African musical heritage and became building blocks for rock and roll" (Friedlander, 2018, p. 16).

Joe Mulholland and Tom Hojnacki, in *The Berklee Book of Jazz Harmony*, note the same structural influence of blues forms on jazz, and the authors go so far as to source jazz harmony primarily in Western art music: "The richly chromatic jazz vocabulary owes much to late 19th century European concert music, and yet the predominant form in which it finds its expression is the 12-bar blues" (Mulholland & Hojnacki, 2013, p. 132).

This focus on rhythm and oversight of harmony in the influence of blues on other styles can be traced to accounts of music in Africa, where blues originated (Southern, 1971), (Kubik, 1999), (Floyd, 1995). This tendency can be seen as part of a wider problem, one that Martin Scherzinger refers to as a "vexing imperialist legacy of under-playing the role of harmony in African music" (Scherzinger, 2001, p. 24). Many African theorists decry an overfocus on rhythm and a concurrent overlooking of African melody and harmony in African-derived music. Kofi Agawu refers to a "kind of mythology that has allowed some Europeans to claim harmony and deny it to the Africans" (Agawu, 2003, p. 60). Composer Olly Wilson outlines the dangers of this perspective in not recognising the full gamut of the characteristics of African and African American music:

> It should be pointed out that [in their writings,] [Don] Knowlton, [Aaron] Copland, and [Winthrop] Sargeant, while recognizing polyrhythm as a non-European element of black rhythmic practices, tended to isolate it as the principle which governed black music. They therefore confused much music written in the twenties and thirties with black music because it superficially contained one of the characteristic elements of Afro-American music, although it lacked most of the others (Wilson, 1974, p. 9)

Of course, this is not to say that blues or other African American styles are devoid of European influence. Scholars of African American music acknowledge that initial fundamental tonal frameworks of these styles were based on European diatonic harmony. As LeRoi Jones notes, there was considerable distance between what Jones refers to as "pure African music" and early African American music, due to the intervening exposure of African slaves to the Euro-American culture. He describes early African American music as "that which contained the greatest number of Africanisms and yet was foreign to Africa. And this was the music of the second generation of slaves, their work songs" (Jones, 1970, p. 18). Hildred Roach notes that the earliest African-based music in America, the spiritual, was considerably influenced by European church music spreading through America through the Evangelical Protestant communities of the Great Awakening. She observes that:

> Common endings in spirituals descended scale-wise from three to one. Certain others ended a fourth, a second, or third below, or from a third above . . . . These melodic outlines could easily be harmonized using I, IV and V . . . Such harmonies were indeed eventually adopted . . . In general, frequent usage of consonances could be sustained by the common chords of the period (I, IV, V). (Roach, 1976, p. 30)

The influence of European tonality on African American music is undoubtedly profound, particularly at its genesis, but there are two main issues with the current conception of how the music of African slaves in America merged with European tonality, and how that merging influenced jazz and popular music.

Firstly, the current perspective overlooks functionality, the way in which functionality is affected by form, and how changes in functionality affect musical narratives and the meaning of harmonic structures within those narratives. Secondly, the current perspective assumes that two amalgamated systems will retain their properties, rather than both symbiotically merging and changing. Blues tonality cannot be imposed on a Western structure without fundamentally changing that structure, and therefore changing the ways in which it subsequently grows and develops. Tallmadge outlines this process and the difficulties of describing it, through his analysis of African American prison work songs:

> The first half of the selection seems to be in minor; the second half, in major; and a considerable portion, in an indeterminate modality. The passages in both selections reflect an *Afro-American modification of the European system of tonality, harmony* [emphasis added], and melody; and as yet we have no

> adequate terminology to describe the tonal effects of this alternate musical system. The terms *blue notes, neutral pitches, indeterminate pitches, blue coloration, blue tonality*, and others have been devised to describe such effects, but these terms have not proved altogether satisfactory. (Tallmadge, 1984, p. 156)

Ethan Hein emphasises the harmonic uniqueness of blues, stating that “we need to understand blues as belonging to its own system of tonality, distinct from major, minor and modal scales” (Hein, 2014, para. 1). Again, in order to obtain a clear picture of musical understanding, assumptions must be challenged.

4.3. African and African American music

4.3.1. Cyclical vs. goal-oriented narratives

Scholars acknowledge that the Western harmonic structures of I, IV, and V may be found in the earliest documented African-rooted music in America. This provides evidence that early African American music was based on a European CP tonal framework. However, a closer look may reveal that this was not simply a binary imposition of African melody onto European harmony, but rather an entanglement of form, narrative, and tonality that gave rise to a new framework. Hence, although these chords, I, IV, V remain enharmonically identical to their counterparts in CP, their meaning may be entirely changed.

When these chords are used within a CP context, their meaning is set by the goal-oriented, hierarchical, and functional nature of CP. Tension and release within CP, as described in the previous chapter, is tied up with musical narrative in terms of form, harmonic momentum, tonal departure/return, and, notably, chord function. However, this is not the case for blues, as noted by Richard Ripani:

> the blues system often uses chords in ways *not* typical of the Western system . . . . Songs that are steeped in the traditions of the blues system can and do use the type of Western chord progressions discussed above. But they also use harmony in a very static manner, in which the chords do not ‘progress’ from one to another in the Western music sense. This harmonic notion goes back at least to the 1800s in the Americas, and the current thought is that it derives from various African musical styles. The music of much of Africa is

> based on cycles or clusters of cycles and a rhythmic relationship to body movement. The chords in such music seem to be perceived as tonal-harmonic steps progressing one to another. (Ripani, 2006, p. 35)

Van der Merwe draws a parallel between the harmonic movements in blues from between I, IV, and V, and the tendency in Renaissance folk and dance harmony to move in stepwise "shifts" rather than chord changes per se. In Renaissance folk music, this involved changes in focus from one "co-tonic" to another a step away, along with a shift in the corresponding harmony. Thus, in blues harmony, each "level" or shift, which swings between the I, IV, and V, is treated like its own one-chord blues. Diatonic function becomes superfluous, as each chord acts as a tonic.

This idea is reinforced by claims that many African societies tend to sing in parallel, rather than diatonic, fifths or fourths. For example, Ofosu and Ofosu (2020) note that many African societies have traditional musical systems that incorporate parallel movement in fourths and fifths between the genders. The Urhobo men, for instance, tend to drone a fourth below the women. The Gogo, Pangwa, and Nyakyusa of Tanzania, and the Wala and Dangwe of Ghana usually sing in parallel fourths and fifths. This is corroborated by A.M Jones, who says that "[w]hen the Africans sing in parallel fourths the lower voice always sharpens the subdominant, thus avoiding a tritone fourth" (Jones, 1961, p. 217).Harmony in fifths, as well as thirds, is also noted by Eileen Southern:

> when a performance involved two or more persons or melody instruments, some parts of a piece were performed in unison . . . and other parts in thirds or fifths. (Southern, 1971, p. 21)

Schuller suggests that this tradition of parallel fourths may have been the progenitor of the fundamental blues progression, i.e. movement up from and down from a tonic in fourths:

> [i]t is entirely conceivable that the blues chord progression of I-IV-I-V-I represented a horizontalized form of the primary intervals used by these fourths- and fifths-based tribes . . . . Summing up, we can say that harmonic elements in the prehistory of jazz were not so much *derived* from European musical sources as carried over . . . from African traditions. Coincidentally, the European and African traditions overlapped enough to offer no profound problems of synthesis. (Schuller, 1968, pp. 42-43)

Thus, when CP chords are used within a cyclical, exploratory structure such as those found in early African American music, and outside of a goal-directed, hierarchical CP context, they may have entirely different functions, meanings, and thus perceptual associations regarding expectation and surprise. This may change how we describe our perceptual understanding of the 12-bar blues progression. If it is perceived by listeners to be a European diatonic structure whose parameters have been constrained by call and response patterns, then its chords should function within that context, i.e. goal-oriented, hierarchical, functional, containing tension and release, and expectation and resolution. If it is perceived as a cyclical, non-hierarchical structure derived from African traditions such as those described above, then the perceptual kinetic effects of these chords will be greatly reduced.

4.3.2. Tonality

In addition to deviations from CP narrative structures and functionality, blues also features deviations from CP tonality. Pedagogical accounts of blues tonality typically refer to the "blues scale" (Nettles & Graf, 1997), (Levine, 1995), notated below. This scale was first introduced in the first edition of Jamey Aebersold's popular teaching manual *How to Play Jazz and Improvise* in 1967 and is found in many contemporary jazz and blues textbooks. The scale consists of a minor pentatonic with an added $\flat 5^{th}$. This note, as well as the $\flat 3^{rd}$ and $\flat 7^{th}$, are often referred to as "blue notes." This terminology is derived from the clash between these notes and their natural counterparts in a major key context.

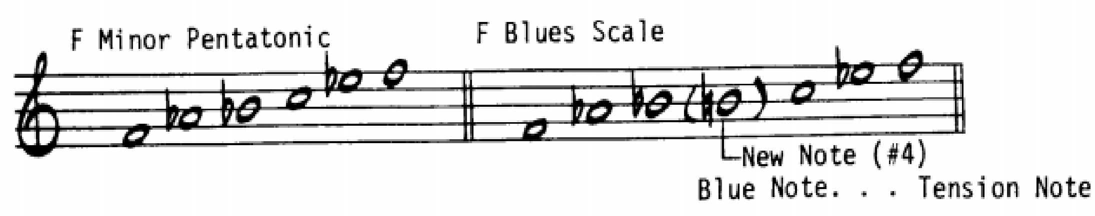

Fig. 19: The blues scale, as notated by Aebersold
(Source: Aebersold, 1992 p. 30)

Even a cursory analysis of early blues melodies reveals that this scale is not an idiomatic blues structure, but rather is, as Hein notes, a pedagogical convenience consisting of "the most prevalent pitches in a larger and more complex set common to blues practice" (Hein, 2014, para. 7). Although this reduction proved to be an efficient and popular tool for students of jazz and blues, it is another example of the oversimplification of complex African-based musical systems in order to make them conform to European strictures.

Gerhard Kubik describes the struggle of Western musicologists to come to terms with pitches that do not conform to Western tonality, such as the aforementioned “blue notes” in their African contexts:

> These two notes [3rd and 7th] seem to be notoriously unstable and somewhat superimposed on the Western major scale like “aliens” . . . . However, we who have worked in African cultures with the most diverse tonal systems cannot help but see the “inflections” on the other side. . . . [Through analysis of melodic lines in isolation] it becomes clear that each vocal line is an integrated, patterned whole, without any particular tones having special status. (Kubik, 1999, p. 118)

Kubik continues by arguing that giving the ♭3rd and ♭7th a designated term such as “blue notes” only makes sense when they are conceptualised within a European framework, rather than the framework within which they were conceived. The term therefore represents a Westerner’s perspective and not the perspective of those who innovated and used these tones. Laz E.N. Ekwueme points out that this may have happened because most early research on the music of Africa was carried out by Western researchers who were often not musicologists but were “missionaries, doctors, explorers, or mere adventurers” (Ekwueme, 1974, p. 35). He notes that “[i]n many cases, it is difficult, if not impossible, for the outsider to obtain a true assessment of folk evaluation and folk theories on their own terms” (Ekwueme, 1974, p. 41). Correspondingly, there is, as Agawu notes “a disjunction between the practice of African music and its scholarly representation” (Agawu, 2003, p. xv).

Kubik warns of the dangers of this perspective in the potential for misunderstanding tension within the blues,

> intraculturally (i.e., for the performers themselves) the blue notes have no reality as separate conceptual pitch units. This is supported by the fact that Deep South blues singers themselves never talk about “blue notes” unless they have had some exposure to the jazz literature, have had Western formal musical training, or are influenced by fans from outside their primary community and audiences. In other words, “blue notes” or any other special type of note in relation to pitch, is not originally an intracultural concept. It seems the term was introduced by various jazz musicians and writers about

jazz, who began to use it by the 1920s – perhaps even a bit earlier – in order to “explain” their music in Western terms.

> Thus, the so-called blue notes are simply part of a blues singer’s total pitch repertoire. Their existence as differential cognitional units is only generated through comparison with an extrasystemic parameter: the European diatonic scale. (Kubik, 1999, p. 123)

Several scholars have attempted to analyse blues tonality without the need to conceptualise it within European tonality. For example, Van der Merwe puts the interval of a “neutral” third at the heart of blues tonality. He roots blues tonality in a “ladder of thirds” based on this interval. The neutral third can be contextualised as either an unstable note dropping onto a stable one below, or a stable note hanging above an unstable one. Van der Merwe refers to these respectively as “dropping thirds” and “hanging thirds”. Both have been found to characterise many African and early African American melodies. The combination of these intervals serves as the foundation of van der Merwe’s ladder onto which more thirds can be added above or below as required (van der Merwe, 1992).

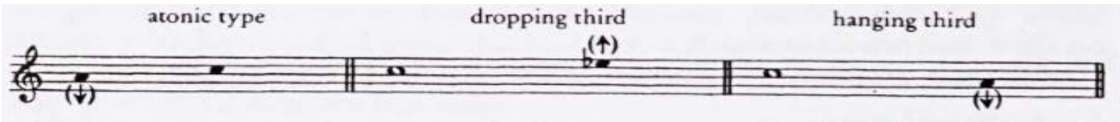

Fig. 20: Van Der Merwe's "dropping" and "hanging" thirds
(Source: van der Merwe, 1992 p. 122)

Roach notes that these minor third motifs often feature as cadential formulae of sorts in the music of Africa. She says that “[i]f West African music approached the idea of a standard cadence, it was through the frequent use of the downward interval of a third . . . a characteristic feature also seen in terminating phrases in Afro-American blues (Roach, 1976, p. 15).

Kubik roots blues tonality in a section of the harmonic series conforming to human speech range. Thus, blues pitches are derived from human speech formants. That is, notes are derived from the section of the overtones of speech signals that are within the typical vocal range, whose intervals are easily singable. This, combined with a tradition in parts of Africa to conceptualise music and musical instruments into two distinct ranges associated with male and female, results in a “combined model [of male and female ranges] that encompasses the melodic repertoire of the blues” (Kubik, 1999, p. 138). Kubik acknowledges the variation of these pitches from the cent value of their equal temperament counterparts.

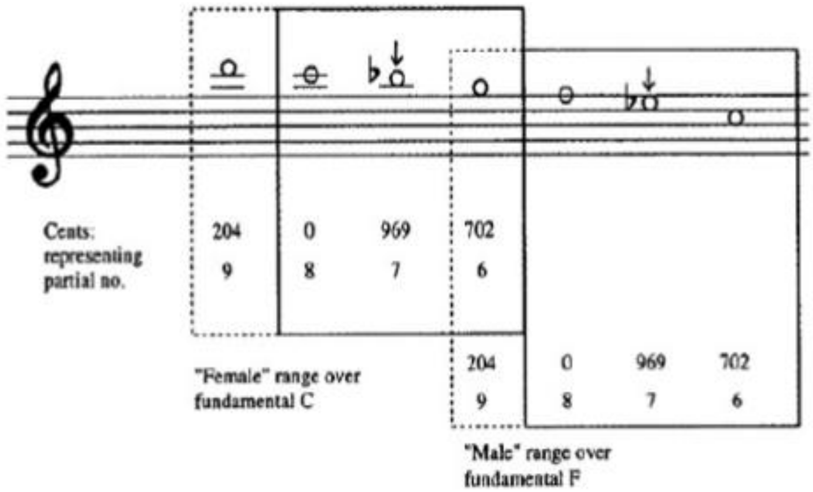

Fig. 21: Kubik's integrated model of blues tonality
(Kubik, 1999, p. 138)

Jeff Titon (1994), in an exhaustive analysis of early blues, refers to "complexes" consisting of multiple pitches within a specific range, and notes that these complexes may be centred around the 3^{rd}, 5^{th}, and 7^{th}.

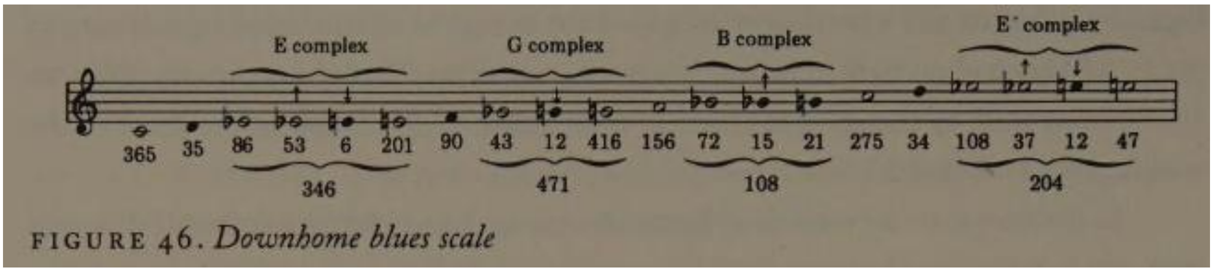

Fig. 22: Titon's blues complexes
(Source: Titon, 1994, p.154)

Evidence of the persistence of Titon's complexes in blues-derived popular music has been found through corpus analysis of contemporary rock. Temperly and de Clercq (2013) tested the tonal distribution of notes in a rock corpus and found them to reflect the distributions described by Titon, albeit with the sole inclusion of tones that reflect equal temperament tuning systems. Notably, Temperly and de Clercq found evidence of the use of what they called a "pentatonic union" scale in the rock corpus; this is essentially a Mixolydian scale containing a ♭3^{rd} in addition to the ♮3^{rd}.

4.3.3. Major/minor melding in blues

Blues complexes around the 3rd, and their evolution within an equal temperament tonal system that permits both ♭3rd and ♮3rd, result in an ambiguity between major and minor in blues and blues derived music (Stephenson 2002). Complexes around the 7th serve to exacerbate this ambiguity. Early blues, as considered from the perspective of Western tonality, could be considered a melding of parallel major and minor tonalities, due to the permissibility of the ♭3rd, ♮3rd, ♭7th, and ♮7th. All four of these tones are considered hierarchically equal, with all featuring as primary, rather than supporting tones. Evidence of this blending may be found in the earliest published blues tunes.

The first notated 12-bar blues form, "I Got the Blues" (1908) was published by Antonio Maggio and consisted of a melody he attributed to a blues musician he had met while on a ferry across the Mississippi River (Hobson, 2014). The three notes of Maggio's melody comprise the ♭3rd, ♮3rd and root of the major tonality, reflecting Titon's "E complex", in the key of C. In CP terms, the ♭3rd would be analysed as a chromatic approach to the diatonic natural third, which indeed is how it functions while the underlying harmony is I, with the root falling on the downbeat. However, on bar 5, when the harmony changes to the IV chord, the ♭3 no longer approaches the ♮3 but instead falls on a downbeat of 3 itself, thus creating a dominant 7th structure on the IV, a chord rarely found in CP harmony. Both the ♮3rd and ♭3rd function as primary melodic tones, reflecting a merging of major and minor.

This complex can also be clearly heard in Sara Martin and Sylvester Weaver's recording "Longing for Daddy Blues/Goodbye Blues" (1923), both written by Clarence Williams. This recording is generally considered to be the first recorded country blues. In "Goodbye Blues", Sylvester Weaver plays primarily triads on I, IV, and a V7, while for the first three choruses, Sara Martin's melody centres around a tetrachord of the 5th, 6th, ♭7th, and root for the first two phrases, altering the ♭7th to a ♮7th for the response phrase. Weaver plays a V7 in the turnaround[9], while Martin emphasises the ♮3rd of the V7, or the ♮7th overall.

These examples are notable in that they demonstrate that although blues musicians considered both the ♭3 and ♭7 as integral parts of the blues tonal system, it is not at the expense of the ♮3rd or ♮7th. This shows evidence of non-hierarchical complexes around the 3rd and 7th and

[9] A turnaround is a short one- or two-bar progression that ends one section and leads harmonically into the next section.

further enhances the idea of a blended major and minor tonality that would influence later popular music.

4.3.4. Harmonic language

Within early African American music, the notes of the blues "complexes" described by Titon integrated with the European triadic I, IV, V harmony of early blues to create new harmonic structures, e.g. I7, IV7, ♭VI7, and ♭VII7. Although these structures may be found in CP contexts, particularly within the late Romantic Period, the overall narrative structures and blended tonalities of the blues change the functions of these chords in comparison to how they may have been used in CP contexts.

Evidence of the effect this liberal tonal palette had in diverting the fundamental Western triadic harmonies of blues away from their CP roots and into what van der Merwe calls a "*language* that [is] subtly but unmistakably different from the classical language" (van der Merwe, 1992, p. 2), can be found in the analysis of early music by African Americans. The lack of hierarchical differentiation between the ♮3rd and ♭3rd, and the ♮7th and ♭7th can be found, resulting in a blending of major, minor and Mixolydian modalities. The co-existence of the ♮7 and the ♭7 means that chords containing the ♭7 can appear regularly, but the functional V7 chord is also available to introduce dominant functionality if required. Harmonic structures with enharmonic equivalents in CP but entirely different functions, and thus meanings and perceptions, can be found, such as dominant 7th structures without dominant function, e.g. the I7 and IV7. Triadic and 7th structures built on traditionally chromatic notes such as the ♭III, ♭VI, and ♭VII, but without chromatic function may also be found. Some of these structures are derived from blues, some from 20th century European CP influences, some from 19th century folk influences, but all amalgamated to create forms and structures that function and are perceived in fundamentally different ways than that of CP.

In addition, the concept of co-tonics underlying chord changes in blues-based music, combined with the prevalence of dominant 7th chord structures results in the placement of dominant 7th chords on strong hypermeasures[10]. This contrasts with CP traditions where

[10] Hypermeasure is the phenomenon whereby individual bars are perceived as beats within larger rhythmic structures. Theorists refer to strong and weak beats of a hypermeasure; chords falling on strong beats of the hypermeasure, i.e. beat 1 of bars 1 and 3 receive more stress; those falling on weak beats,

dominant structures are traditionally placed on weak hypermeasures, thereby functioning as propulsive chords that "launch" a subsequent resolution onto a strong hypermeasure. Within a CP context, this tradition creates a strong perceptual link between dominant structure, dominant function and weak hypermeasure. In blues, the use of dominant 7th structures to delineate harmonic shifts between co-tonics, rather than goal-oriented functionality, disconnects these perceptual links and results in dominant 7th structures functioning as tonics and subdominants, occupying the hypermeasures traditionally reserved for resolutions.

The four primary non-dominant functioning dominant 7th structures in blues, I7, IV7, ♭VI7, and ♭VII7 are outlined below.

4.3.4.1. IV7

The IV7 chord is the earliest definitive non-CP chordal structure that appears in blues. In Maggio's "I Got the Blues", the IV7 is not notated but is clearly implied by the combination of a ♭3 downbeat melody note over the IVma triad. A similar effect occurs in "Dallas Blues" (1912) by Hart Wand. This tune also features triads in the accompaniment, but a dominant 7th structure is implied on the IV chord through the use of the ♭3 on a downbeat in the melody, which functions not in its traditional chromatic approach manner but as a primary tone. The first published IV7 can be found in both of W.C Handy's early pieces "The Memphis Blues" (1912) and "St. Louis Blues" (1914).

In the earliest recorded classic blues, Mamie Smith's 1920 recording of "Crazy Blues", composed by Perry Bradford, the IV chord is a triad but gives the impression of a IV7 when coupled with the emphasised ♭3 in the melody. By the time of the first recorded country blues and jazz blues, dominant 7th chords are clearly implied through arpeggiation, such as Weaver's guitar patterns on "Guitar Blues" (1923). Riffs on the ♭3 can be heard over the IV chord in King Oliver's "Riverside Blues" (1923). Clear IV7 chordal structures are also heard in John Irving's piano accompaniment on Bessie Smith's "Jailhouse Blues" (1923).

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i.e. beat 1 of bars 2 and 4 receive less stress (Stephenson, 2002). Where the harmonic rhythm is doubled or halved, so are the stress points.

4.3.4.2. I7

The I7 chord structure evolved at a slower rate than the IV7. Theorists have speculated that the I7 structure arose from musicians singing or playing the ♭7 as a melody note over the I triad (Nettles, 2007a). However, this combination is not regularly found within popular sheet music prior to 1924, although an exception exists for a single I7 in the coda of W.C Handy's "Memphis Blues" (1912). A more likely derivation for this chord is the secondary dominant V/IV, which became very popular as a transitional chord between the I and the IV in early blues-influenced Tin Pan Alley and ragtime tunes. For example, it may be found in "Dallas Blues" and in other popular songs of the time, such as "Baby Seals Blues" (1912) by Franklin "Baby" Seals. The transitional V/IV is heard in the earliest recorded blues, such as Mamie Smith's first recording of "Crazy Blues" (1920), composed by Perry Bradford.

In "Longing for Daddy Blues/Goodbye Blues", I7 is implied through the combination of the I triad and Martin's emphasised ♭7. Weaver also plays a transitional V/IV, and unambiguously ends the tune with a resolution to a full I7. Bessie Smith's recording of the Clarence Williams composition "Jailhouse Blues" (1923) also features vamps on a I7 as well as V/IV approaches to IV. Fats Waller, accompanying Sara Martin on "Mama's Got the Blues" (1923) opens the arrangement with a I7. Waller can also be heard vamping on I7 on the Spencer Williams composition "Midnight Blues" on a 1923 piano roll.

Riffs containing the ♭7 and implying I7 become more and more common throughout the late 1920s and 1930s into the 1940s. For example, Blind Lemon Jefferson plays a riff in thirds featuring the flattened 7^{th} from the first bar of the I chord in "That Crawlin' Baby Blues" (1929). It is also heard in boogie-woogie piano recordings of the day, with Pinetop Smiths' recording of "Pinetop's Boogie-Woogie" (1928) featuring ♭7 riffs that demonstrate that players were clearly treating the I chord as a dominant 7^{th} structure. Skip James plays a ♭7 riff on "Cypress Grove Blues" (1931), while "I'm a Rattlesnakin' Daddy" (1935) by Blind Boy Fuller features the same pattern. By the 1940s the I chord was firmly established as a dominant 7^{th} structure, as can be heard in the Muddy Waters recording "Country Blues" (1941), built on a bass riff featuring the ♭7. Although the ♭7 riff never replaces the triad and transitional V/IV chord and both coexist throughout the 20th century, the transition into I7 as the tonic, as well as the IV7 as default, become standardised. The transitional V/IV can still be heard as late as Robert Johnson's "I'm A Steady Rollin' Man" (1937), and in Leadbelly's first recordings, including "New Black Snake Moan" (1935), and "Pig Meat Papa" (1936), but by 1940, even Leadbelly appears to abandon this practice, instead, for the most part, playing a I7 from the beginning, or playing a I6 arpeggio and skipping the V/IV, as heard in “Good Morning Blues” (1940) and “Worried Blues” (1940).

4.3.4.3. ♭VI7

Another structure rooted in early blues that transitioned into common practice of jazz/popular music styles is the ♭VI7. This chord can be heard from the earliest recorded blues. However, this chord may not be derived from the same combination of blues melodic complexes as the I7 and IV7. It is likely that this chord may instead have been adopted by blues musicians from the common practice $^{+}6$ chord, or even the modal mixture IVm and developed into a fundamental structure to be used both cadentially as a pre-dominant and as a fundamental chord.

Augmented 6^{th} ($^{+}6$) chords were common in the popular songs of black American composers before the turn of the century. For example, the composer Gussie Davis used $^{+}6$ chords in several of his compositions, including “Fatal Wedding” (1893), and “In the Baggage Coach Ahead” (1896). Sam Lucas also uses the $^{+}6$ in his composition “Down by the Sunrise” (1884).

These $^{+}6$ chords, found in both German and French variations, functioned in the same manner as traditional $^{+}6$ chords, with the ♭6 and ♭5 both voice-leading to the 5^{th} of the key. After the turn of the century, variations on the $^{+}6$, such as the ♭VI root position triad can be found. In Charlotte Blake’s ragtime piece, “The Wish Bone” (1909), a ♭VI major triad is heard preceding a 2^{nd} inversion I chord. In a repeated section, this chord is heard with an $^{+}6$, voice-leading in the traditional manner. This suggests that composers of the time may have been using ♭VI triads and $^{+}6$ chords interchangeably.

The ♭VI also features in Ayer and Brown’s “Oh You Beautiful Doll” (1911). This song features a 12-bar form section, suggesting a blues influence, and demonstrating that this chord may have become strongly associated with blues by this time. Chris Smith’s hit “Balling the Jack” (1913) features a progression from ♭VI7 to IV7, clearly suggesting a blues association with ♭VI7, given that it is paired with a IV7, and does not follow the traditional voice-leading of CP $^{+}6$ chords. Smith features this chord in several of his compositions. His composition of the following year “Fifteen Cents” (1913) features a ♭VI7-V turnaround. This song contains I7 and clearly has blues influences. Evidence that this progression is not the traditional $^{+}6$ - V progression, although it may have been based on it, is found in the voice-leading of the upper voice downwards to the

♭7 of the V chord, rather than the traditional ascending movement to the 5th, or root of the V chord. In his later composition “Down in Honky Tonk Town” (1916), the ♭VI7 is featured, as is the ♭III7, and another ♭VI7-V turnaround is used in his tune, with Cecil Mack, of the same year “Never Let the Same Bee Sting You Twice” (1916).

The IVm may also serve as an alternate source for the ♭VI7 as a turnaround chord. In Gerard and Armstrong’s “Sweet Adeline” (1903), Chris Smith’s “Right Church but the Wrong Pew” (1908), and Chris Smith, Fred E. Mierisch, and Luckeyth Roberts “Junk Man Rag” (1913) the IVm can be found in first inversion approaching the V chord, resulting in a variation on the ♭VI-V turnaround. Eubie Blake plays a ♭VI-V turnaround in his “Charleston Rag” (1917) but voices the ♭VI as a 1st inversion IVm6. In the same year, the same chord is found in the Tin Pan Alley standard “Indiana” (1917) by MacDonald and Hanley. The idea that jazz musicians viewed this chord as akin to the IVm is supported by Mary Lou Williams version of “Lullaby of the Leaves” (1944), where she reharmonises the IVm in the bridge as a ♭VI7 chord.

By the time the first country and classic blues were recorded, the ♭VI had been firmly established as a fundamental part of the blues’ harmonic language. In “Longing for Daddy Blues”, Weaver uses the ♭VI in three different ways. He slides through it to get from the V to the VI, uses it as a replacement for the traditional IV chord in bar 5 of the final chorus, and his turnaround comprises a ♭VI-V progression, rather than the V, or V-IV traditional turnaround associated with early blues.

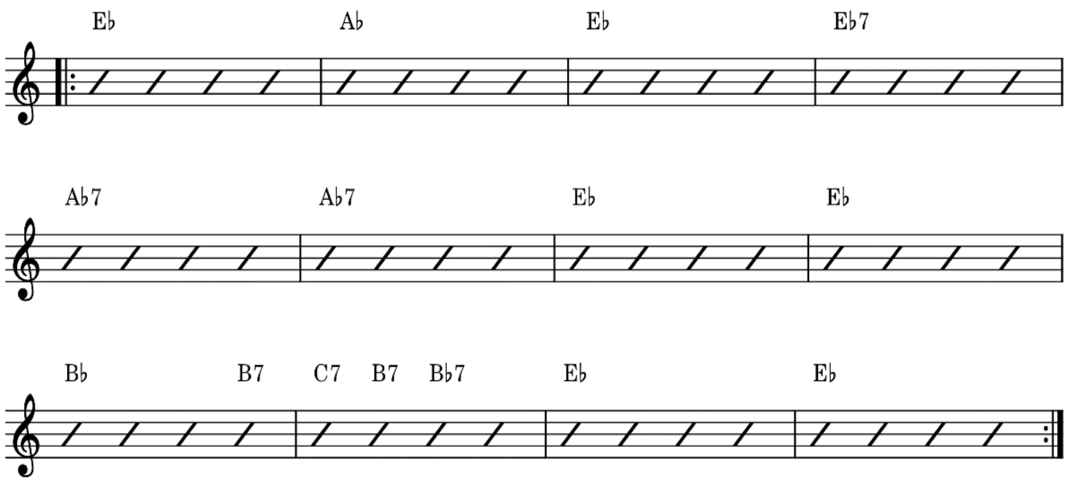

Fig. 23: Longing for Daddy Blues chord transcription

Weaver also uses this chord liberally in his 1923 recording “Guitar Blues” (1923), through slides and turnarounds. Weaver’s slides would pave the way for the triad-doubled systems featuring parallel movement between major triads that will come to feature in Chicago blues and later rock music. These kinds of movements were extremely common in the early days of the Delta blues, when musicians typically used knives or bottles on the frets of the guitar to achieve smooth parallel movement (Titon, 1994).

The ♭VI-V turnaround can also be heard prominently in Blind Willie McTell's "Drive Away Blues" (1929) and on Fats Waller's piano roll recording of "Midnight Blues" (1923), with some notable variations in the middle of the form, and features prominently in Ma Rainey's recording of "Blues Oh Blues" (1927) with Fletcher Henderson.

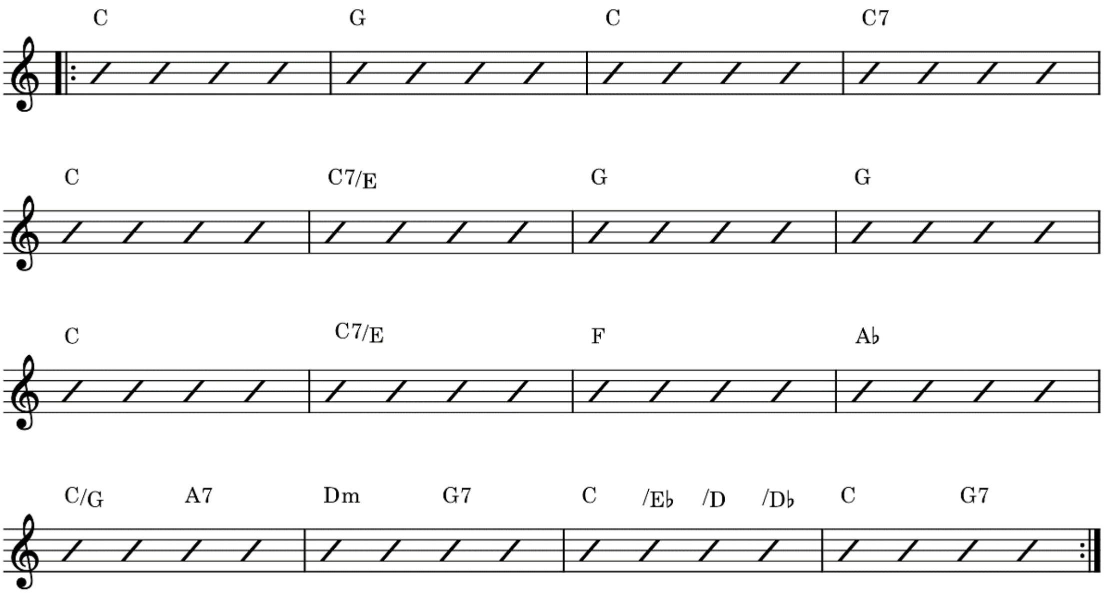

Fig. 24: Blues, Oh Blues chord transcription

Jazz and popular music composers began to use the ♭VI7 as a colour chord in the 1920s and 1930s. An early example may be found in James Blythe's 1923 piano roll of "Last Night on the Back Porch" (1923). The 1925 hit by Lown, Gray, Bennett, and Hamm "Bye Bye Blues" (1925) features a ♭VI7 colour chord following I. Other examples include hits on the ♭VI in Papa Charlie Jackson's song "Shake That Thing" (1925). ♭VI7 hits are also features in Benny Goodman and Billie Holiday's recording of "Riffin' the Scotch" (1933). Duke Ellington features the ♭VI turnaround as a means of modulation in his tune "Choo Choo" (1924), and prominently features the chord in his "Cotton Club Stomp" (1929); Ellington also features this chord prominently in his song "Flamingo" (1940). This chord was to later become a favourite of Thelonious Monk; Monk features it in several of his compositions, including "I Mean You" (1946) and "In Walked Bud" (1947).

4.3.4.4. ♭VII7

The ♭VII triad, although rarer than the ♭VI7, can also be found throughout early blues, and in the music of early black popular composers. For instance, the composition “Down by the Sunrise” (1884) by Sam Lucas features a ♭VII triad, as does the Tom Turpin piece “Harlem Rag” (1897), and the Gussie Davis piece “Down in Poverty Row” (1896), as a passing root. Within the early recorded Delta blues repertoire, the ♭VII is played as part of a slide to I by Sylvester Weaver in “Guitar Blues” (1923) and is a feature of Skip James’ “Special Rider Blues” recorded in 1931, where James vamps between it and the I. “Special Rider Blues” also includes an innovative use of the ♭III chord in its guitar break.

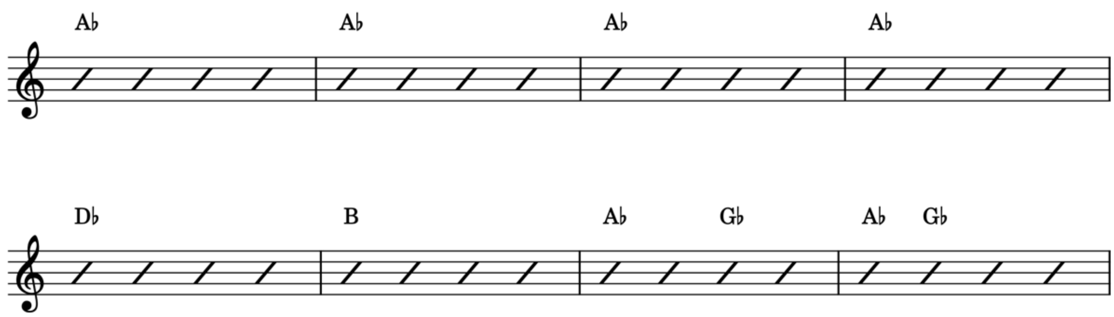

Fig. 25: Special Rider Blues Guitar Break chord transcription

Evidence can also be found for the blues-rooted ♭VII being used by Tin Pan Alley songwriters. What is notable here is that these blues chords are inserted into the fundamentally CP based frameworks of Tin Pan Alley songs, with the effect of introducing a kind of blues modal mixture. For example, “Sweet and Lovely” (1931) by Arnheim, Daniels, and Tobias features a ♭VII paired with a IV7. The pairing with IV7, an exclusively blues chord, demonstrates that composers of the day considered this chord to be rooted in the blues. Jazz musicians also began to incorporate the ♭VII chord, most often as a full dominant 7th structure, into their tunes and arrangements, particularly as a colour chord in intros and vamps. For example, Fletcher Henderson’s recording of “It’s the Talk of the Town” (1933) features an introductory vamp between the I7 and ♭VII7, giving an early hint at the modal mixture harmonies to come in jazz. Chick Webb’s recording of “I’ll Chase the Blues Away” (1935) featuring Ella Fitzgerald, incorporates a I-♭VII9-I pattern as an ending.

Duke Ellington, Billy Strayhorn, Count Basie, and Charles Mingus also incorporated the ♭VII, along with the I7, IV7, and ♭VI7 into their compositions, creating a unique jazz language based on these blues harmonies displaced from their traditional 12-bar blues context. Examples include Strayhorn's "Lush Life" (1991), written in 1936, where the ♭VII7 is used as a modal mixture vamp. Benny Carter's arrangement of Hoagy Carmichael's "Rockin' Chair" (1941) for the Gene Krupa Orchestra features a IIm-♭VII7-♭VI7-V7 progression for the intro, although it is likely that listeners may perceive the IIm as a tonic and thus the ♭VII7 as a ♭VI7.

Many jazz tunes incorporate the ♭VII7 as a passing chord, such as Count Basie's recording of "Blue and Sentimental" (1938). Earl Hines' recording of "Jersey Bounce" (1941) features a ♭VII7 in its bridge, between the I and ♭VI7. The effect of this chord used in this manner is to create a blues/Mixolydian tonality without the requirement for a blues form. This sound would later characterise the compositions of the hard-bop era, where chords such as the I7, IV7, ♭VII7, and ♭VI7 featured prominently.

4.3.5. The effects of the guitar on function and language

Blues has strong associations with the guitar. Preference for the guitar among early blues musicians may have been due to its portability and its links to the banjo, an instrument of West African origin that was commonly played among the first generations of slaves in America. As such, blues is a music composed at the guitar. It is easy to see how differences in harmonic language can come about through differences in composition instruments: ascending through the piano keyboard using the same simple shape results in the diatonic chords of the major key, while the same motion achieved on a guitar by sliding a bottle across the frets results in ascending chords of the same quality, e.g. major triads. Theorists contend that many of the non-CP harmonic structures found in blues, such as the ♭VI7, ♭VII7, and ♭III7 described above, originate from slide bar chord techniques.

Alf Björnberg was among the first to describe tonal frameworks made up of chords of the same quality, likely derived through blues slide guitar techniques. Björnberg (1984) outlines a system of major triads built on the minor pentatonic, a framework through which many popular songs can be described. Walter Everett elaborated on this tonal framework, referring to it as a "triad-doubled . . . minor pentatonic system" (Everett, 2004, Table 1). Biamonte (2010) expands this system by noting that any root within the system may function as a tonic, thereby giving rise to a family of tonal systems within the same framework.

Several scholars have theorised that the tuning systems used on guitars in the US in the 19th century may have also been contributory towards a decrease in functionality in the blues, in comparison to CP. This is partly because of an elevation in the importance of the IV chord due to the fact that guitars are tuned in fourths, in contrast to the tuning of traditional CP instruments in fifths. Titon describes the effect of this:

> Sometimes guitarists attained . . . harmonic ambiguity by playing the key of E in standard tuning and using the lowest-pitched bass string (E) to suggest the tonic, and the next lowest bass string (A) to suggest the subdominant. (Titon, 1994, p. 42)

Koozin states, with reference to rock patterns traceable to early blues, that "[t]his rendering of the major triad voicings that comfortably fit a single location on the fretboard suggests a correspondence between fretboard design and idiomatic patterns of blues-rock guitar music that often feature chromatic third-related modal colorations and *subdominant-driven harmony* [emphasis added]" (Koozin, 2011, para. 3).

Biamonte argues that in addition to an elevation of the subdominant, guitar tuning in fourths precipitated increased root movements in fourths, and a subsequent decrease in the traditional CP root movement in fifths. Middleton notes the common tone between chords in retrogressive movement and thus speculates that these movements may thus have less tension (Middleton, 1990), further reducing tension-based functionality in blues-rooted music.

These triad-doubled systems permeated into the later blues and rock repertoires of the mid- and late 20th century. In the late 1930s the United States began to recover from the effects of the Great Depression, which had left many southern states particularly hard hit economically. Black Americans in the south were at the time living under Jim Crow laws, which would not be repealed until the 1960s. This resulted in an exodus of blues and jazz musicians from the South to the Northern cities such as Chicago, in the Great Migration. Chicago became a hugely important place in the history of blues; it was where the primary blues record companies, such as Chess records, were based and where many leading blues musicians performed. The Delta blues musicians of Mississippi who had moved from the south combined their traditional blues sound with a rhythm section and began performing on electric guitars, which were just becoming commercially available, to create what became the Chicago blues sound. The wide variety of Delta blues progressions were narrowed down to a set of two blues forms, major and minor, while melodies generally became constricted to the minor pentatonic scale. Blues began to attract a wider audience, particularly internationally, following an English tour by Muddy Waters. Blues labels began to record rock 'n' roll bands and the British invasion of rock bands kicked off.

Many early rock ‘n’ roll artists incorporated the blues form wholesale into their songs. According to Tagg

> a large proportion of rock ‘n’ roll hits from the mid-1950s . . . follow the basic twelve-bar blues format. . . . That sequence performed loud and up-tempo had immediate forerunners in the music of jump bands, boogie-woogie trios and other small combos in the milieu of jive and jitterbug that until the end of World War II had been the territory of riffing big bands . . . . The breakthrough of rock ‘n’ roll in the mid-1950s that those loud, uptempo renderings of the twelve-bar blues format entered the mainstream en masse. That breakthrough has considerable harmonic and historical significance. (Tagg, 2014, p. 412-413)

Pinter traces the early use of ♭VII outside of a native blues or jazz context to Bo Diddley, an important transitional figure between blues and rock ‘n’ roll. Diddley heavily influenced the bands of the British invasion, e.g. the Beatles and the Rolling Stones, who incorporated the use of this chord liberally into their repertoire (Pinter, 2019). Later 1960s and 1970s rock bands such as Led Zeppelin, Cream, and the Yardbirds were heavily influenced by both the Chicago blues innovators such as Muddy Waters and Willie Dixon, and the Delta blues pioneers that came before them.

Thus, the harmonic language of Delta blues musicians, their melding of major, minor, and Mixolydian tonalities, use of non-dominant functioning dominant structures, and use of “chromatic” structures built on ♭III, ♭VI, and ♭VII as primary structures, became the harmonic language of rock.

4.3.6. Modal interchange[11]

The primary modal mixture chord in CP music is the IVm chord. This colour chord can be found in popular songs and marches of the late 18th century, for example in the songs of Gussie Davis, e.g. “Irene, Good Night” (1887) and “Down in Poverty Row” (1896), and the marches of F.W. Meacham, e.g. “American Patrol” (1885). This chord was very popular in the mid-1920s, featuring in many Tin Pan Alley compositions, such as Jones and Kahn’s “It Had to Be You” (1924) and “I’ll See You In My Dreams” (1924), and Irving Berlin’s “Blue Skies” (1927).

[11] While the borrowing of chords from a parallel mode is commonly known as “modal mixture” within CP contexts, in jazz this technique is referred to as “modal interchange”. Their meanings are identical.

Most often, the IVm generally served as a pre-dominant in root position, or resolved to I. Soon however, jazz musicians began to pair this chord with a ♭VII, to create a type of deceptive IIm7-V7 progression with I chord resolution. This followed the transition of the primary cadence in popular music from IV-V-I to IIm7-V7-I6 or Ima7, and the advent of related II chords of secondary dominants. This progression, which later became known to musicians as the *back door* progression (Mulholland & Hojnacki, 2013, p. 124), can be heard as early as 1938, in Benny Goodman's recording of "Lullaby in Rhythm" (1938). The progression had clearly become a popular harmonic phrase during the musician's recording strike, given its ubiquity in the early recordings of the bebop era, such as Charlie Parker's recording of "Koko" (1945), where Dizzy Gillespie reharmonises the changes with a back door progression, and "Yardbird Suite" (1946) where a back door progression is clearly part of the original changes. In Lester Young's recording of "East of the Sun" (1947), the modal mixture origin of the progression is clearly heard when Young reharmonises the IVm of the original composition as a back door progression.

Other modal interchange chords that became common within jazz are the ♭II, ♭III, and ♭VI, most often played as major 7th chords. These chords are rarely found within the popular music idiom prior to the 1920s, but they can be found in Tin Pan Alley standards. The most common of these within Tin Pan Alley is the ♭VIma7, which can be found in Porter's 1923 song "Night and Day" (1923). An early ♭II may be found in Green, Heyman, Sour and Eyton's "Body and Soul" (1930). These chords were favoured by Billy Strayhorn and Duke Ellington, who used them in the intro to "Chelsea Bridge" (1941), along with a ♭Vma7. Count Basie also uses a ♭VIma7 in his intro to "This Heart of Mine" (1945). Other jazz musicians began to feature these chords in their compositions in the late 1940s, such as Thelonious Monk in "Monk's Mood" (1947), which features a cadence to the ♭IIma, and Woody Herman in "Early Autumn" (1948), which features a ♭VIma7 and ♭VIIma7. These colour chords continued to be used by Tin Pan Alley and Broadway composers in tandem with jazz composers. Examples include Kern's "Up with the Lark" (1946), Meredith and Eileen Wilson's "Till I Met You" (1950), and Lee and Russell's "Blue Gardenia" (1953).

Several contemporary theorists have contended that ♭IIma7 chords in jazz are related to the CP N^6 chord (Nettles & Graf, 1997). However, its usage in jazz/popular music often features very different functionality to the typical CP usage, meaning that it will be perceived differently by listeners. In CP, the N^6 functions as a preparatory chord for the V, whereas in the examples above, the ♭II is a deceptive resolution following V, or functions as part of a modal interchange sequence. In addition, the modern ♭II often contains a natural 7th, which is not generally featured in N^6 chords of the 18th and 19th centuries. Traditional N^6 chords are much more common in minor keys than in major, but the ♭IIma7 chords found in jazz/popular music are almost always within major keys. A more likely influence for these modal interchange chords in the songs of Tin Pan Alley and Broadway composers, and those of swing and bop era jazz, is the chromatic harmony of much European art music of the late 19th and early 20th centuries, particularly third relations.

These influences began to assert themselves during the period between 1920 and the Great Depression, which is considered by many to be the golden age of Tin Pan Alley (Pessen, 1985). Songwriters and, importantly, arrangers, who some consider to be the real driving force behind the musical innovations of early Tin Pan Alley (Wilder, 1972), began incorporating elements of the music of 20th century European composers such as Debussy, Ravel, and Milhaud. Cole Porter himself studied in Paris in the Schola Cantorum, whose instructors included Milhaud and Satie, while George Gershwin has cited Stravinsky and Debussy as influences (Wyatt & Johnson, 2004). The influential jazz composer Billy Strayhorn initially studied classical music and his work draws from French Impressionist composers such as Debussy and Ravel (van de Leur, 2002).

The most well-known combination of modal interchange chords in jazz is the *Lady Bird turnaround,* which in its modern iteration consists of the chords Ima7, ♭IIIma7, ♭VIma7, and ♭IIma9. Third relations are evident in this progression in the transition from I to ♭IIIma7 and then to ♭VIma7. This progression is so-called as it is derived from the Tadd Dameron standard "Lady Bird" (1948), believed to be composed in 1939, although not released for another nine years (Combs, 2012, p. 211). Although colloquially, the Lady Bird turnaround is understood to include all major 7th chords, on the original recording by Dameron, dominant 7th chords are played on the ♭III and ♭II, and a major 7th is only heard on the ♭VI. The year that "Lady Bird" was released, the same iconic turnaround can be heard in Miles Davis's composition "Half Nelson" (1948), and again the following year in his version of John Carisi's "Israel" (1949). In 1950, Bud Powell reharmonised the tune "All God's Chillun'" (1950) to feature a Lady Bird progression, coming closer to the all-ma7 form by substituting a ♭IIma7 for Dameron's ♭II7. Art Farmer's composition "Farmer's Market" (1952) features a Lady Bird turnaround with all major 7s except for the ♭II, while Hank Jones reharmonises "The Song is You" (1953) on Charlie Parker's recording to feature a Lady Bird turnaround with a ♭III7 and ♭IIma7.

Thus, the harmony of jazz further diverted from that of CP through not just the influence of blues and the use of blues structures within major key frameworks, but also through the influence of 20th century European composers, who were pushing the boundaries of CP harmony, functionality, and structure.

4.3.7. Functionality and momentum

Within American music of the early 20th century, a bifurcation occurred between music with increased momentum and functionality, and that of decreased momentum and functionality. This can be conceptualised as a difference between blues and popular music, and that of jazz. Evidence for this increased momentum within the evolution of jazz can be seen by tracing the increasing prevalence of the primary cadence and secondary dominants within jazz harmony. This increased momentum went hand in hand with more focus on local harmonic goals and less focus on large-scale goals, which served as an ideal framework for improvisation.

In mid-19th century America, the most popular music consisted primarily of marches and what is often termed parlour music[12]. Within these styles, the primary cadence was the IV-V-I and harmonies were almost entirely diatonic, with diminished chords primarily accounting for any chromaticism. This is due to the strong influence of European CP (Starr & Waterman, 2014). CP harmony also influenced marches, but due to their more energetic nature, harmonic rhythm was faster in this style. Around the turn of the century, three factors led to a decrease in this kind of simplistic harmony in mainstream music. The first was the influence of blues, as detailed in the previous sections. The second was the development of commercialised music and the dominance of the music industry by publishing companies, such as those centred around West 28th Street in Manhattan which became collectively known as "Tin Pan Alley". The third was the advent of ragtime.

Secondary dominants began to appear in the popular songs of the late 19th century. Early examples can be found in the compositions of James Bland in the 1870s, e.g. V/V featuring in "In the Morning in the Bright Light" (1879), and V/VI in "The Angels Am a-Coming" (1880). They

[12] Parlour music is a subset of European music that existed in the space between art music and folk music in the early 19th century, and which subsequently spread to the United States. Starr and Waterman not that parlour music in America consisted of "folk ballads, popular songs printed as sheet music, and various types of dance music [and it] established early on a kind of 'mainstream'" (Starr & Waterman, 2014, p. 17)

can also be occasionally found in marches of the turn of the century, such as a V/III featuring in "The Liberty Bell" (1893) by Sousa, and V/III and V/VI featuring an early ♭9 alteration in "American Patrol" (1885) by Meacham. The use of secondary dominants increased the number of dominant to tonic resolutions within a piece and thus the propulsive, functional nature of the music, creating increased energy. These chords became characteristic of ragtime, a vibrant energetic style rooted in dance. Ernest Hogan's "La Pas Ma La" (1895), generally considered to be the first ragtime composition, features V/V, V/II and a V/II/5th as a passing chord.

The most common turnaround in early ragtime consisted of a V7 in 2nd inversion leading to a V7 in root position. Examples can be heard in the Tom Turpin rag "The Bowery Buck" (1899) and May Aufderheide's piece, "Blue Ribbon Rag" (1910). Around the late 1910s, this chord progression began to be replaced by a variation with a V/V chord occurring in place of the V7 in 2nd inversion. This maintained root movement in fifths, but also increased the harmonic momentum and energy due to the addition of a secondary dominant. This progression can be found in much of the ragtime and early jazz of the late 1910s and early 1920s, such as Joplin's "Reflection Rag" (1917), Kid Ory's song "Ory's Creole Trombone" (1922), and Ed Andrews' "Barrel House Blues" (1924).

While some jazz recordings continued to feature the V/V-V-I turnaround, more progressive jazz artists began to transition to the IIm7-V7-I. Early examples may be heard in Louis Armstrong's Hot 7's recording of "Alligator Crawl" (1927), and on Benny Goodman's first recording date with Ben Pollack's Orchestra on "Louise" (1929). Broadway showtunes written by Tin Pan Alley composers such as Richard Rodgers and Cole Porter also began to use the IIm7-V-I, including Cole Porter's hit "I Get a Kick out of You" (1934) and Rodgers and Hart's "Blue Moon" (1934).

Jazz musicians of the 1930's began to further intensify harmony, increasing functionality and momentum, often in improvisational settings. In many cases this was achieved by adding additional secondary dominants, as well as related II chords, and thus increasing the number of local cadences in tunes. Examples can be heard in a comparison of Creamer and Layton's original tune "After You've Gone" (1918) with versions played by Fats Waller (1930) and Art Tatum (1935). Both pianists add dominant chords to the tune, Waller a secondary dominant V/II and Tatum sequences of dominant chords in fourths and semitones, greatly increasing the energy and momentum of the tune.

The functionality of jazz was also affected by the commercial nature of the Tin Pan Alley publishing companies that provided so much material to jazz artists. In the popular music of the

19th century, true to its European CP roots, A sections of songs were generally structured in periods, with a four-bar phrase ending in a half cadence followed by a four-bar phrase ending in a full cadence. The lyric was generally contained within this structure; the final phrase concluded with a full stop. The chorus would then begin on a I with a new phrase and new sentence in the lyric. This structure can be found in many of the popular songs of the mid-1800s; examples include several compositions of Stephen Foster, including “Angelina Baker” (1859), “Camptown Races” (1851),“Old Folks at Home” (1851), and “My Old Kentucky Home” (1853).

After the turn of the century however, a new convention arose, whereby the final lyric of the A section, rather than ending in a full stop and concluding the verse, began to “set up” the first line of the chorus (Tawa, 1990). This change may have come about because Tin Pan Alley songwriters were constantly under pressure to create what publishers referred to as “punch”: the elusive element that would make a song into a hit. The punch was often the first line of the chorus, which was also the title of the tune. Thus, songwriters would draw attention to the punch by creating a sense of anticipation leading into it, lyrically and melodically, giving the effect that “[t]he music has been intentionally left up in the air and demands continuation” (Tawa, 1990, p. 171). The nature of how tension and release, and thus the eliciting and meeting of expectations was beginning to change.

This was increasingly reflected in harmony. The full cadence which traditionally ended the verse was gradually replaced by an elongation of the dominant V chord, in order to increase anticipation into the “punch” on the first hypermeasure of the chorus, thus making the chorus more memorable to listeners. Examples of this practice can be found in many of the Tin Pan Alley songs of the early 20th century, such as “A Bird in a Gilded Cage” (1900) by Lamb and Von Tilzer, Ager and Yellen’s “Ain’t She Sweet” (1927), “All Alone” (1924) by Irving Berlin, and “Baby Face” (1926) by Akst and Davis.

This change had the effect over time of displacing the CP norm of concurrently resolving melody and harmony in the final bar of a section, resulting in more frequent cadential resolution into the first bar of a new section. Listeners’ expectations for cadential resolution would therefore become uncoupled from the hypermeasure structures that previously defined cadences. This practice would characterise 20th century popular music.

4.3.8. Melodic-harmonic divorce

Popular music often features a divergence between melody and harmony that is not typically found in CP music. This is a feature of much of the antecedent styles of popular music, such as parlour music, Tin Pan Alley repertoire, and blues. This separation is known as the melodic-harmonic divorce, a term coined by Allan Moore (1995). This phenomenon occurs when the pitches of a melody do not relate strictly to the underlying harmony. In the melodic-harmonic divorce there is no adherence to rules governing melodic stability and instability that are typically obeyed in CP music. This is in contrast to what Tymoczko describes as the "two-dimensional coherence, both harmonic (or vertical) and melodic (or horizontal)" (Tymoczko, 2011, p. 27) found in CP music. Melodies in popular music tend to follow pentatonic structures, rather than outlining harmony. Thus, the functionality of melody is reduced, which serves to reduce the overall functionality of popular music (Biamonte, 2010).

Temperley (2007) describes this phenomenon as a stratification of pitch organisation, whereby melody and chords are governed by two different frameworks. He demonstrates this through multiple examples of melodies in the pentatonic scale that feature unresolved non-chord tones in relation to the chord of the moment. This phenomenon may relate to how form is outlined in popular music. For example, within CP music, the length of a harmonic progression is determined by the length of its melody. However, in popular music it is the hook, riff, or chord progression that delineates the phrase length, and so the melody can be more ambiguous.

4.3.9. Extended voicings and substitutions in jazz

The chromatic alterations and extensions beyond the 7th that would later define jazz harmony began to appear in American music around the late 1910s and 1920s, likely as a result of the influence of 20th century European composers. The 9th and 13th began to appear on dominant chords in the songs of Tin Pan Alley and can be found as early as 1914 in Euday L. Bowman's "Twelfth Street Rag" (1914). Later examples of extensions to the 9th include Chris Smith's "The Camel Walk" (1925), and Irving Berlin's hit "Blue Skies" (1927). Berlin also featured extensions to the 13th in his standard "Always" (1925). Major 7th extensions were slower to appear, although an early example can be found in Green, Heyman, Sour, and Eyton's "Body and Soul" (1930).

Initially, chromatic alterations were centred on the V chord, with V7♯5 commonly found in blues and blues-based songs, such as in Handy's song "St. Louis Blues" (1914), Fats Waller's piano voicings on Sara Martin's recording of "Mama's Got the Blues" (1923), and Hoagy Carmichael and Mitchell Parish's "Stardust" (1927). "Stardust" also features an early example of a ♯11 over the IV chord. The ♯5 alteration on the V chord became very common in the standards of the early 1930s, featuring in Hoagy Carmichael and Stuard Gorrell's "Georgia on My Mind" (1930) and Simons and Marks "All Of Me", (1931). The ♭9 also became popular on the V chord; notable examples include the Monaco and McCarthy's hit "You Made Me Love You" (1913), Youmans and Ceaser's tune "Tea for Two" (1925), and Arlen and Koehler's "Stormy Weather" (1933).

However, it was not until the late 1930s that musicians and composers began to feature chromatic alterations on chords other than the primary dominant. These initially appeared on non-dominant functioning dominant chords, such as the IV7, ♭VII7, and were often ♯11s, which emphasised the overall key through their diatonicism. A ♯11 on the IV7 can be found in Carmichael and Parish's "Stardust" (1927), while a ♭VII7♯11 features in Irving Berlin's "Cheek to Cheek" (1935). Billy Strayhorn featured a ♯11 on a ♭II7 in his 1936 composition "Lush Life" (1991). Early examples of alterations on secondary dominants can be found on the pre-musicians strike recording of Charlie Christian at Carnegie Hall in 1939, and by the bebop revolution of the mid-1940s, altered dominants had become commonplace in jazz, as evidenced on Coleman Hawkins' album *Rainbow Mist,* recorded in 1994.

Chromatic chords such as tritone substitutions began to appear in the repertoires of jazz musicians in the mid-1930's. For example, Ella Fitzgerald's first recording date on Chick Webb's "Rhythm and Romance" (1935) features a tritone substituted V/II. Hoagy Carmichael's 1931 "Lazy River" (1931) features multiple chromatic passing dominant chords that give the effect of tritone substitutes. An even earlier example may be found in the sheet music of Fats Waller's 1929 standard "Ain't Misbehavin'" (1929). A possible precursor to the subV/II, featuring the same root movement, can be found in the common progression in early jazz arrangements I-♭IIIdim-II or I-♭IIIdim-V/V, found in the Earl Hines 1929 recording of "Good Little, Bad Little You".

By the time the recording embargo of 1944 had passed, tritone substitutions had clearly become part of the jazz lingua franca. They can be heard in many jazz recordings of the early 1940s, such as Coleman Hawkins' recording of "Woody 'n' You" (1944), Charlie Parker's recording of "Red Cross" (1944), and Ellington/Strayhorn's "Day Dream", as recorded by Johnny Hodges (1940).

Up until the 1950s, jazz improvisers and rhythm section players generally tended to use alterations and extensions as tensions to be resolved, particularly on dominant chords, rather than as suggestions of a new key. For example, bebop players usually either avoided the 9th on the IIIm7 chord or played a ♭9 as a passing note, rather than extending to the ♮9 and suggesting the dominant or supertonic key. Few of these extensions can be found on recordings prior to around 1955. Thus, although bebop is an extremely chromatic style of music, players generally stayed rooted to an overall tonic.

However, towards the end of the 1950s and into the 1960s, more musicians can be heard playing and emphasising non-diatonic extensions. For example, the ♮9th on the IIIm7 chord, which previously was rare, can be heard regularly in recordings post-1959. This demonstrates an important way in which jazz musicians began to extend tonalities in the post-bop era.

4.4. Expectation in popular music

The previous sections outlined the ways in which jazz and popular music differ from CP in terms of narrative, functionality, tonal frameworks, and harmonic language. This section discusses how these differences may lead to differences in how expectation and surprise function within jazz and popular music. As outlined in Chapter 2, the primary means of eliciting expectation and surprise in CP are through cadences and chromaticism, including modal mixture, and so this discussion will centre around those techniques.

4.4.1. Tonal frameworks and chromaticism

A strong and clear tonal framework is critical to the ability to categorise harmonies as either diatonic, i.e. within the framework, or chromatic, i.e. outside the framework. Thus, a strong and clear tonal framework is essential to the elicitation of surprise related to chromaticism. However, the previous section argues that tonal frameworks are not as clear cut in popular music as they are in CP. Greater freedom around the use of ♭7 and ♭3 due to the normalisation of blues complexes around the 3rd and 7th, the prevalence of chords such as the I7, IV7, ♭VI and ♭VII mean that the contrast between major, minor, and indeed modal frameworks is less sharp in blues-rooted music than in CP music. Ambiguity can also arise between the relative major and minor, or the parallel major and minor (Stephenson, 2002). As de Clercq states, "it is sometimes difficult in popular music to determine whether the tonality of a song is major or minor (or both or neither)" (de Clercq, 2021, para. 1.5). Due to the permissibility of both the natural and flattened 3rd and 7th, a wider range of tonal and modal frameworks are available than in common practice, and these frameworks are more malleable. In a corpus analysis of popular songs, Moore discovered that many chord progressions in rock music are modal, specifically using Mixolydian (♮3rd, ♭7th), Dorian (♭3rd, ♭7th) or Aeolian (♭3rd, ♭7th, ♭6th). Many songs modulate between modes (Moore, 1992).

Defining chromaticism in popular music thus becomes difficult. For example, the V chord, an unambiguously diatonic major key chord, functions as chromatic within a Mixolydian context. Many popular music songs feature both the V chord and the ♭VII chord; in this case, which, if either, chord will be perceived as chromatic, and thus surprising? Within a CP context, the ♭VI augmented 6th chord is unambiguously chromatic, presumably this chord is diatonic within a triad doubled system, but what happens when a triad doubled system is combined with a major key context, as is common in many popular songs?

4.4.2. Functionality

Tonal frameworks also fulfil a role in establishing functionality within a system. In CP, function has been strongly linked to expectation by both theorists (Terefenko, 2018), (Schoenberg, 1922/1978) and music cognition researchers (Sears et al., 2018), (Steinbeis et al., 2006). The previous section argued that functionality within popular music is reduced. This means that expectations associated with functionality may not have the same effects as they do in CP contexts. This is not to suggest that popular music harmony is necessarily devoid of function. Much popular music may indeed be functional, but in a way unrelated to the hierarchical scale tone characteristics and syntactical norms that underly CP functionality. Moore (1993) stresses that harmony in rock is only 'non-functional' in the sense that it does not necessarily evoke strong expectations for specific continuation.

Functionality in CP is related to global structures and narrative, and in local contexts derives from the leading-tone, whose resolution to the tonic characterises the cadence. The leading-tone is found in both the major and harmonic minor key contexts that characterise CP music. Biamonte notes the lack of leading tone in many popular music pentatonic and blues-based frameworks, such as those that include the ♭VII as described above, and the resulting reduction in CP-type functionality. She also points to the influence of modalism on this reduction, given the similar lack of leading tone in most modal contexts, including that of the natural minor, or Aeolian:

> Harmony in rock has been described by several commentators as less directional or functional than in conventional tonality, which is due in no small part to the prevalence of pentatonic, modal, and blues-based structures, and the corresponding lack of a leading tone in many styles, deriving from their roots in both the blues and the modal-folk revival. (Biamonte, 2010, p. 95)

CP functionality is rooted in a chordal hierarchy that elevates the V and I chords above all other diatonic chords. However, evidence for non-hierarchical chord relationships in blues can be found in the elevation of the subdominant chord to a position structurally equal to the dominant, likely due to early blues guitar tuning and fretting techniques. Nicholas Stoia says that "[t]he IV chord rarely functions as a pre-dominant, but instead usually functions as a true subdominant, and more often than not leads back to the tonic." (Stoia, 2010, para. 16). Thus, two fundamental elements of goal-directed CP harmony, i.e. the resolution of the leading tone to the tonic found within the V-I cadence, and the use of IV as a pre-dominant chord, subordinate to the dominant it prepares, are significantly deprioritised in blues music. Given that the V-I cadence is the primary expectation-related element of CP music, this has substantial implications for how expectation functions within blues and styles influenced by the functional and narrative characteristics of blues.

Theorists have suggested that within modal systems, chords may derive some elements of functionality based on their chord tones. Biamonte (2010) models chord function in terms of chord tones, following Agmon's model. This theory is based on the idea that subdominant-functioning chords contain one or both of the scale tones surrounding the 5th, thus creating a pull towards the 5th, while dominant-functioning chords contain one or both of the scale tones surrounding the root, for the same reason. Biamonte contends that modal triads such as the ♭II, ♭III, ♭VI, and ♭VII can be included in Agmon's functional model.

> Tonics contain scale-degree 1 and/or some form of 3, subdominants contain forms of 4 and/or 6, the adjacencies above and below the dominant degree 5, and dominants contain forms of 7 and/or 2, the adjacencies above and below the tonic degree 1. Doll has observed that in pentatonic systems, in which the two sizes of scale step are major second and minor third, the adjacencies above and below the tonic that suggest dominant function could also be ♭3 or 6; similarly, the adjacencies surrounding the dominant are 3 and ♭7 (Biamonte, 2010, p. 97)

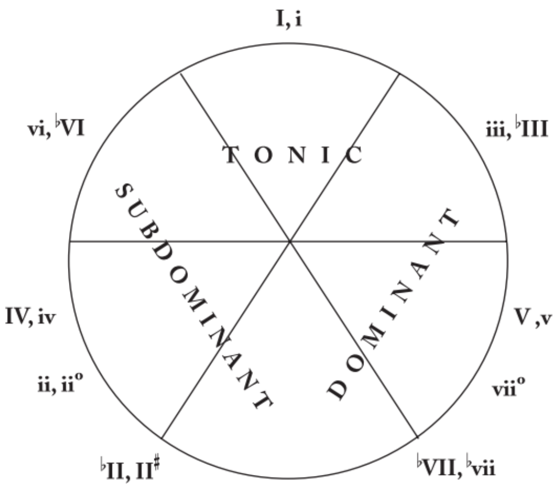

Fig. 26: Biamonte's functional model
(Biamonte, 2010, p. 96)

Tagg (1982) has focused on the role of chord function within what he refers to as chord shuttles and chord loops. Chord shuttles consist of a continuous back-and-forth between two chords, while chord loops consist of repeated loops of three or four chords. These patterns are ubiquitous within popular music, as Tagg demonstrates with exhaustive lists of examples.

A traditional functional analysis of a shuttle would generally apply tonic, dominant, and/or subdominant functions to the chords of the shuttle. For example, a commonly found shuttle between a minor chord and a major chord an ascending fourth apart would likely assign subdominant (II) and dominant (V) functions to these two chords, implying a recurring unmet need to resolve in each iteration of the shuttle. Therefore, this analysis suggests that tension will dominate the progression. However, Tagg points out that this is not the case perceptually. Rather than either of these chords “pointing” elsewhere, i.e. to a tonic, neither “points” anywhere, and so instead of being thought of as a process, they should be thought of as a state or condition. Tagg gives an example with reference to the Eddie Cochran song “C’mon Everybody”, and highlights the inefficiency of traditional analysis methods in describing this song.

> The Cochran tune’s chords are simply I, IV and V in E, but V (B) *is no dominant and* IV (A) *no subdominant* for two reasons: [1] return to the tonic (E) is not from a supposed ‘dominant’ on B (V-I) but from IV; [2] the Cochran B (V) chord occupies only two of the loop’s 16 beats while A (IV) occupies six and E eight. This means that in terms of both duration and cadential function IV (A) is more ‘dominant’ and V (B) more ‘subdominant’, so to speak. Still, switching the meaning of those two terms of euroclassical theory to cater for

other harmonic realities, although illustrating a valid point, would cause even more confusion. (Tagg, 2014, p. 414)

Tagg suggests a model which replaces traditional functional labels of dominant and subdominant with the terms outgoing/departure chord, medial chord, and incoming/turnaround chord to describe harmonies within chord loops. He explains the terms thus: outgoing/departure refers to the first chord after the tonic, medial refers to the chord placed after the outgoing chord, and incoming/turnaround chord refers to the last chord before the tonic is reprised.

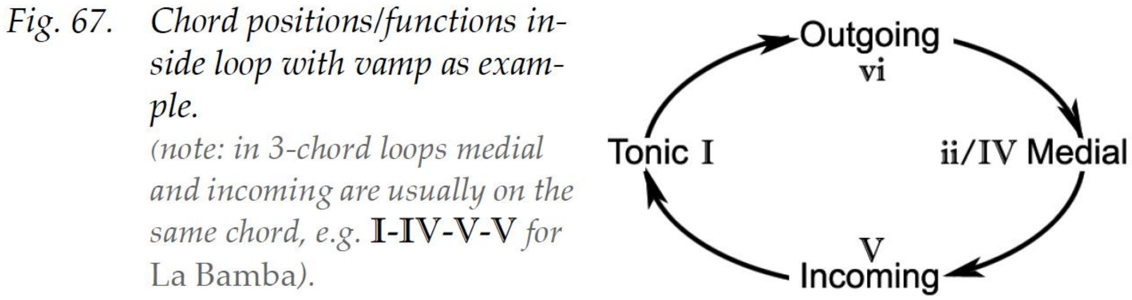

Fig. 27: Tagg's chord loop functions
(Tagg, 2014, p. 413)

Tagg argues for this model by explaining that chords within these loops rarely function according to their traditional labels due to their placement within the hypermeasure. As with shuttles, these progressions are generally perceived as a state rather than a functional process. He gives an example of the common blues-based progression I-IV-V-IV-I, where the dominant and subdominant chords are reversed in relation to their traditional placement. Describing these chords in terms of their perceptual effects instead of by traditional monikers will more accurately outline their functions.

A similar syntactical system to Tagg's is proposed by Nobile, who says that "the syntactical role of the dominant . . . is often played by chords unrelated to V, such as IV, Im, ♭VII, or even versions of I" (Nobile, 2016, p. 149). Thus, Nobile notes that a "theory of harmonic function rooted in theory category – e.g. ascribing dominant function to any chord related to V – inadequately accounts for rock's harmonic organisation" (Nobile, 2016, p. 149). Like Tagg and Doll, he argues to separate out harmonic function from chord identity, unlinking dominant function and V. This is because popular music "does not exhibit the same coordination between chord identity and syntactical role that does common-practice tonality" (Nobile, 2016, p. 151).

Nobile roots his theory in what he calls the functional circuit: a chord progression perceived as a single unit that cycles through tonic, pre-dominant, dominant, tonic. He argues for separation of dominant as a category (V-related) and dominant as a syntactical function (pre-closure), given that in rock music they are not as tightly coupled as in CP music.

Christopher Doll (2017) has argued to separate harmonic function from chord identity altogether in rock music, unlinking dominant function and the V chord. He maintains that the Riemannian method of assigning the same function to chords containing related scale tones is flawed when used in a popular music context. This is because it is predicated on the idea that chords containing the required notes will sound perceptually similar to each other, and that chords in different functional categories will sound perceptually contrasting. However, Doll argues that this is not the case in rock music. He gives an example of a chord perceived as leading to a I chord resolution, and sounding perceptually similar to a V chord, that yet is not a V. Both chords elicit an expectation for I however, and therefore should be categorised together. He contends that it is the eliciting of the expectation for I that justifies these chords being grouped together, rather than the notes they contain:

> Dominant as a scale degree and as a function are historically linked, yet if we are thinking of dominant function as a category of pre-tonic function and not as a label indicating the scale degree of the chordal root, we should label a chord a "dominant" if, and only if, its effect is one of anticipating another more stable sonority that contains the centric pitch class. (Doll, 2017, p. 26)

Therefore, Doll argues for a system of functions based on predictions instead of the inclusion of given tones. Rather than labelling chords as subdominant or dominant, Doll prefers the term "pre-tonic" to label any chord that "pre-dicts" the I;

> Pre-tonic harmonies project the desire to move from their own scale-degree voices to those of the forecasted tonic, and these expected motions correspond to pre-tonics' distinctive qualities . . . . Dominants and subdominants are thus distinguished from one another not simply because they feature dissimilar scale degrees, but because there is a qualitative difference in their anticipated voice leading, in their projected scale-degree motions to tonic. (Doll, 2017, pp. 29-30)

Thus, Doll places perceptual effects at the heart of his conception of function. The only difficulty that arises from this is reliance on personal judgements of perceptual effects. Through an investigation of the perception of function among the general population, functional analysis methods that are unable to account for the differences between CP and popular music can be replaced by idiomatic analysis systems based on empirically verified accounts of the harmony of popular music.

4.4.3. Narrative

Tagg contrasts the long-term musical unfolding that occurs in CP forms with what he refers to as the 'extended present' as experienced in popular music. Tagg's extended present is of a duration roughly equivalent to no more than that of a music phrase, and is perceived "as 'now' rather than an extended sequence of musical ideas" (Tagg, 2014, p. 488). He notes that

> [c]onventional approaches to music analysis in the West may serve some use in helping us appreciate how a sense of narrative works in sonata form ('diataxis', the 'extensional' aesthetic), but they have done very little to help us understand other equally important aspects of form that exist inside the extended present ('syncresis', 'intensional' aesthetics). (Tagg, 2014, p. 12)

Tagg borrows the terms "intensional" and "extensional" from Andrew Chester (1990) who first used them to describe this fundamental difference between classical music and popular music. Chester notes that Western classical music, being extensional, develops outward from simple, unaltered musical units, to form a complex whole. For example, a large-scale sonata form may be built outwards from a combination of (relatively) simple themes. CP music theorists speak of differentiation between temporary, local tonics and global tonics in 18th and early 19th century art music. This is exemplified in the sonata form model, where multiple modulations may occur during the development, only to defer to the global opening tonic during the recapitulation. According to Schenker, these temporary modulations are hierarchically weaker than the return to the tonic and represent a short-term deviation from the overall tonality, or Stufe. Analysis methods by theorists such as Schenker and Lerdahl imply that listeners will experience a return to the opening tonal centre as a tonal closure, i.e. that they will retain a sense of the original tonality and experience modulation back to that key as a return. It can be inferred from this that a lack of return will be experienced as a lack of closure.

However, this is not the case in popular music. While 18th and 19th century composers used tonality to convey large-scale structure, contemporary songwriters often use texture, timbre and dynamics instead (Biamonte, 2017). Often, modulations in popular songs never return to the tonic. In this case, do listeners continue to 'expect' a return to the original tonality? Do they experience the new tonic as hierarchically equal or subordinate to the original key? Is tension increased past the point of the modulation? Or, as is suggested by recent cognitive studies, do listeners simply reframe the music within the new key and experience it as a stable tonality with no reference to any other key? (Marvin & Brinkman, 1999)

Rock and other non-European musics often develop intensionally, not by combining simple units into a complex whole, but by developing a simple whole by combining increasingly complex units. Chester gives an example of a blues musician improvising (complex units) over a repeated strophic 12-bar blues form (simple whole). Thus, the listener experiences the development of the music in Tagg's extended present (simple whole), rather than in the long-term (complex whole).

Theodor Adorno has claimed that this difference in narrative structure and temporality between the styles affects how it is perceived. He notes that in classical music "every detail derives its musical sense from the concrete totality of the piece" (Adorno, 1941, p. 19), but with popular music "the listener becomes prone to evince stronger reactions to the part than to the whole. His grasp of the whole does not lie in the living experience of this one concrete piece of music he has followed" (Adorno, 1941, p. 18). Adorno was highly critical of popular music because of this. He claimed that its reliance on standardisation and repetition meant that its value lay in the extent to which it "distracted from the demands of reality by entertainment that does not demand attention" (Adorno, 1941, p. 37).

Mark Abel points out, however, that Adorno may be elevating the mode of listening required by Western art music to an ideal. He points out that art music is not unique in requiring long-term comprehension, given that "[m]ost kinds of music require the use of memory for their appreciation just as the comprehension of a sentence requires that the beginning of it is held in the memory while its end is spoken" (Abel, 2014, p. 182). In his view, there is an intrinsic dissociation between the composer and listener as a result of this kind of representative large-scale musical narrative. Popular, groove-based, music, in contrast, allows for an immediate interactivity.

4.4.4. Cadence

The perception of a chord or harmonic progression is not only influenced by its tonal elements and context, but also by where it is placed within a phrase structure, which is related to hypermeasure.

The effect of this phenomenon is felt most strongly with cadences. The phrase structure of much CP music tends to fall into a pattern of periods and sentences, whereby cadences, whether they are open or closed, usually fall within the final bar of the hypermeasure (Aldwell et al., 2011). However, the harmonic-melodic divorce in popular music has led to a decoupling of melodic and harmonic cadence, creating a tendency for melodies to extend past the hypermeasure on which they began. In addition, alterations in phrase structures intended to increase anticipation for the "punch" at the top of the chorus, innovated by Tin Pan Alley songwriters at the turn of the 20th century, have led to the displacement of resolution from the last bar of the hypermeasure to the first. Stephenson points out that this has become commonplace within 20th century rock: "In many songs the V chord may end most or even all units" (Stephenson, 2002, p. 20). This contrast between CP and popular music may be seen in the examples below.

Fig. 28: Example of cadence onto weak hypermeasure
(*Mozart Piano Sonata K.331, I*)

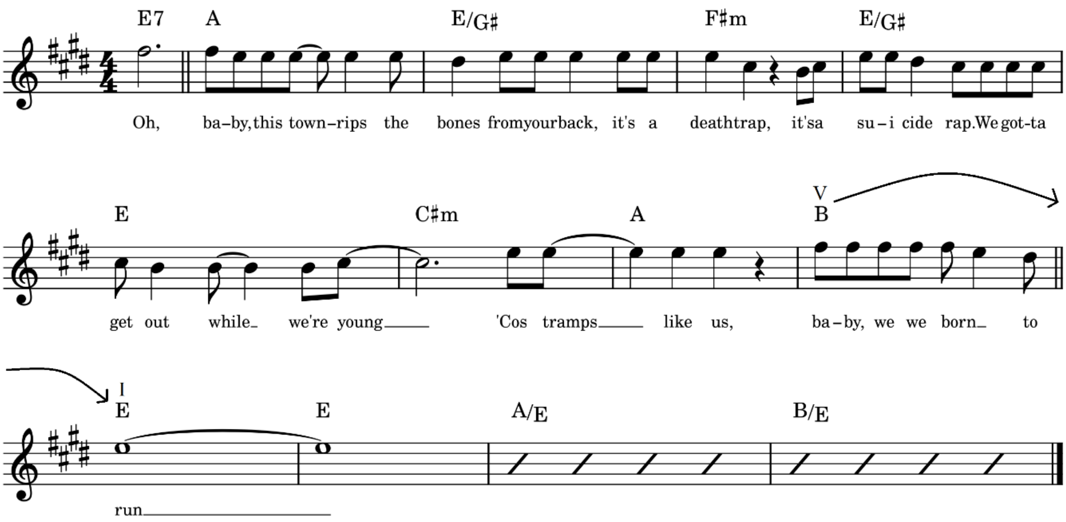

Fig. 29: Example of cadence onto strong hypermeasure
(Bruce Springsteen, "Born to Run", 1975)

In addition to alterations to the placement of cadences within hypermeasure, theorists have noted that, as Nobile put it "it is not uncommon to find rock songs that use IV, ii, ♭VII, or some other chord [cadentially to lead to a tonic]" (Nobile, 2016, p. 151). For these reasons, it is difficult to define cadences within popular music. According to Temperley, "[i]n rock, there is no consensus as to what the term "cadence" means; it is clear that there is no mandatory cadential gesture analogous to the perfect cadence of classical music." (Temperley, 2018, p. 61)

Theorists have considered how cadential harmonies function within the repetitive structures common to popular music. Many repeated harmonic patterns, such as the ubiquitous axis progression VIm-IV-I-V, and the popular turnaround I-VIm-IV-V, feature authentic or deceptive cadential harmony at the juncture of the hypermeasures. Often in these cases the melody will also cadence on the first beat of the hypermeasure. Do listeners thus perceive these progressions as cadences, either deceptive or authentic, if they are not linked with a resting point, but rather a starting point, if, as Stephenson notes, the "tonal resolution provided by the harmonic formula . . . does not line up with the metrical resolution" (Stephenson, 2002, p. 20). Stephenson continues, noting that many rock songs never resolve in a traditional cadential manner, but instead consist of

> overlapping propelling gestures. During the last measure of a four-measure unit, the standard time for closure in traditional music, harmonic forces, and sometimes melodic forces . . . carry the music into the next measure. . . . This next measure, however, does not represent a point of metrical repose: the

> hypermetrical downbeat in its turn implies the succession of three more measures. (Stephenson, 2002, p. 21)

This phenomenon is particularly important for the study of expectation. Cadence is invariably the musical technique mostly clearly linked with expectation, and most discussed by those working in the area of expectation. In CP music, the listener often hears the effect of a dual expectation resulting from two different kinds of cadences, melodic and harmonic, converging on an expected point at the end of a hypermeasure, and preceding a point of closure. In popular music, however, both melodies and progressions tend to cadence into the next hypermeasure. Thus, expectation occurs at the end of the hypermeasure and anticipates not a rest, but the beginning of a new unit. The harmonic closure traditionally associated with a hypermeasure is denied. This is likely to have a marked effect on listeners' experiences of closure and expectation. Temperley summarises the primary difference between CP and popular music cadences in terms of expectation:

> when a section in a rock song ends on non-tonic harmony (again, in a distinctive gesture that is not part of a repeating pattern), the effect is not so much of closure but of an increase in tension and anticipation for the move to tonic (Temperley, 2018, p. 63)

4.5. Expectation in jazz

4.5.1. Tonal frameworks

In contrast to popular music, overall tonal frameworks in jazz prior to the post-bop period are relatively unambiguous. Modality did not become commonplace within jazz until the release of Miles Davis's *Kind of Blue* in 1959, and most jazz standards derived from the Broadway/Great American Songbook repertoire are essentially either major or minor. Despite this, there are several important differences between jazz and CP harmony. For example, blues harmony has had a profound influence on jazz tonality, while the nature of jazz as an improvised music has led to changes in narrative structures. In addition, although jazz is rooted in the same fundamentally major and minor frameworks as CP, it is extensively chromatic, and its fundamental harmonic structures extend to the seventh. Given the strong links between all of these factors and the perception of expectation and surprise, it is therefore likely that expectation and surprise function differently in jazz than in CP.

Contrasts also exist between jazz and popular music. Jazz, pre-1959, is primarily functional (Mulholland & Hojnacki, 2013). According to David Baker, when listening to jazz "the ear is more apt to hear function than actual quality. That is, if the chord operates from within the proper place in the II-V-I formula, the listener hears it as the proper chord" (Baker, 1988, p. 120). Short-term functionality may be elevated in jazz as a result of numerous secondary dominants in the standard repertoire, resulting in near-constant "mini-cadences". Steven Strunk describes jazz as having "at the foreground level a strong sense of forward motion: series of unstable chords seem to push forward toward relatively stable harmonic goals which often initiate further progressive movement toward new goals" (Strunk, 1979, p. 7). However, due to the cyclical, exploratory, and improvisational nature of jazz forms, where narrative is primarily structured around the melodic, rhythmic and textural flux of a multi-chorus improvisation, large-scale narratives based on functionality such as those found in CP are unlikely to occur regularly in jazz standard repertoire forms.

In 1982, Kenneth Stanton published *Jazz Theory: A Creative Approach.* Stanton's work, inspired by that of Strunk, is notable in that he appears to be the first jazz theorist to attempt to explain the many chromatic chords found in jazz within a cohesive system grounded in a simple diatonic foundation. Stanton is also innovative in that he may be the first jazz theorist to incorporate listeners' experiences, specifically those related to expectation, into his methodology. Speaking of deceptive resolutions, Stanton says

> [o]ne of the most effective harmonic devices is the <u>Deceptive Cadence</u>. Most simply defined, it is a technique that allows the flow of harmony to lead away from an expected resolution.
>
> The Deceptive Cadence deceives. It is used to fool the listener. The listener <u>expects</u> a <u>logical resolution</u>. In jazz, the technique is most often employed to <u>delay</u> the final ending and add depth and emphasis to a melody, harmony, and often, a lyric. (Stanton, 1982, p. 185)

John Mehegan describes the fundamental tonal framework of jazz as "diatonic or major scale harmony" (Mehegan, 1984, p. 6). Mehegan created a model of jazz harmony with a fundamentally diatonic major/minor key tonality, but inclusive of a great variety of chromatic chords, with the justification that these are simply variations on the seven diatonic chords. According to Henry Martin, Mehegan

> codified much of what is now taken for granted in jazz theory . . . seventh chords are normative . . . Roman numeral designation to simplify description of function . . . five seventh chord qualities . . . seven diatonic modes, [relating] chord types of scales and modes. (Martin, 1996, p. 8)

Since then, this conception of a major/minor tonal framework, with multiple different methods of introducing chromaticism has become the norm within jazz theory. This is in contrast to popular music, where the key and chromaticism are often ambiguous.

This conceptualisation of jazz tonality has much in common with that of Riemann, whereby both diatonic and chromatic elements may exist with reference to an overall tonic. Riemann, in his *Musik-Lexikon*, declared the modern conception of tonic as that which "passes far beyond the limits of harmony as represented by the scale" (Riemann, 1882/1896a, p. 796). Riemann gives an example of a progression consisting of chromatic mediants and notes that the succession of chords "in the sense of one key is not possible according to the older system of harmony, although no one could deny that the ear receives it as such" (Riemann, 1882/1896a, p. 796). Riemann was primarily referring to chromatic relations in thirds in his concept, while contemporary jazz theory allows for a broader range of chromatic chords. However, jazz theory similarly conceives of chromatic elements as related to the established tonic, rather than as suggestive of a modulation or tonicization. Wayne Naus goes so far as to suggest that chromatic elements, which he refers to as "diatonically related chords", may help to establish the overall tonic: "[t]he key becomes established through the use of a number of 'grounding' elements, including diatonic melody, diatonic and diatonically related chords" (Naus, 2004, p. 20).

Steve Rochinski, in his book *Harmony 4*, part of the series of four textbooks that make up the core Harmony curriculum of Berklee College of Music and its associated schools, categorises all functional jazz harmony into three groups. The first of these is diatonic harmony, which comprise diatonic chords of the given tonality. The second is diatonically related harmony, as referenced above by Naus, which Rochinski defines as "chromatic alteration of diatonic chords or borrowing diatonic chords from a parallel system . . . chords that . . . progress or resolve to a diatonic or another diatonically related chord" (Rochinski, 2001, p. 113). Rochinski's third category is non-diatonic harmony, which he defines as "[c]adential chords or patterns that do not fit into the two previous categories and that do not create the expectation of resolving to a new I chord" (Rochinski, 2001, p. 113). He lists extended dominants (cycle of fifths progressions) and non-diatonic related II chords as examples of this kind of harmony.

The most notable feature of the latest conceptions of jazz harmony, such as Steve Rochinski's *Modern Jazz Theory and Practice* (Rochinski, 2022), Darius Terefenko's *Jazz Theory: From Basic to Advanced Study* (Terefenko, 2018), and the most recent editions of the Berklee Core Harmony curriculum textbooks (Mulholland & Hojnacki, 2015), is that they explicitly link function in jazz to prediction and the meeting or thwarting of expectations. As Terefenko puts it, "[c]hords from each functional family create certain expectations and display behavioral patterns" (Terefenko, 2018, p. 30). This means that the capacity of a chord, whether diatonic or chromatic, to manipulate expectations can be determined through analysis of its relationship to the tonal centre, which persists at all times.

4.5.2. Chromaticism

Rochinski (2001) cites secondary dominants, tritone substitutes, and modal interchange chords as chromatic, but diatonically related. These chords therefore potentially have the ability to elicit surprise.

4.5.2.1. Secondary dominants and tritone substitutes

Of the many chromatic elements in jazz, the most common are secondary dominants. "Jazz, excluding some avant-garde styles . . . makes considerable use of secondary dominants" (Benward & Saker, 2009, p. 299). "Secondary dominants are an important harmonic function in jazz language" (Mulholland & Hojnacki, 2013, p. 39). While earlier jazz theories such as Stanton's emphasised the surprising sound of the non-diatonic nature of secondary dominants, Berklee theorists emphasise instead their propensity to elicit expectation for resolution, and surprise if that resolution is thwarted: "Secondary dominants are dominant chords that create an expectation of resolution down a fifth to a diatonic chord" (Mulholland & Hojnacki, 2013, p. 39). "[They] generally resolve directly to their target chords, but deceptive resolution is also possible . . . the function and/or the quality of the chord of resolution will be *something other* than expected" (Mulholland & Hojnacki, 2013, pp. 47-48).

There are two important points to be made regarding how secondary dominants and jazz functionality might affect expectation. The first is that the prevalence of secondary dominants increases the harmonic rhythm and thus the complexity of the music. Given that complexity, predictability, and preferences have been shown to be linked (Orr & Ohlsson, 2005) (Lisøy et al., 2022), this raises questions as to whether this increase in dominant functioning chords results in expectations being elicited at a much higher temporal rate than in CP or popular music, and, if so, whether music listeners find these increases to be pleasant or unpleasant.

> Secondary dominants are strongly key-related. Their function is to draw the listener's attention to a diatonic chord by advertising its arrival. Their use does *not* mean we have left the key, even temporarily. If anything, the sense of relief associated with the normal resolution of a secondary dominant only reaffirms the original key identity. (Mulholland & Hojnacki, 2013, p 39)

Another point can be made in relation to the extent to which these secondary dominants, and the related II chords which usually accompany them, tonicize other keys. This question is related to the dichotomy between the primarily diatonic chord-scale theory expounded by Berklee theory, and the non-diatonic chord-scale theory expounded by Jerry Coker and Jamey Aebersold's pedagogical systems. According to Berklee theory, the chord-scale, that is the scale that consists of the relevant chord tones and extensions, for any secondary dominant is the one most diatonic to the overall key, i.e. Mixolydian ♭13 for a V/II, Mixolydian ♭9♭13 for V/III. In addition, the primary scales for the related II chords for these secondary dominants are the diatonic choices, e.g. Phrygian for the related II chord of V/II, Aeolian for the related II chord of V/V. The altered extensions in these chord scales will emphasise the overall key.

However, Coker and Aebersold's methodology advocates for Mixolydian to be used over any secondary dominant, and Dorian on its related II. This method of improvisation is summarised by Jerry Coker:

> a major scale [is] used for the M7 chord, a Dorian Mode for m7 chords, and the Mixolydian Mode for the 7 chord (Coker, 1964, p. 39)

Within this simple explanation, Coker makes a crucial point about the nature of jazz harmony, and its departure from CP norms, through his advocating for non-diatonic chord scales. By recommending "Dorian-Mixolydian" pairings on all m7-7 pairings a fifth apart, he is emphasising an inherently chromatic way of thinking about chord changes and improvisation. A m7-7 progression therefore, instead of being conceived of as a diatonic m7 chord paired with a secondary dominant, is thought of as a brief excursion into a new tonality, and that new tonality should be emphasised by the improviser by playing extensions (non-chord tones) rooted in the key of the new tonality rather than the old. This results in a system of tonicisations akin to Weber's (1817/1846) conception of secondary dominants as brief modulations.

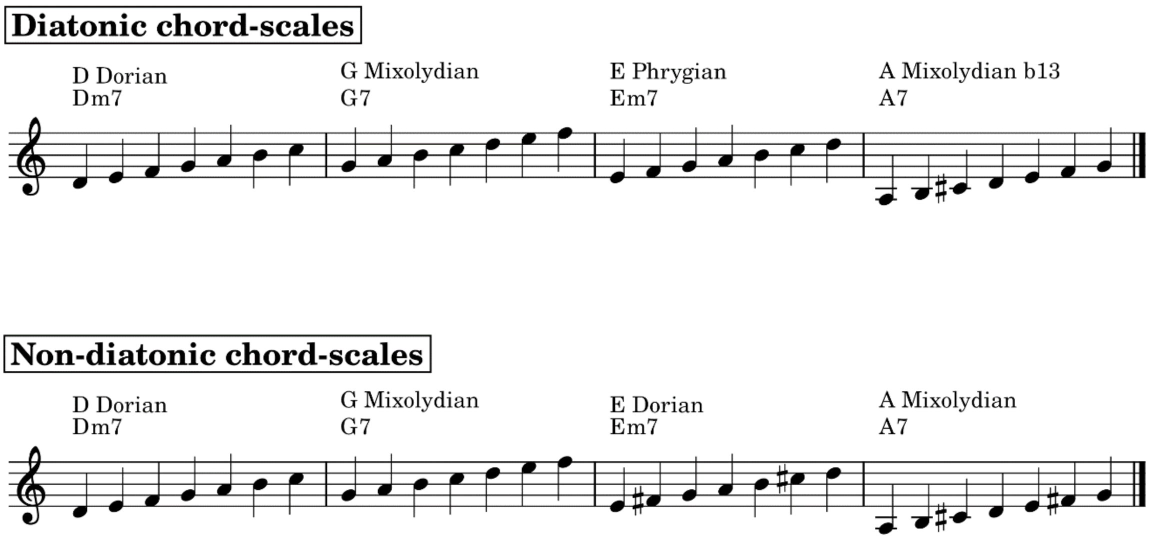

Fig. 30: II-V-III-VI progression with diatonic and non-diatonic chord scales

Steve Rochinski notes the effect of using non-diatonic extensions on expectation in *Modern Jazz Theory and Practice*, suggesting that an improviser or rhythm section player can confirm or thwart the perception of a given tonality through their use of diatonic or non-diatonic extensions. “Harmonic tensions create a powerful verifying or denying influence on tonal centers” (Rochinski, 2022, p. 5). It is likely that an emphasis on the parent keys of the secondary dominants would also further increase complexity, given that this would likely generate expectations for tonicisations which would most often not be met. This would raise further questions about whether this results in the perception of multiple deceptive resolutions for listeners, an increase in complexity, or an increase in pleasantness/unpleasantness. Meyer has pointed out that excessive chromaticism in late Romantic art music may have had the effect of reducing its deceptive effect:

> [I]n the nineteenth century chromaticism becomes an almost indispensable resource of composers, and one can find it at work on all levels of the musical organization-in the melodies, their harmonization, and in the construction of the musical periods, sections, and tonal structures. Indeed, it can be argued that its extravagant and prodigal use served, in the last analysis, to weaken and destroy its effectiveness because it tended to become normative within the style. (Meyer, 1956, p. 222)

Could an argument be made that the same occurs within jazz?

Stanton acknowledges the ability of substitute chords, such as the tritone substitutes described in the previous section, to thwart listeners' expectations. "During a jazz chord progression, many chords that are often unexpected may take the place of chords that are normally anticipated. These so-called unexpected chords are called Substitute chords" (Stanton, 1982, p. 101). These chromatic chords violate the expected continuation of the current diatonic context and thus may be perceived as surprising by listeners. Given that these chords feature roots built on chromatic notes, their perceived surprise level is likely to be higher than that of secondary dominants, which feature only one or two chromatic chord tones. In contrast to secondary dominants, however, tritone substitutes are unlikely to function as precipitators of deceptive resolution, as the rarely resolve any other way than down a semitone, as expected.

4.5.2.2. Blues chords (Special Function Dominants)

Early jazz theorists such as Mehegan consider "blues harmony" and "jazz harmony" to be separate and distinct, with the first contained strictly within 12-bar blues forms and variations on them. According to Mehegan "[t]o a jazz musician, the blues means a fairly fixed set of chords or "changes" (Mehegan, 1984, p. 146). However, more recently, theorists have begun to acknowledge the part played by blues harmony within the fundamental language of jazz, and its perceptual effect as chromatic or diatonic depending on context. The use of blues harmony within major key contexts and non-blues forms is a significant feature of the hard-bop era of the 1950s, where many composers, such as Horace Silver, Charles Mingus, and Thelonious Monk made blues chords part of their fundamental tonal language.

As outlined in the previous section, the structures that most differentiate the blues from the major/minor system are the I7 chord, which appears to have evolved from the use of the V/IV, and the IV7 chord, found as a dominant 7th structure from the earliest blues and likely derived from the combination of the ♭3 melody note and the IV triad. Other non-CP chords found consistently throughout recordings of early blues include the ♭VII and the ♭VI.

These chords also appeared within the traditional forms of contemporaneous ragtime tunes and popular songs, where their blues origins can be assumed given the blues-related titles of many of these songs, and later in many bebop jazz standards. In these situations, these chords are borrowed from their native blues contexts and transplanted into major/minor key contexts in a kind of blues modal interchange. Mulholland and Hojnacki emphasise the colourisation effect of this system of modal interchange, stating that "IV7, the blues subdominant, is an integral part of jazz language and is widely used or substituted in major key progressions where a bluesy flavor is desired" (Mulholland & Hojnacki, 2013, p. 236). Assuming that these chords were and are perceived as diatonic to a blues context, their transplanting into a major key context would introduce chromatic notes, such as the ♭7, ♭3, and ♭6, and therefore these chords may be perceived in such contexts as chromatic. This is the perspective taken by Berklee theorists, who categorise these chords as a type of Special Function Dominant (SFD).

The SFD categorisation appears to come from Stanton's categorisation of Special Case chords, within which he lists the IV7 and ♭VI7 chords and defines their sound as blues based.

According to Stanton,

> [a] <u>special</u> <u>case</u> must be considered at this point. Without going into the historical background, musical form and overall importance of what "<u>Blues</u>" means to jazz, there is a <u>Sub-Dominant</u> type chord that has come from Blues music. It is a <u>Dominant</u> <u>Seventh</u> chord which has its root based on the <u>Sub-Dominant</u> (IV) degree position. . . . It <u>does</u> <u>not</u> <u>function</u> as a <u>Dominant</u> <u>Seventh</u> chord however—its tritone is virtually ignored . . . . Normally . . . it will precede the Tonic chord. (Stanton, 1982, p. 137)

Thus, in contrast to Mehegan, Stanton acknowledges the influence of blues harmony within the context of diatonic major tonalities. Stanton expands on this to include the ♭VI7:

> If ♭<u>VI7</u> moves <u>directly</u> to the <u>Tonic</u> (I or Im), it assumes a "<u>special</u> <u>case</u>" status not unlike the "Blues" IV7. Its tritone is ignored and accordingly, the chord's function as a Dominant Seventh chord is never fulfilled. This is an example of chord color usage that is so artistically inherent in jazz. (Stanton, 1982, p. 141)

Ulanovsky in the Berklee harmony textbook *Harmony 4* defines SFD chords as dominant chords without dominant function, describing the blues-derived chords I7 and IV7 as such: "I7 in the blues sounds like the tonic chord, and IV7 sounds like the subdominant chord" (Ulanowsky, 1988, p. 8). In Rochinski's 2001 updated version of *Harmony 4*, he expands on this topic, referring to "[d]ominant 7th chords without dominant function [with] no expectation of resolution down a perfect fifth or down a half step" (Rochinski, 2001, p. 33), noting that these chords had previously been termed SFDs. Barrie Nettles in *Harmony 2* acknowledges that the transplanting of these blues chords into the parallel major and minor key is common within jazz: "the blues chords I7 and IV7 have become commonly used in major and minor key progressions" (Nettles, 2007a, p. 51).

In terms of the ♭VI7, often found in delta blues and concurrent popular songs as part of a minor turnaround, Ulanowsky describes this as potentially having a tritone substitute dominant function, but on resolving directly to I, a special function. He maintains that this chord is derived from the $^{+}6$ of 19th century Classical harmony. This is supported by the examples described in the first half of this chapter, demonstrating clear links between the $^{+}6$ and the ♭VI and ♭VI7. Ulanowsky does not elaborate on this claim, but it is clear that as this chord evolved, it became less and less inhibited by the CP strictures that reduced its function to a pre-dominant voice-leading structure. Once this chord had been treated by blues, jazz, and Tin Pan Alley composers, its functions widened, enabling it to act as part of a turnaround, as a chromatic colour chord, as part of triad doubled systems, and as a fundamental part of the tonal language of blues.

Rochinski adds two "blue note rooted" chords to the list of SFDs in his updated *Harmony 4*,, in the ♭III7 and ♭V7, with the justification that these are structures often found in contemporary blues contexts that "move as parallel structures to any other chord, especially I and IV" (Rochinski, 2001, p. 41). In *The Chord Scale Theory and Jazz Harmony,* Barrie Nettles and Richard Graf describe the ♭VII7 as a blue note rooted chord, maintaining that although this chord is "most often a modal interchange/subdominant minor chord . . . [it] may sound and function as [a] diatonic blues chord" (Nettles & Graf, 1997, p. 123).

It is likely that there are overlaps between Berklee's categorisation of blues-rooted SFD chords, and the triad-doubled systems that many popular music theorists have described as derived from the use of sliding bar chords by Delta blues guitarists. For example, in Björnberg's pentatonic system he roots triads on the notes of the minor pentatonic scale; thus his system almost fully overlaps with Nettles and Graf's blues-based SFD chords based on the roots of Aebersold's "blues scale".

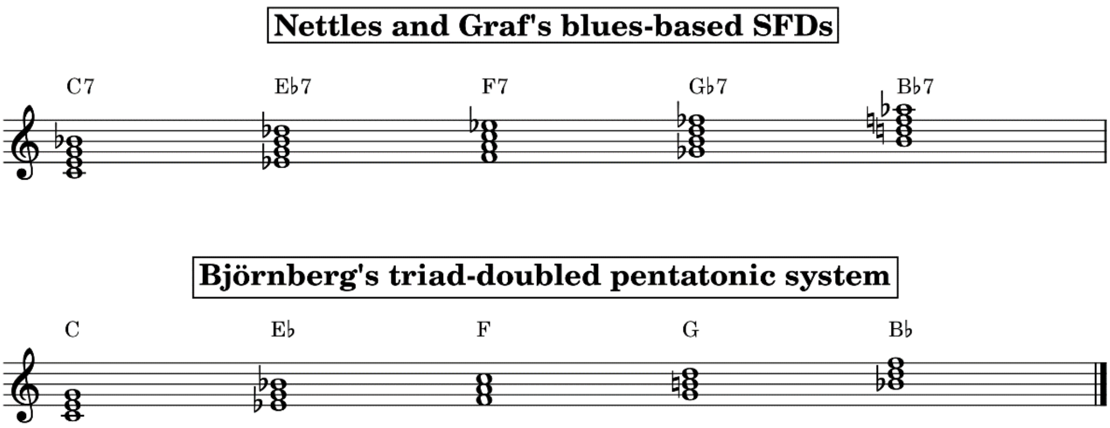

Fig. 31: SFD chords according to Nettles & Graf, (1997) and Björnberg, (1984) In addition to blues-based chords, Berklee theory acknowledges another grouping of chords as SFDs. These consist of non-dominant functioning dominant chords built on diatonic roots. In the first edition of *Harmony 4,* Ulanowsky (1988) lists the II7 and VII7 in this category.

SUMMARY OF SPECIAL FUNCTION DOMINANT SEVENTH CHORDS

Chord	Special Function	Special Function Chord Scale	Analysis with Dominant Function
I7	Tonic Blues	Blues, Mixolydian, Lydian b7	V7/IV
IV7	Subdominant Blues or Subdominant Melodic minor	Blues, Mixolydian, Lydian b7	subV7/III
bVII7	Subdominant minor	Lydian b7 in Major Mixolydian in minor	subV7/VI
bVI7	Altered Subdominant minor	Lydian b7	subV7/V
II7	Altered Subdominant Major	Mixolydian or possibly Lydian b7	V7/V
VII7	Cadential	Lydian b7 or Mixolydian	V7/III

Fig. 32: Ulanowsky's Special Function Dominants (Source: Ulanowsky, 1988, p. 17)

Rochinski differs from Ulanowsky in his categorisations of these chords only in that he adds the III7 when resolving to IV, and the VI7 when resolving to IV or ♯IVm7♭5. Thus, Rochinski dispenses with the requirement that these chords resolve directly to I.

SUMMARY – DOMINANT CHORDS WITHOUT
DOMINANT FUNCTION

CHORD	NONDOMINANT FUNCTION	RESOLUTION CHORD	NONDOMINANT CHORD SCALE	DOMINANT FUNCTION
I7	tonic blues	N/A	blues, mixolydian, or lydian♭7 (with ♯9)	V7/IV
IV7	subdominant blues or SD melodic minor or dorian minor	I	blues, lydian♭7, or mixolydian	subV7/III
♭VII7	subdominant minor	I	lydian♭7 in major, mixolydian in minor	subV7/VI
♭VI7	altered subdominant minor	I	lydian♭7 or mixolydian	subV7/V
II7	altered subdominant	I	mixolydian or lydian♭7	V7/V
VII7	cadential	I	mixolydian or lydian♭7	V7/III
III7	cadential or altered tonic	IV	mixolydian or lydian♭7	V7/VI
VI7	cadential or altered tonic	IV or ♯IV-7(♭5)	mixolydian or lydian♭7	V7/II

Fig. 33: Rochinski's Dominant Chords without Dominant Function
(Source: Rochinski, 2001, p. 42)

Mulholland and Hojnacki also add further context to the II7, noting that it “can act as a brighter subdominant, in effect a II chord from the parallel Lydian” (Mulholland & Hojnacki, 2013, p. 237)

These chords may be distinguished from secondary dominant chords built on the same roots by two factors. The first is their tendency to resolve directly to I rather than down a perfect fifth. The second is their typical placement on strong beats and hypermeasures; secondary dominants tend to fall on weak beats while placement on a strong beat will reduce dominant functionality. The rhythmic placement of these chords may also affect their expectedness as chromatic chords: if the most common placement of dominant functioning chords is on a weak beat, then those on strong beats will not only affect a change of function, but they may also be considered rhythmic deviants and thus may elicit more surprise than a secondary dominant.

4.5.2.3. Modal interchange

In the first edition of the Berklee harmony textbook *Harmony 2*, Nettles defines modal interchange as "the borrowing of diatonic chords from a parallel mode (scale) and using them in the primary key" (Nettles, 1987, p. 43). The colouristic and potentially surprising effects of these chords are described by Nettles in the 2007 revision of *Harmony 2,* "[w]hen used appropriately, modal interchange chords add variety and color to a major key progression" (Nettles, 2007a, p. 36). Mulholland and Hojnacki further elaborate in the 2015 edition of *Harmony 2:*

> Modal interchange . . . is an important part of the expressive language of music . . . . Since the prevailing modality of a composition is one of the most important factors in creating its mood, chords from a contrasting mode create moments of emotion which interrupt the basic mood. These moments of emotion are bumps in the road on a musical journey . . . . they are effective because they contrast with the clearly established home key. (Mulholland & Hojnacki, 2015, p. 90)

Mulholland and Hojnacki also elaborate on the contexts in which modal interchange chords are likely to be found. They state that subdominant minor chords, i.e. modal interchange chords specifically from the parallel natural minor, can

> *replace* major key subdominant chords or serve as variations of them. [They] have several possible roles:
>
> - to embellish a tonic-oriented phrase
> - to function as an alternative stable area within the key
> - to serve as a dominant preparation . . .
> - to serve as an alternative cadential chord, in place of V.
>
> (Mulholland & Hojnacki, 2015, p. 95)

They also refer to their potential roles as subdominant cadential chords, in effect substituting for the IV in a plagal cadence. Examples given include resolution from IVm7, ♭VIma7, and ♭VII7 to the major I chord. These functions parallel those of modal mixture chords in the CP period, whereby the IVm often replaced IV before resolving to I.

SDM (♭6 scale degree as root, 3rd, 5th, or 7th)	TM (♭3 scale degree as root or 3rd)	MODAL – MINOR CADENCE
	I-7 = dorian I-6 = dorian or melodic minor I-(maj7) = melodic minor	
II-7(♭5) = locrian♮9 ♭IImaj7 = lydian		II-7(♭5) V7(♭9) = locrian mixolydian♭9♭13 from parallel **HARMONIC MINOR**
	♭IIImaj7 = lydian ♭III+maj7 = augmented lydian	
IV-7 = dorian IV-6 = dorian or melodic minor IV-(maj7) = melodic minor		IV7 = mixolydian scale from parallel **DORIAN MINOR**
		V-7 = dorian scale from parallel **MIXOLYDIAN**
♭VImaj7 = lydian ♭VI7 = lydian♭7		
♭VII7 = lydian♭7		

Fig. 34: Table of modal interchange chords
(Source: Rochinski, 2001, p. 53)

Mulholland and Hojnacki note the prevalence of the IVm7-♭VII7 “back door” progression, which became common as a variation on the IVm7 in early bebop era jazz. They consider this a natural minor modal interchange progression. They also note the prevalence of several non-diatonic triads in popular music that may be considered to have modal interchange origins, such as the ♭VI-♭VII-I progression and the ♭VII7-IV7-I cadence.

Stanton categorises several chords as substitutes for the modal interchange IVm chord, as part of what he refers to as the Sub-Dominant Minor Cadence of IVm-I. These include the

♭VII7, which he acknowledges may be preceded by the IVm7 in the back door progression, the IVm6, and IIm7♭5, which he describes as an inverted IVm6. Included also in this Sub-Dominant Minor substitute category are the ♭IIma7 and the ♭VI6, ♭VIma7, and ♭VI7 chords, all justified as inverted IVm chords.

It may be noted from the review of modal interchange and SFD chords above that many chords, particularly dominant 7th chords, can be defined within multiple categories. For example, the ♭VII7 is described by Rochinski as both a subdominant minor chord derived from the parallel natural minor and an SFD, while Nettles and Graf point to this as a blues chord, and Biamonte acknowledges it in triadic form as having multiple interpretations. “It can be interpreted as diatonic to the Mixolydian mode, as an instance of major-minor mixture, or more simply as a chromatic inflection of major” (Biamonte, 2010, p. 98).

Additionally, the ♭VI7 is interpreted by both Ulanowsky and Rochinski as an alteration of the parallel minor derived ♭VIma7, even though its blues origins are well documented and its use in contemporary blues persists. Given that the most common use of the ♭VI7 in blues is as part of a turnaround, it is likely that both theorists consider this chord to be a tritone substitute with dominant function and therefore outside of the category of SFDs. However, its usual placement on a strong beat, preceding the V, may serve to weaken its dominant function. The rarity of this chord combined with a related II lends weight to the argument that it is not generally thought of by composers and improvisers as a tritone substitute. Regardless, many early blues and blues influenced composers used this chord devoid of dominant function regularly and thus a case arises to consider this a blues SFD.

Further confusion arises around these chords when paired with others in progressions. For example, according to Ulanowsky, both chords in the back door progression are subdominant minor and perceived as such; thus the ♭VII7 will have neither dominant function nor blues sound. However, Chris Stover quibbles with this assignment of subdominant function to the ♭VII7, arguing that this chord will be perceived by listeners as dominant functioning.

> The problem with these modal interchange models is that they derive what is nearly always a dominant-functioning chord from a pre-dominant prototype. . . . ♭VII7 [following IVm and approaching I] is clearly functioning as a dominant substitution, with dual dominant function in the local key (as V of the II-V in the relative major), and in the home key (as pushing towards its tonic arrival). . . . There are theories that locate ♭VII7 as a substitution

> for V7 (c.f. Martin 1980), but these are not considered by either Berkman or Mulholland and Hojnacki. (Stover, 2014, pp. 173-174)

Although Stover argues against the subdominant reading of ♭VII7 in the back door turnaround, he concedes it when the progression is reversed, i.e. when ♭VII precedes IV. Indeed, this may be related to hypermeasure, given that in the back door progression the ♭VII usually falls on a weak beat, while in the ♭VII-IV-I, which Biamonte (2010) refers to as the "double plagal", it falls on a strong beat, likely weakening any possible dominant function, and thus any expectation for resolution.

4.5.3. Cadence and function

Given that jazz harmony is fundamentally functional, cadences will inevitably arise as part of that functionality. In fact, if one were to consider the resolution of a secondary dominant a "mini-cadence", then cadences abound in jazz, given the prevalence of secondary dominants. The potentiality of cadences in effecting expectation and surprise is noted by Rochinski, who states that "[d]eceptive resolution is widely used in jazz and popular contexts for the purpose of creating an unpredictable or 'surprise' element (Rochinski, 2001, p. 17).

As well as generating harmonic interest and surprise, jazz theorists acknowledge multiple other uses of deceptive cadences, some of which hark back to its functions within CP. These functions include

> extending the endings of arrangements and as a means for creating spontaneous extended endings in playing situations. In songwriting, they can serve to reharmonize a repeated melodic phrase or add an element of surprise to a conventional chord progression. They are also very useful in creating a pathway to a new tonal centre, resulting in a modulation or just a temporary tonicization of a closely related key. (Nettles, 2007b, p. 22)

Mulholland and Hojnacki describe further means of using deceptive resolutions "to create a final extended ending or coda [and] to create interludes in arrangements" (Mulholland & Hojnacki, 2013, p. 233)

Jazz theorists follow Rameau in ascribing the need for the V chord in a cadential context to resolve due to the tritone contained within it:

> The function of the dominant chord is to cause the listener to expect resolution to the tonic. . . . This expectation is created by the vertical combination of unstable scale tones in the V7 chord: the interval of a *tritone* . . . created by the combination of scale degrees 4 and 7. (Mulholland & Hojnacki, 2015, p. 4)

This is an important consideration as it opens up the possibility of multiple deceptive resolutions. If the primary characteristics of a cadence are based on voice-leading, and not the inherent quality of a chord, then any chord that fulfils those voice-leading requirements will suffice as a cadence. This also extends cadential possibilities to both secondary dominants and tritone substitutes, given their default makeup as dominant 7th chords containing a tritone.

Nettles and Graf note that "[i]n jazz, nondiatonic deceptive resolutions are common" (Nettles & Graf, 1997, p. 33). Rochinski expands on this in *Harmony 4* and outlines the justifications for chromatic deceptive resolutions through voice-leading, specifically the resolution from the 3rd of the V chord to the root of I, whether this is the 3rd, 5th, or 7th of the deceptive resolution chord. Rochinski (2001) maintains that these chromatic deceptive resolutions keep the same chord quality as the I but sacrifice its tonic function. Baker, in *Advanced Improvisation*, adds weight to this justification by pointing out the tension inherent in the chord tones of dominants, and the anticipation of resolution that is elicited by them:

> [C]onditioning leads us to expect certain notes in particular scale systems to react in specific ways; for instance, the tendency of the leading tone . . . to resolve up, or the dominant seventh . . . to resolve down a step in the major-minor system. When the resolution takes place, we experience pleasure; when it does not, we experience frustration. (Baker, 1998, p. 114)

According to Rochinski, root movement of traditional deceptive cadences (up a whole tone or down a minor third) justify root movement to the chromatic ♭VIma7 and ♭IIIma7. The ♭IIma7 is also justified given that it contains the root in its 7th. The ♭VIIma7 is included, but Rochinski acknowledges that this is rare given that this chord does not contain the root.

Deceptive movement to ♯IVm7♭5 is also included, and Rochinski justifies this in three contexts: firstly, where the chord serves as the IIm7♭5 of the V/III in a continuous progression; secondly, where it serves as a passing chord between V and IV, and thirdly, where it serves to give a Lydian sound in place of the tonic Ionian sound.

SUMMARY OF THE STANDARD DECEPTIVE RESOLUTIONS OF V7

V7 to:

CHORD:	FUNCTION:	ROOT MOTION:
VI-7	tonic substitute	↑ 2nd
III-7	tonic substitute	↓ -3rd
♭VImaj7	subdominant minor	↑ -2nd
♭IIImaj7	tonic minor	↓ 3rd
♭VIImaj7	dorian minor	↑ -3rd
♭IImaj7	altered subdominant minor	tritone
♯IV-7(♭5)	1) related II-7(♭5) of V7/III or 2) altered subdominant and/or 3) tonic lydian modal interchange	↓ -2nd

Fig. 35: Rochinski's deceptive resolutions of V
(Source: Rochinski, 2001, p. 16)

Mulholland and Hojnacki (2013) also list ♯IVm7♭5 as a deceptive resolution but, in a nod to Riemann, justify it as fulfilling the same function as VIm given their common tones, i.e. an inverted VIm6, and voice-leading resolution of the V chord tritone to the root and 3rd. They, like Rochinski, acknowledge that this generally does not function as an ending resolution per se, but rather as a harmonic continuation. ♭IIma7 and ♭VIma7 are also acknowledged as valid deceptive resolutions, and again voice-leading to the tonic (via the 7th of the ♭IIma7 and the 3rd of the ♭VIma7) is the justification. The ♭IIIma7 is justified as a tonic minor modal interchange chord. Deceptive resolution to ♭VIIma7 is justified through common tones.

Thus, these theorists outline a wide variety of chords that can fulfil the role as a deceptive resolution. This contrasts with contemporary accounts of deceptive resolution in CP music, which allow for only the VIm, but tallies with the accounts of late 18th and early 19th century theorists such as Daube, Türk, and Reicha, who allowed for a range of deceptive cadences, and a gradation of surprise levels inherent within them.

In *Harmony 3*, Nettles notes the characteristics of CP cadences, particularly the link between harmonic and melodic cadences. “In a traditional major key context, when V7 resolves deceptively the resolution often occurs at both a melodic cadence and on a strong harmonic stress point, that is, at the beginning of a phrase or section” (Nettles, 2007b, p. 22). This has also been noted by Stephenson. “It is essential to the idea of resolution that the harmony and melody arrive on the tonic not just together but also . . . at the end of a phrase” (Stephenson, 2002, p. 55). According to Mulholland and Hojnacki, however, this is not the case for jazz because “the harmonic phrase is often separate from the melodic phrase. The harmonic phrase is a potentially independent *accompaniment* to the primary melody.” (Mulholland & Hojnacki, 2015, p. 14). In *Modern Jazz Theory and Practice*, Rochinski notes that the resolution of a melody note to the tonic does not necessarily mean that the harmonic phrase will resolve at the same time:

> It should also be understood that, by itself, a melodic function at a threshold point may or may not contribute to a stable ending of the phrase or section. The relative stability or instability of the melody note is ultimately determined by the supporting chord and the resulting melody/harmony relationship. (Rochinski, 2022, p. 13)

Given that most music cognition experiments to date have used only CP stimuli, it is not known whether this change of structure and hypermeasure around the cadence has an effect on expectation. Does the move to resolve into a new section heighten anticipation, as intended by the Tin Pan Alley composers who innovated this technique? Or does the change from traditional structures weaken expectation, given the relative newness of this phenomenon? When primed with a jazz or popular music context, do listeners then expect these kinds of resolutions, and vice versa for a CP context? These questions remain unanswered.

4.6. Conclusions

The review above provides evidence that the narrative structures, tonal frameworks, functionality, and harmonic language of both jazz and popular music differ significantly from those of CP, due to the influence of blues and other factors. Evidence includes the prevalence of tone clusters around the 3rd and 7th, the subsequent permissibility of harmonies related to the ♭3 and ♭7 within a major key framework, a merging of major and minor, and lower functionality due to the concurrent use of both ♭7 and ♮ 7. Evidence also includes the elevation of the subdominant chord to a position equal to that of the dominant leading to reduced V-I functionality, reduction of large-scale functional and harmonic goals and elevation of cyclical harmonic patterns. Other evidence includes differences in how functionality relates to hypermeasure and a decoupling of melody and harmony and thus a reduction in functionality of melody.

These differences directly affect the elements associated with expectation and surprise in CP, i.e. cadence and chromaticism, in the following ways, raising several questions to be answered in Part 2.

4.6.1. Cadence

1) Popular music often has reduced functionality in comparison to CP. Narrative structures may be intensional rather than extensional. This means that chords that are strongly dominant-functioning in CP, such as the V chord, may not elicit specific expectation for resolution to I, and surprise for non-I resolutions in popular music. Conversely, expectation may arise from chords other than the V, e.g. the hierarchically strong IV chord, or the ♭VII. This raises the question of whether deceptive cadences are perceived in the same way within a less functional context.
2) Most jazz prior to the post-bop period is functional, but prioritises short term, rather than long term harmonic goals. Longer term goals tend to be determined by the trajectory of improvisations. Given the regularity of the appearance of cadential dominant structures within jazz, it is likely that expectation is evoked more regularly than in popular music or CP. Multiple II-V-I progressions and secondary dominants result in the potential for increased deceptive resolutions, and this potential is enhanced by the high number of chromatic chords permitted in jazz. This array of cadences speaks to the way in which surprise was thought of by theorists of the Classical period such as Daube, Türk, and Reicha, that is, as a gradated phenomenon that could be elicited by multiple harmonic structures. This raises two questions. The first is whether listeners accept and are surprised by the myriad of allowable deceptive cadences in jazz, and if their surprise reactions are gradated or binary. The second is whether the increase in expectation related to cadences, which can be perceived as met according to Berklee theory, or unmet according to the theories of Aebersold and Coker, and thus complexity, result in increased or decreased preferences for listeners.

4.6.2. Chromaticism

1) Tonal systems in popular music are less discrete and demarcated than the major/minor system of CP. Due to the amorphous nature of the 3rd and 7th, several different modes are found, and individual songs can often incorporate more than one tonal or modal system. This blurs the meaning of diatonic and chromatic as perceived by listeners; chords that could be considered strictly chromatic in a CP major key context may be less so in a popular music context. This raises the question: to what extent does tonal context affect surprise in popular music?

2) Jazz contains many chromatic elements as part of its tonal language, including secondary dominants, tritone substitutes, non-diatonic related II chords, and blues chords. This again blurs the definition of chromatic for listeners' perceptions, raising the question of whether these elements cause the same amount of surprise in a context where they regularly appear in comparison to a context where they are rare.

3) The review also found that many chords derived from blues, such as the I7, IV7, ♭VI7, and ♭VII7 are used in both jazz and popular music contexts outside of strict blues forms, as a type of modal interchange. Given that these chords are part of the lingua franca of both jazz and popular music, are these chords perceived as chromatic by listeners?

4) The review identified several types of chromatic structures that may elicit surprise in jazz and/or popular music. These structures are: secondary dominants, tritone substitutes, modal interchange chords, related II chords, and altered dominants. The question arises as to whether these chords are perceived as chromatic and therefore surprising within jazz and popular music contexts.

Overall, several unique musical techniques, verified by contemporary jazz and popular music theory have been suggested as relating to expectation and surprise in jazz popular music. The aim of the next section is to therefore test these techniques and determine if a model of surprise and expectation in musical language can be made available for the benefit of music theory.

4.7. Summary

The primary aim of Part 1 of this thesis was to defend the assertion that CP harmony is not representative of either jazz or popular music and thus expectation and surprise do not function in the same way within these genres. Through critical analysis of historical texts and popular music and jazz theory, the following points were made in support of this argument:

1) Expectation and surprise in CP music are inherently linked to functionality. The primary means of deceiving listeners in CP is to elicit a specific expectation through the use of dominant functionality, and subsequently thwart that expectation through a deceptive cadence. Given that dominant functionality is derived from the hierarchical nature of CP tonalities, the argument is made that the elicitation of surprise in this manner is dependent on an underlying hierarchical, functional system.
2) There are fundamental differences between the functionality of CP, and that of jazz and popular music. Analysis of the origins of 20th century American music revealed a strong harmonic influence of African tonal systems, which prioritise cyclical, non-hierarchical structures. This opposes the hierarchal underpinnings of CP music, and thus weakens the functionality directly associated with expectation. The use of expectation built on hierarchical functionality is therefore undermined in non-CP contexts.
3) Surprise in CP is also commonly elicited through means of chromatic chords such as the N^6, $^+$6 and IVm modal mixture chord. This method of eliciting surprise is dependent on a clear and unequivocal tonal framework, against which deviations can be clearly perceived.
4) Tonal frameworks in jazz and popular music are significantly more ambiguous than those within CP. Early blues harmony contains complexes around key tones which allow for both major and minor variations within the same tonality. Modal contexts are common to jazz and popular music, and modalities are commonly mixed in both styles. This means that the distinction between diatonic and chromatic is often unclear, and thus, the CP method of eliciting surprise through chromaticism is undermined in both jazz and popular music.

Part 2 of this these describes an experimental methodology building on the arguments above, whereby the unique aspects of expectation and surprise in jazz and popular music may be revealed.

Part 2

Introduction

The primary aim of this thesis is to fill the knowledge gap in music cognition caused by the assumption that CP is paradigmatic of all Western music styles and thus, the exclusion of jazz and popular music and musicians in harmonic expectation research.

In Part 1, evidence was presented to support the case that such a gap exists. Chapter 2 revealed the narrow focus on CP stimuli and dependence on conservatory trained expert listeners within the study of harmonic expectation. Chapter 3 revealed that the parameters that govern harmonic expectation in CP are tonal frameworks, narrative structures, and functionality, while Chapter 4 revealed fundamental differences between these parameters in CP, jazz, and popular music. Taken together, this suggests that the current data on harmonic expectation may not be representative of all western tonal music or all expert listeners.

Part 2 describes four harmonic expectation experiments carried out using jazz/popular music stimuli. Participants in the experiments included musicians with expertise in jazz, popular music, and improvisation. There are two overall objectives of this series of experiments. The first is to discover the mechanisms that elicit expectation and surprise in jazz and popular music. The second is to present these findings in the language used by the music theory, education, and performance communities, in order to bridge the gap between music theory and music cognition, and to allow musicians and music educators to make practical use of knowledge about harmonic expectation in their music.

Methodology

Behavioural data in harmonic expectation studies is generally gathered using either implicit or explicit measures. Implicit measures involve those where participants respond quickly to a timed secondary cover task, such as identifying mistuned stimuli (Tillmann, Janata, & Bharucha, 2003), (Tillmann et al., 2008), (Justus & Bharucha, 2001). These paradigms reveal the implicit knowledge of participants, but have been criticised for issues disentangling responses related to primary tasks and secondary cover tasks (Bigand et al., 2001), and for poor sensitivity related to technological limitations (Chander & Aslin, 2023). Explicit measures, on the other hand, ask for direct responses and allow participants to consider their answers (Schmuckler, 1989), (Chander & Aslin, 2023). Results using explicit measures may be influenced by listeners' learned experiences (Bigand, 2003), but are easily measured and will not be confounded by a secondary task.

Experiment 1 in this study uses explicit measures to determine listeners' surprise ratings in response to a range of deceptive cadences. Participant cohorts include jazz, classical, and pop/rock musicians, and general listeners. The experiment aims to determine if there are differences in explicit expectations between stylistically varied cohorts. A range of deceptive cadences, including those typically found in jazz/popular music contexts are used.

Experiment 2 uses implicit measures to determine listeners' reaction times (RTs) to a range of deceptive cadences sourced from the jazz and contemporary music theory literature. In this experiment, a novel RT paradigm is implemented, with the aim of disentangling results of the primary and secondary tasks. In addition, experiments were conducted in person within a controlled environment in order to maximise technological accuracy. The range of cadences is expanded, and listeners liking ratings are recorded in order to determine relationships between expectation and preferences.

Experiments 3 and 4 use ecologically valid, real-life musical examples selected to contain specific musical techniques theorised to be related to harmonic expectation, as per the discussion in Chapter 4. Listeners are again asked for explicit ratings but are encouraged to respond as quickly as possible. The aim of these experiments is to determine if the results of Experiments 1 and 2 extend to ecologically valid contexts and to explore other idiomatic musical techniques that may relate to expectation in jazz and popular music.

Material for Experiments 2 and 3 were derived from corpuses of jazz and popular music. The jazz corpus contained 200 songs, details of which may be found in Appendix A. A selection of 90 of the songs, consisting of standard Real Book charts, had previously been compiled over the course of seven years of teaching jazz harmony as part of the BA in Jazz and Contemporary Music Performance at Dublin City University. These songs had been used in-class to demonstrate the harmonic techniques of deceptive cadence, Modal Interchange (MI), tritone substitutes, and Special Function Dominants (SFDs). The remaining 110 songs consisted of audio recordings, selected as they appeared to contain the relevant harmonic techniques; these were harmonically transcribed and analysed for this thesis.

The popular music corpus contained 400 songs and may be found in Appendix B. Approximately 300 of these songs were part of the performance repertoire of a professional pop/rock musician in the form of lyric sheets and chord charts. The remaining ~100 were selected as they appeared to contain harmonic techniques relevant to the experiment. All 400 songs were harmonically transcribed and analysed.

Harmonic transcriptions consisted of determining the tonality, chords, melody with reference to the underlying chord, and hypermeasure of each chord. All harmonic structures were transcribed and named with reference to the entire musical context rather than a single instrument, e.g. a Cm in a keyboard part combined with a B♭ in the voice was transcribed as a Cm7 structure. Analysis of both corpuses consisted of roman numeral analysis and categorisation of each chord as diatonic, secondary dominant, related II, tritone substitute, MI, SFD, chromatic mediant, diminished passing chord, and cadential structure. Further details such as the type of secondary dominant were also gathered. Cadences were analysed in terms of whether they fell on a strong or weak hypermeasure and/or co-occurred with a melodic cadence, as well as the type of cadence. Modulations were analysed as prepared or unprepared. Root movements were gathered, as were data on whether chords occurred as part of pedal points.

Experiments 1 and 2 were designed in the order presented, but due to location constraints were carried out in reverse order. Analysis of results, however, were performed in the order presented. Experiment 2 was conducted at the School of Media at Technological University Dublin, formerly Dublin Institute of Technology, as this PhD was begun there, prior to a transfer to Dublin City University.

Further methodological details on material, experimental paradigms, and analysis methods are outlined within the methodology sections of each individual experiment chapter.

Ethical approval for experiments was given by the DCU Faculty of Humanities and Social Sciences Research Ethics Board, and DIT Research Ethics Committee. Confirmation of ethical approval may be found in Appendix H. For all experiments, participants were recruited through social media (Twitter, Instagram), mailing lists to professional networks and university poster campaigns within music departments.

5. Experiment 1: Explicit reactions to deceptive cadences among stylistically diverse participants (Explicit Experiment)

5.1. Introduction

The primary objective of this experiment is to begin to introduce musical diversity to the study of harmonic expectation through the participation of stylistically diverse expert participants and musical stimuli. The explicit perceptions of general listeners and musicians with expertise in jazz, popular music, and classical music will be investigated. Through this investigation, the experiment aims to answer the following three research questions:

1) What are listeners' own experiences of expectation and surprise?

While many studies have measured listeners reaction times (RTs), brain activity, and physiological responses to surprising harmony, few have probed listeners' own opinions and experiences of harmonic expectation. This is surprising, given that other aspects of music listening such as emotional reactions to music have been explored in great detail through the accounts of listeners' own experiences (Sloboda, 1992), (Gabrielsson, 2001), and that emotional reactions to music have been explicitly linked to expectation and surprise (Tillmann et al., 2014).

Valuable details may be found in listeners' experiences, which may inform subsequent research questions. Therefore, following the experiment, participants in this study were asked if they would like to volunteer any information on their own perspectives on harmonic expectation and surprise in order to determine if this is an important factor for listeners themselves, and if themes could be deduced from their answers.

2) Do listeners rate surprise on a gradient?

Previous experiments have generally explored expectation and surprise as a binary phenomenon, utilising a single chromatic chord such as a N^6, or an open versus closed cadence (Koelsch et al., 2000), (Loui et al., 2005), (Bigand & Pineau, 1997). However, the reviews in Chapters 3 and 4 demonstrated that there are a wide variety of deceptive harmonies available to composers, and that theorists throughout the ages have considered expectation and surprise on finely calibrated gradients. Contemporary jazz and popular music theorists have outlined multiple harmonic structures that can function as deceptive resolutions in cadences, in contrast to mainstream CP theorists who often limit the deceptive cadence to the VIm.

Studies that have investigated a range of cadences are rare, but those that have been conducted using multiple CP cadences have found results suggesting a hierarchy of surprise in listeners (Tillmann et al., 2008), (Sears et al., 2018). Thus, this experiment aims to expand the range of deceptive harmonies by testing two additional deceptive cadences using chords from the jazz/popular music repertoires and exploring whether participants rate these additional chords on a binary or gradated scale.

3) Does stylistic training and/or improvisation affect ratings of expectation and surprise?

Although several studies have investigated differences between general listeners and musicians in harmonic expectations and found results indicating that differences exist, few have investigated the effects of stylistic training or improvisation. These are relevant questions for two reasons. Firstly, initial studies have found evidence of unique musical schemas associated with different styles within Western tonal music (Hughes, 2011), (Vuvan & Hughes, 2021), (Craton et al., 2016). Secondly, scholars have suggested that anticipating and responding to surprising information are core aspects of improvisation (Kenny & Gellrich, 2002), and that jazz and improvising musicians have heightened abilities to respond to unexpected stimuli (Vuust et al., 2012), (Tervaniemi et al., 2016).

5.2. Methodology

5.2.1. Material

A prime-target rating paradigm was used for this experiment. A II-V triad progression was chosen as the prime stimulus. This subdominant to dominant progression is well recognised as a core cadential pattern which will give rise to expectations for a resolution I chord. Prior to the II-V progression, a I chord was played to establish key context.

Five chords were chosen as targets to follow the prime stimulus. The first of these was the Ima chord. The combination of the prime stimulus and a target Ima chord results in a full perfect cadence. This condition was thus designated an “expected” condition. A ♭VIaug triad was selected to fulfil an “unexpected” condition. This chord has no theoretical justification and is unlikely to be found following a V chord in such a progression. Thus, this chord would likely be perceived as tonally incongruous by listeners.

Three chords were then chosen to fulfil three distinct “deceptive” conditions. The first of these was the VIm chord. As outlined in Chapter 3, the VIm is the oldest deceptive resolution in Western art music, described as early as 1597 by Thomas Morley. This cadence was used throughout the Baroque and Classical periods and is also found within the jazz and popular music repertoires (Nettles, 2007b). Thus, this chord represents an established cross-genre deceptive cadence, notwithstanding issues relating to narrative and hypermeasure that may change the perception of cadence in popular music and jazz. These issues will be addressed in later experiments.

The second deceptive cadence chord chosen was a ♭VIma chord. Chapter 3 outlined the prominence of this chord as a fundamental structure within early blues. The ♭VI has become commonplace within the repertoire of popular music as a part of triad-doubled tonal systems (Stephenson, 2002). Within both jazz and popular music, the ♭VI is likely to be found as a modal interchange (MI) chord in a cadential context, for example as found in Paul Desmond’s “Wendy” (1976), Glen Campbell’s “Wichita Lineman” (1968), The Beatles’ “I Will” (1968), and Mike Stern’s “Nu Som” (2019). Rochinski (2001) describes this chord as a standard deceptive resolution of V within the jazz and contemporary popular music repertoire, justifying its resolution through voice-leading of the 5th of the V chord to the 3rd of the ♭VIma.

The final deceptive resolution is the modal mixture Im chord. This chord is commonly found in pieces that modulate between parallel major and minor. Within the jazz repertoire, it is often found as a cadential chord, such as in Scott LaFaro’s “Gloria’s Step” (1961), Bill Evans’ version of the Carter, Ellis, and Frigo standard “Detour Ahead” (1962), and the Antônio Carlos Jobim tune “Wave” (1967), but in popular music and art music is more likely to follow a Ima, such as in “Tempted” (1981) by Squeeze, Michael Jackson’s “Ben” (1972), the opening bars of *Also sprach Zarathustra, Op. 30* by Strauss, and the first movement of Haydn’s *String Quartet in Eb major, Op. 9, no. 2*. Overall, it is less frequently heard in comparison to the ♭VI. According to Kostka and Payne, “[t]he most frequently encountered examples of mode mixture in major mode involve chords that employ ♭6” (Kostka & Payne, 2009, p. 366)

These three deceptive cadences to VIm, ♭VI, and Im therefore represent three degrees of familiarity within different stylistic contexts. The VIm is likely to be familiar to all listeners as the primary deceptive cadence in Western music. The ♭VI is likely to be less familiar to classical musicians, but this chord is likely to be very familiar to rock musicians as it forms part of the fundamental tonal structure of rock (Biamonte, 2010). The Im is likely to be less familiar to all participants, but more familiar as a cadential chord to jazz musicians. In addition, the Im and ♭VI may be grouped together as chromatic deceptive chords, in contrast to the diatonic deceptive VIm. This classification may provide more information about how harmonic surprise may relate to chromaticism.

Using this particular selection of chords meant that all progressions would voice-lead similarly in the top voice, that is, any perceived melody elicited from the soprano line would be identical between progressions, eliminating voice-leading as a potential confounding factor. In all cases, the soprano line would move from 'so' (I chord) to 'la' (IV chord) to 'ti' (V chord) to 'do' (final chord).

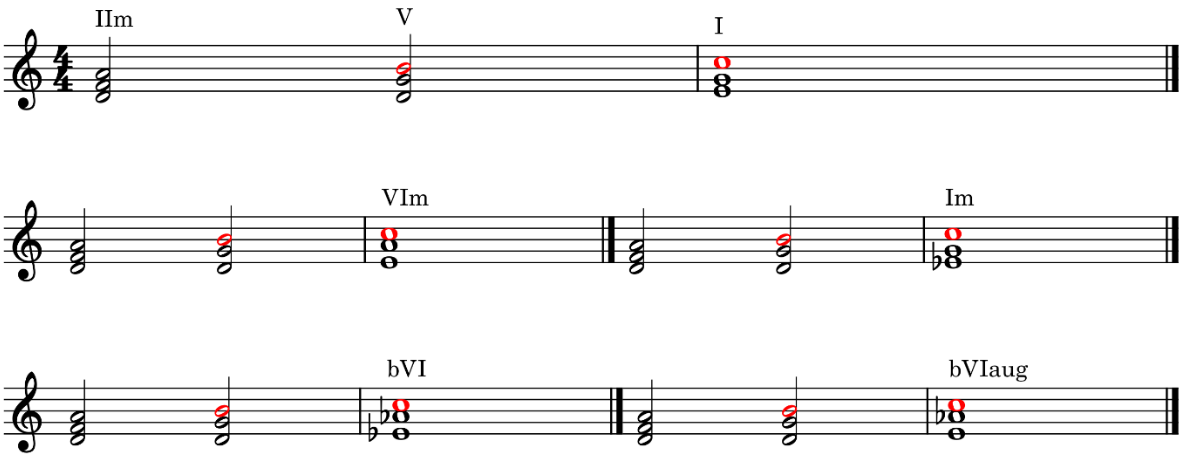

Fig. 36: Voice-leading pattern in the Explicit Experiment stimuli

Following Janata (1995), (2001), and Janata and Paroo (2006) in which researchers found quantifiable brain responses corresponding to listeners' musical predictions, a silent gap was introduced between the prime and target chords in order to determine qualitatively if listeners experienced musical predictions, and how they conceptualised these predictions. The pause was of one bar duration, or ~2667ms at 90bpm. The purpose of this gap was to allow time for listeners to form predictions and become aware of them. In order to minimise the effect of demand characteristics (Leustek, 2017), whereby listeners may deliberately try to imagine sounds that they would not normally imagine in a real-life setting, participants were not specifically asked to imagine any sounds and were not given any information about why the gap was inserted. Rather, at the end of the experiment they were asked retrospectively whether they had found themselves imagining any chords during the experiment.

Fig. 37: Notated example of Explicit Experiment stimuli

Distractor tones were inserted between each progression, following Deutsch (1999). This ensured that no effects of echoic memory occurred and that listeners would not be influenced in one progression by the tonal centre of the previous. Progressions were generated using MIDI. Four progressions were played, in different keys, for each of the five categories of chords. The prime context was played at 90bpm on a MIDI piano sound. Audio files were generated in MuseScore ("MuseScore," 2002) and exported as .wav files. The keys of the progressions were randomised, as was the order in which they were presented.

5.2.2. Procedure

The experiment was conducted online using the software Gorilla Experiment Builder, a cloud-based research platform for developing behavioural experiments online (Anwyl-Irvine et al., 2019).

An initial questionnaire was presented to participants before the experiment proper, requesting details on whether they performed or had studied music, what style they primarily performed/studied, and whether they performed or had training in musical improvisation. This may be found in Appendix D.

In the main part of the experiment, listeners were presented with a question screen, as seen below, and were asked to play audio files consisting of the chord progressions. On each question they were asked to move a slider to indicate how surprising they found the final chord.

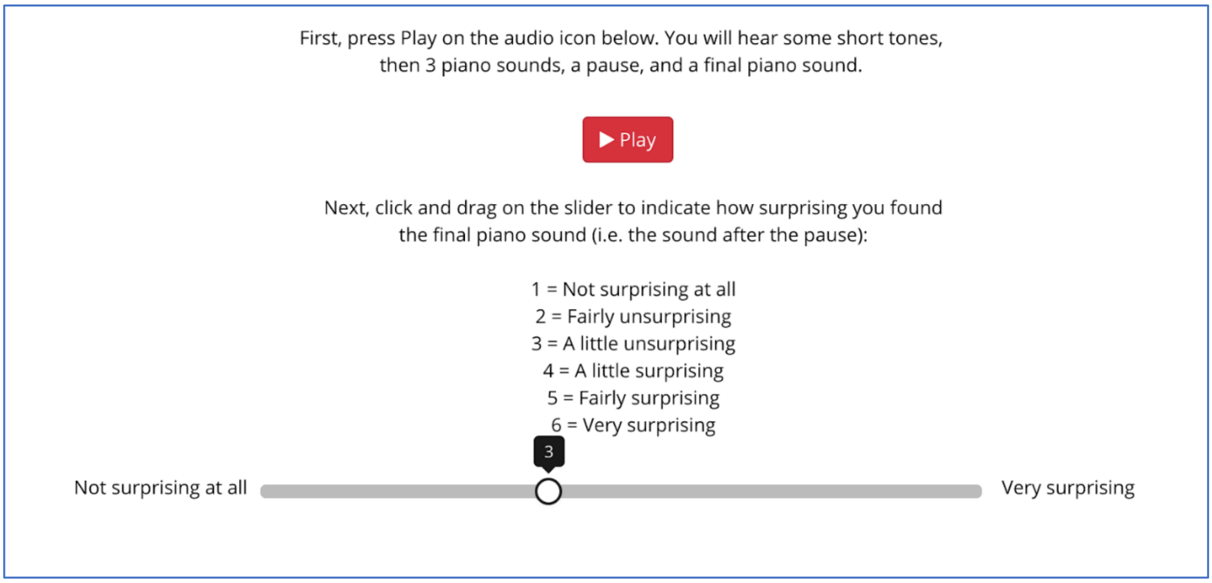

Fig. 38: Main question screen in the Explicit Experiment

At the end of the experiment, listeners were asked if they recalled predicting or imagining sounds during the pauses between the primes and targets. They were asked, if they wanted, to give an open-ended response to their experience of predicting during the experiment, and what they thought they had predicted. They were told that both music-theory based descriptions and broader non-theory based descriptions were welcome.

5.2.3. Participants

103 participants completed the experiment in full. The data from two participants were deleted as one had given the same rating for all questions in the experiment, and another had failed to play the audio files for 16 of the 20 questions. This left a total of 101 participants. The number of participants recruited allowed for sufficient observed power (>0.8) for all statistical tests used in the analysis.

31 participants were female, 69 were male, and one indicated that they preferred not to say. Participant ages ranged from “<20” to “>60”, with the largest cohort of participants (35.6%) falling in the 31-40 age bracket. When asked about their musical experience, 24 participants selected the category “non-musician” to describe themselves, 34 participants selected “amateur musician/part-time music student”, 10 selected “full-time music student”, and 33 “professional musician/music teacher”. Participants who selected “non-musician” will be subsequently analysed and referred to within the category “general listeners”, while all other participants will be analysed and referred to within the category “musicians”.

24 participants indicated that the style they primarily played/studied was classical music, 21 indicated jazz as their primary style, and 18 indicated pop/rock music. 14 participants indicated that their primary style was not of these main three, these included folk, gospel, traditional Irish and electronic music. These musicians were classed as "other", as there were too few participants within each individual style to have sufficient statistical power in analysing them as stylistic groups.

30 of the musicians indicated that improvisation was an integral part of their performance or practice. 19 indicated that it was an occasional part, while 18 indicated that they rarely improvised and 10 never did. Although a large proportion of musicians practiced improvisation, a smaller proportion had studied it formally, with 23 having had several lessons in improvisation. 12 participants had had occasional lessons, 13 had studied on their own, and 29 had never or rarely studied improvisation.

In terms of musical styles, only 4% of classical musicians claimed that improvisation was integral to their practice, while 82% of jazz musicians rated improvisation as integral, as did 44% of pop/rock musicians. Of the "other" musicians (soul, folk, electronic, traditional Irish etc.), 25% rated improvisation as integral to their practice. Of the musicians who had formally studied improvisation, 78% were jazz musicians.

5.2.4. Data cleaning and test selection

Data received from the online experiment was in the form of Likert ratings of surprise from 0 to 6. There were a total of 2020 data points. Nine of these values, or 0.4%, were determined to have been selected before the corresponding audio file had been completed. These were deleted and imputed with values determined by measures of central tendency on two dimensions, that is, the mean value for the given participant, and the mean value for the given chord, per Lachaud and Renaud (2011).

Data were analysed using SPSS and R. Significance values reported in SPSS as .000 are reported as <0.001 (Cronk, 2018).

Correlation tests were determined to be the most effective option to investigate participants' agreement with each other in their ratings. These tests will give information about how much participants in different cohorts agreed with each other in comparison to participants in other cohorts. Thus, this will give indications about the extent to which their results were influenced by their membership within a particular stylistic/improvisational cohort.

Classification analysis was used to determine the ways in which cohorts of participants grouped resolution chords together in their surprise ratings. A hierarchical cluster model was used in order to understand how listeners grouped multiple chords together. Cluster analysis involves classifying multivariate data into groups in order to reveal patterns within the data (Everitt et al., 2011). It was first used in the area of music cognition by Krumhansl and Shepard (1979) in their investigations of tonal hierarchies. Hierarchical clustering allows for a model of hierarchical groupings to be created based on the similarities of participants' ratings.

Linear mixed models (LLMs) were used, with chord ratings as the continuous outcome variable, in order to determine the factors most affecting participants' ratings. LLMs were chosen in contrast to the simpler repeated measures ANOVA test because of their ability to control for factors, their increased statistical power, and the reduced likelihood of Type I error (West et al., 2007). LMMs have become increasingly popular within music cognition due to their advantages over traditional analysis of variance tests (Chander & Aslin, 2023), (Armitage & Eerola, 2020), (Sears et al., 2018)

5.3. Results

5.3.1. Intersubject correlations

Correlation matrices were calculated in order to assess the participants' consistency with each other in their responses. This would help to determine the robustness of the participants' answers as representative of their cohorts and discover patterns in the data related to stylistic expertise. Participants were found to be strongly consistent with each other overall. The mean intersubject correlation across all participants was 0.6, indicating a high degree of agreement between participants in their ratings. However, when musicians were excluded from the analysis, the mean intersubject correlation dropped to 0.42. While still a significant correlation, this suggests that general listeners are less consistent with each other in their explicit ratings of expectedness of cadence chords than musicians. This difference in agreement between the two cohorts was shown in a one way ANOVA to be statistically significant, $F = 154.589$, $p < 0.001$, suggesting that musical training may have an effect in providing greater consistency in determinations of harmonic surprise.

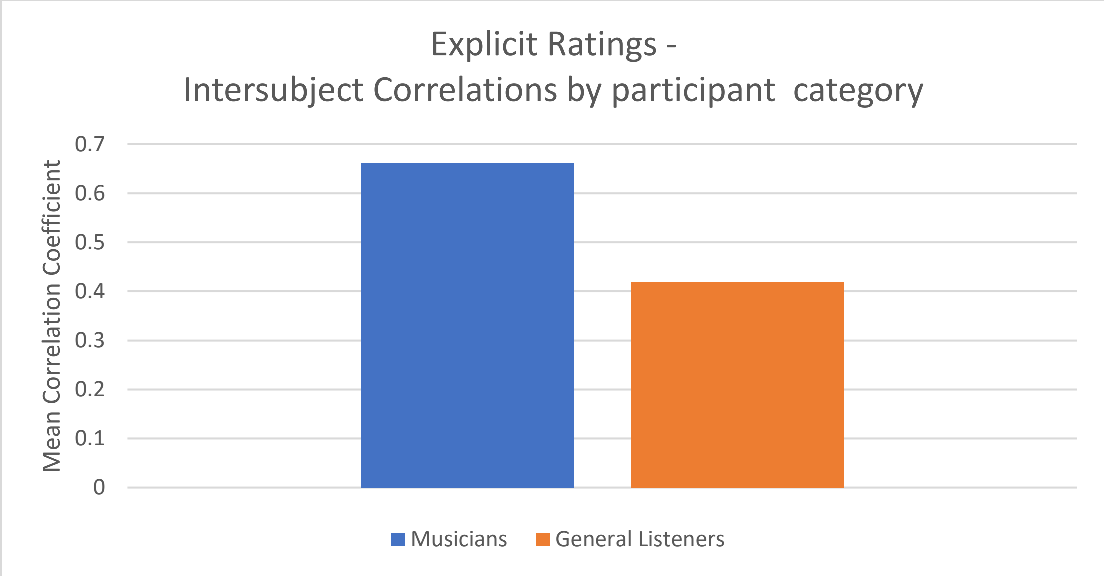

Fig. 39: Mean intersubject correlations: musicians and general listeners

Jazz musicians were found to have the highest intersubject correlation, with a mean of 0.72. This difference in agreement was shown to be statistically significant with reference to both classical musicians, $F = 18.121$, $p < 0.001$, and pop/rock musicians, $F = 5.587$, $p = 0.019$. The homogeneity within this cohort suggests a quantifiable difference in harmonic expectation between jazz musicians and other musicians, with greater consistency and definition found among jazz musicians in comparison to other musicians.

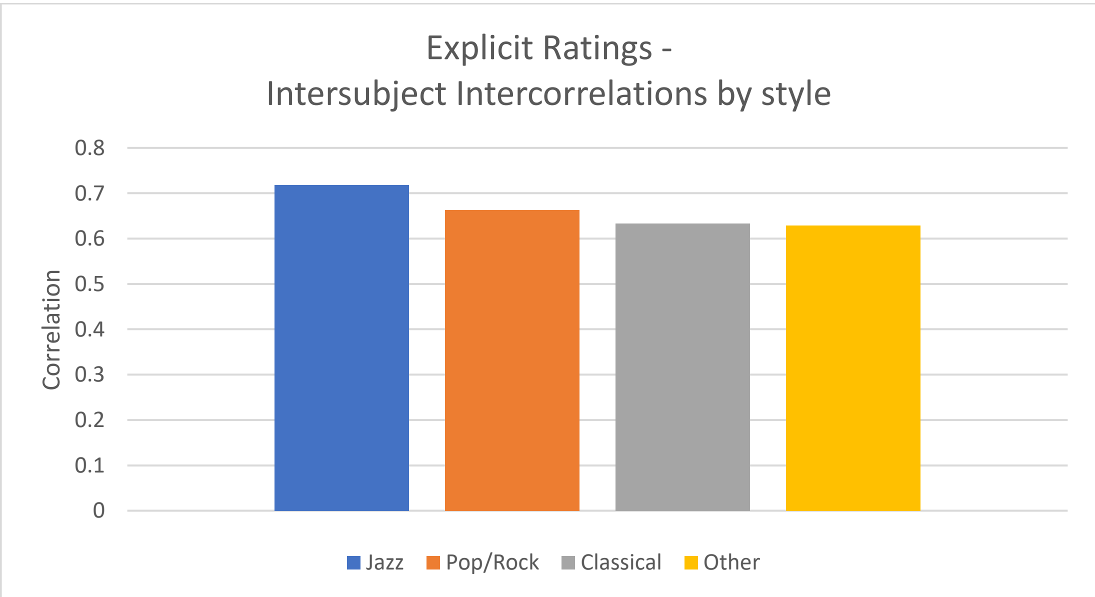

Fig. 40: Mean intersubject correlations: stylistic cohorts

Musicians who had formally studied improvisation demonstrated strong homogeneity in comparison to those who had not. Improvising musicians had a mean intersubject correlation of 0.712, while non-improvising musicians had a mean intersubject correlation of 0.571. This difference was found by a one-way ANOVA to be statistically significant, $F = 109.255$, $p < 0.001$.

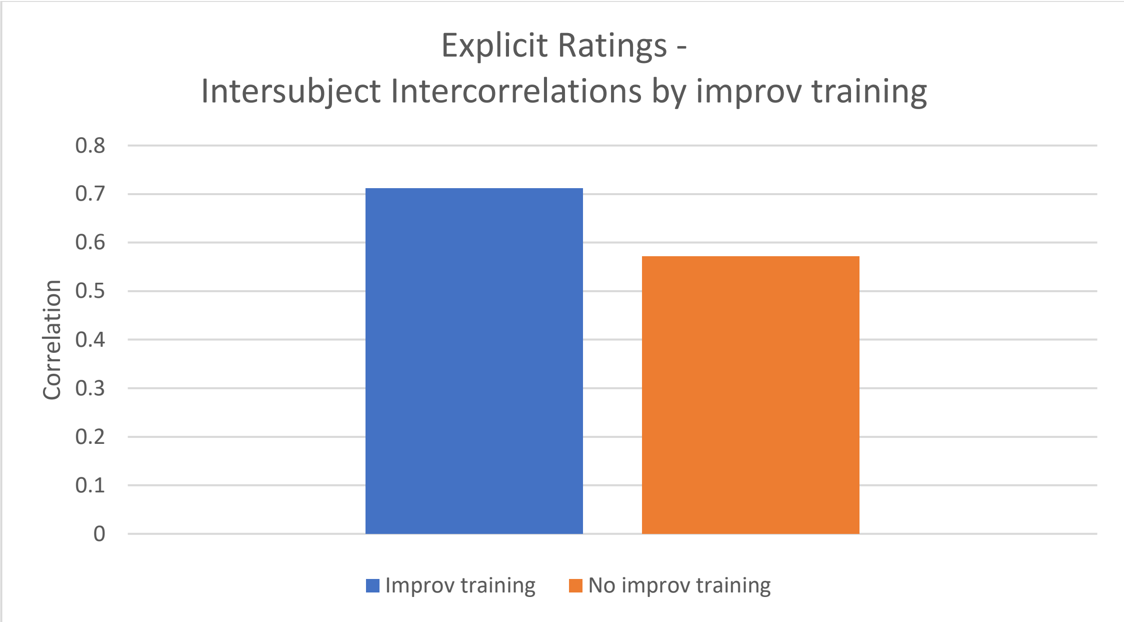

Fig. 41: Mean intersubject correlations: improv and non-improv musicians

Overall, intersubject correlation tests suggest that musical training causes an increase in consistency in ratings of surprise. This effect appears to be heightened for training in jazz and improvisation. Given that the majority of jazz musicians indicated that they improvised and jazz musicians making up the majority of musicians who had studied improvisation, it is difficult to determine whether this effect is related to improvisation or experience in jazz. Given the strong links between improvisation and expectation noted by scholars, however, the prevalence of improvisation with jazz is likely to be an important factor in these results.

5.3.2. Chord ratings and clusters

An LMM with chord rating as the dependent variable, chord type as fixed factor, and participant as random factor revealed that listeners perceived differences in expectedness between the chords tested, $F(4, 1459) = 685.729$, $p < 0.001$. Post-hoc analysis with Tukey adjustments revealed that listeners perceived each of the different chord types (inclusive of all four iterations of each chord type) as having differing expectedness levels from each other. The only exception was for the ♭VIma and Im chords, which participants considered to have the same expectedness levels.

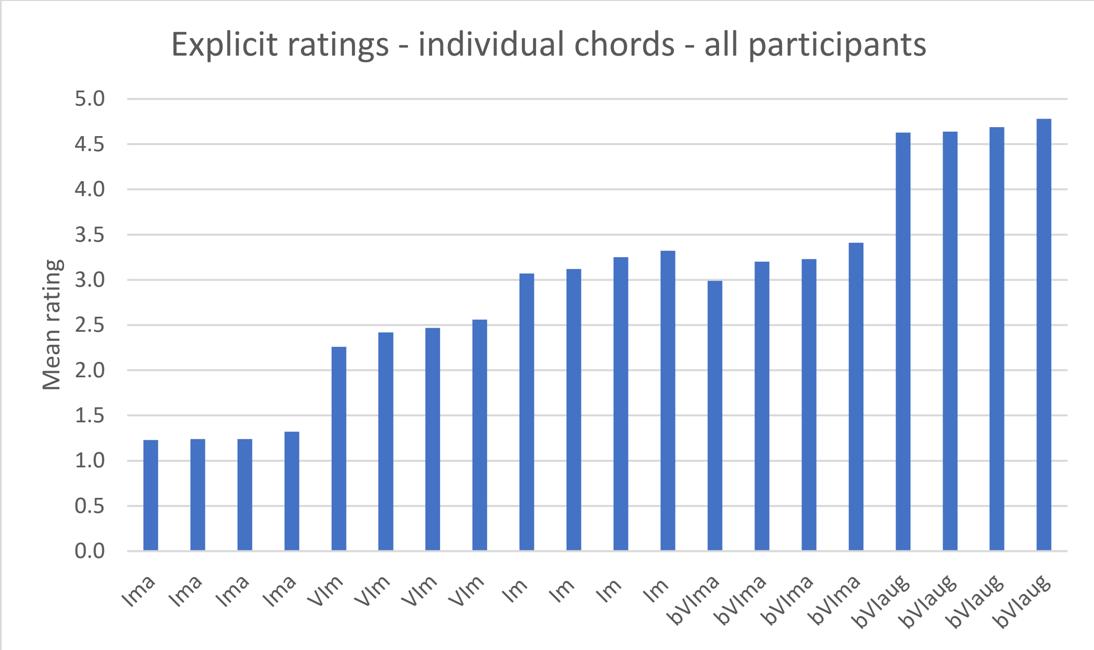

Fig. 42: Explicit ratings of chords: all participants

These results are notable as there was no verbal or written labelling of any resolution chords. Participants, including general listeners, demonstrated the ability to aurally differentiate multiple randomly presented chords in terms of their surprise levels.

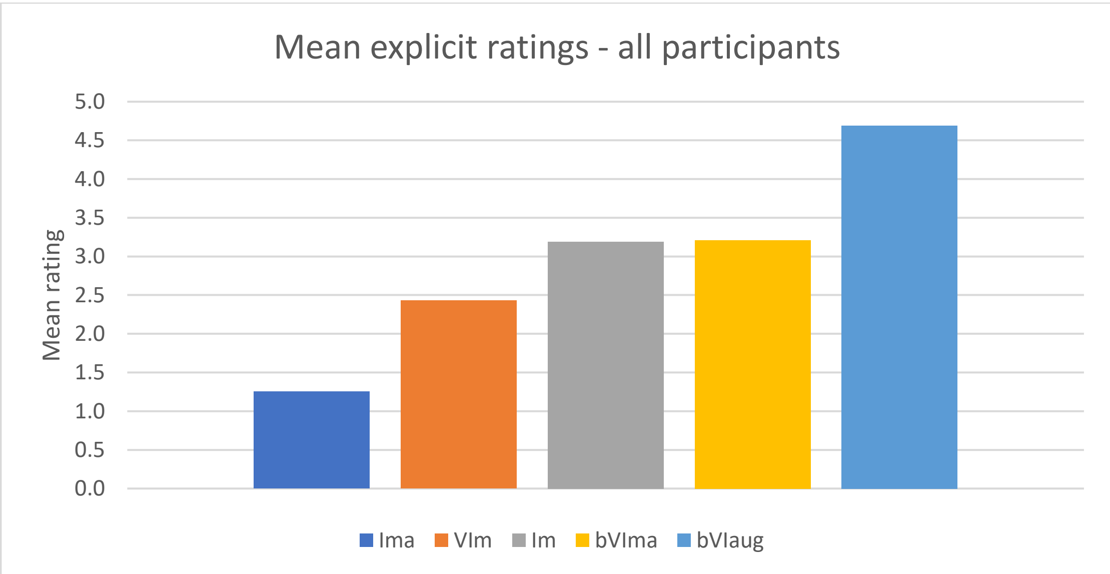

Fig. 43: Mean explicit ratings: all participants

Further analysis using hierarchical cluster modelling provided a more nuanced picture of listeners' ratings. A dendrogram plot, shown below, suggested that listeners, as a single cohort, grouped the four Ima chords and four ♭VIaug chords into two separate distinct clusters. A third cluster consisted of subgroups of the Im, ♭VI and VIm chords, with a further subgrouping of ♭VI and Im. While the LMM did not reveal significant differences in rating between the Im and ♭VI, it can be seen from the clusters that listeners, as a whole, nonetheless differentiated these chords from each other.

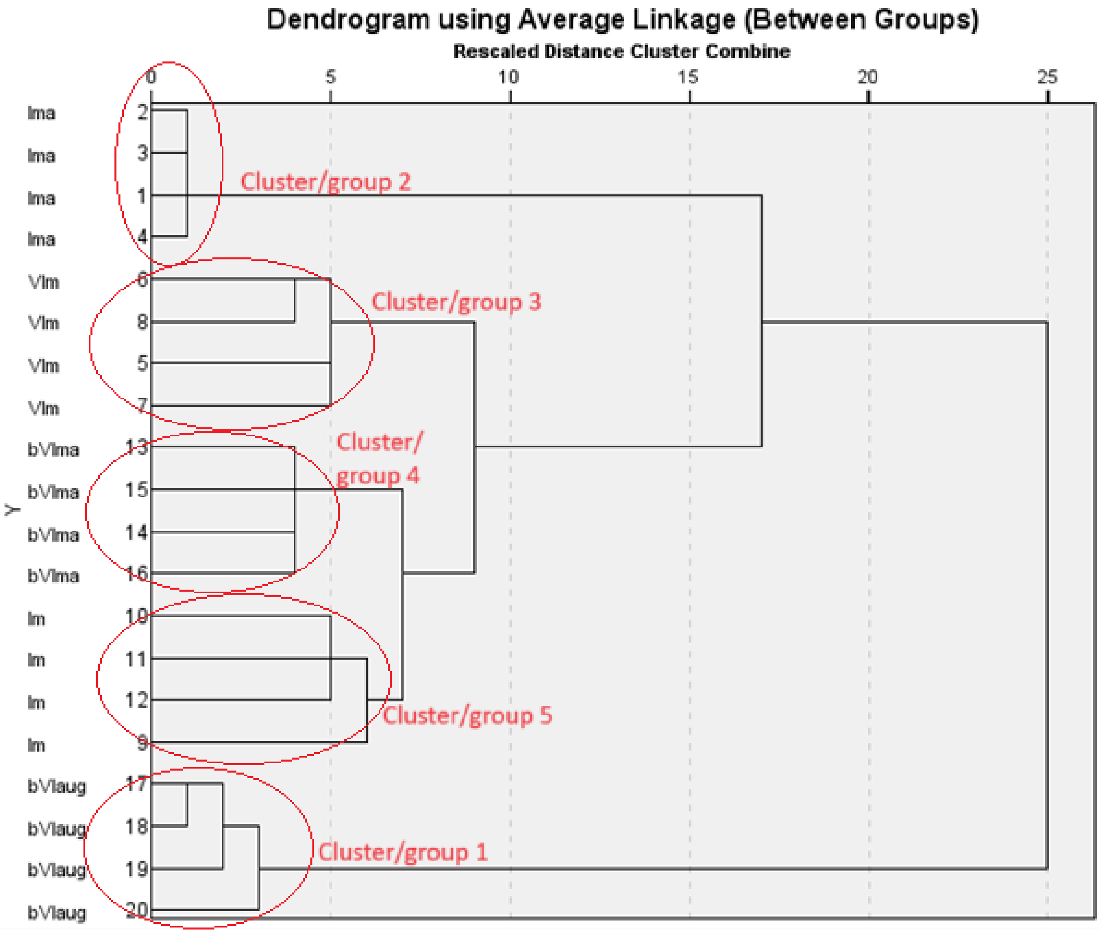

Fig. 44: Dendrogram showing hierarchical clustering of explicit ratings

All participants	
Group 1	♭VIaug, ♭VIaug, ♭VIaug, ♭VIaug
Group 2	I, I, I, I
Group 3	VIm, VIm, VIm, VIm
Group 4	♭VI, ♭VI, ♭VI, ♭VI
Group 5	Im, Im, Im, Im

Table 1: Chord clusters for explicit ratings: all participants

Participants therefore demonstrated clear gradients of expectedness. Rather than experiencing a binary effect of surprise/no surprise, participants differentiated between chords on a spectrum of four surprise levels, one for expected chords, one for diatonic/familiar deceptive chords, one for chromatic/less familiar deceptive chords, and one for incongruous/unfamiliar deceptive chords. This is an important finding as it demonstrates that binary paradigms of surprise/no surprise such as those typically used in harmonic expectation experiments may be insufficient to discover the range of surprise experienced by listeners in response to different chords. In addition, the ability of participants to differentiate between chords based on their surprise levels indicates the importance of expectation and surprise as a core element of music listening.

Although participants as a whole were generally consistent across their ratings, minor differences could be found between the reactions of musicians and general listeners, reflecting differences found in the intersubject correlation tests. This was verified by an LMM, which found a statistically significant interaction between participant category (i.e. musician or general listener) and chord type, $F(4, 1911) = 8.538$, $p < 0.001$.

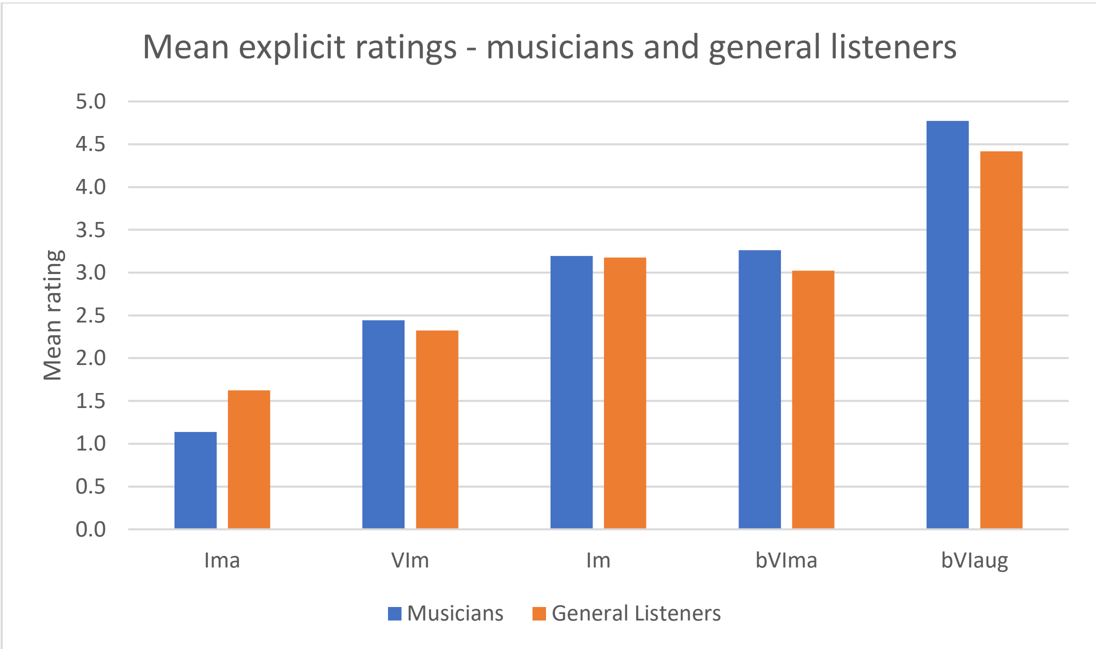

Fig. 45: Explicit ratings of chords: musicians and general listeners

The ratings of general listeners were found to be less differentiated than those of musicians. Tukey adjusted post-hoc results revealed that general listeners rated the I chord as more surprising than musicians, with an estimate of 0.483, at p = 0.009. Cluster analysis revealed that general listeners had grouped the I chord together with three iterations of the VIm. Musicians on the other hand grouped all iterations of the I chord as a distinct cluster and grouped the VIm with the other deceptive cadence chords. This indicates that musicians' ratings may have been influenced by their knowledge of the VIm as a deceptive and therefore theoretically surprising cadence, but general listeners may have been influenced more by diatonicism in their determinations of surprise.

General listeners in general showed less distinction and separation between the three different kinds of deceptive resolutions than musicians did. This provides further evidence that musical training results in a more refined ability to quantify one's own experience of musical surprise and to discriminate musical sounds by their expectedness levels. Dendrograms for all further cluster analyses may be found in Appendix D.

Musicians	
Group 1	I, I, I, I
Group 2	♭VIaug, ♭VIaug, ♭VIaug, ♭VIaug
Group 3	VIm, VIm, VIm, VIm
Group 4	♭VI, ♭VI, ♭VI, ♭VI
Group 5	Im, Im, Im, Im

Table 2: Chord clusters for explicit ratings: musicians.

General Listeners	
Group 1	♭VIaug, ♭VIaug, ♭VIaug, ♭VIaug
Group 2	VIm
	VIm, VIm
	I, I
	I, I
Group 3	VIm
	Im, ♭VI
	♭VI
	♭VI
	Im, ♭VI
	Im, Im

Table 3: Chord clusters for explicit ratings: general listeners.

Stylistic training was also found to influence participants' ratings. A significant interaction was found between jazz, pop/rock, and classical musicians with respect to chord type, $F(8, 1184.999) = 1.966$, $p = 0.047$. Post-hoc Tukey tests revealed that the pop/rock group were the only group to differentiate between the ♭VIma and the Im. This group were significantly more surprised by the Im than by the ♭VIma, $t(1185) = 2.775$, $p = 0.0445$, while the other groups rated these two chords as similarly surprising.

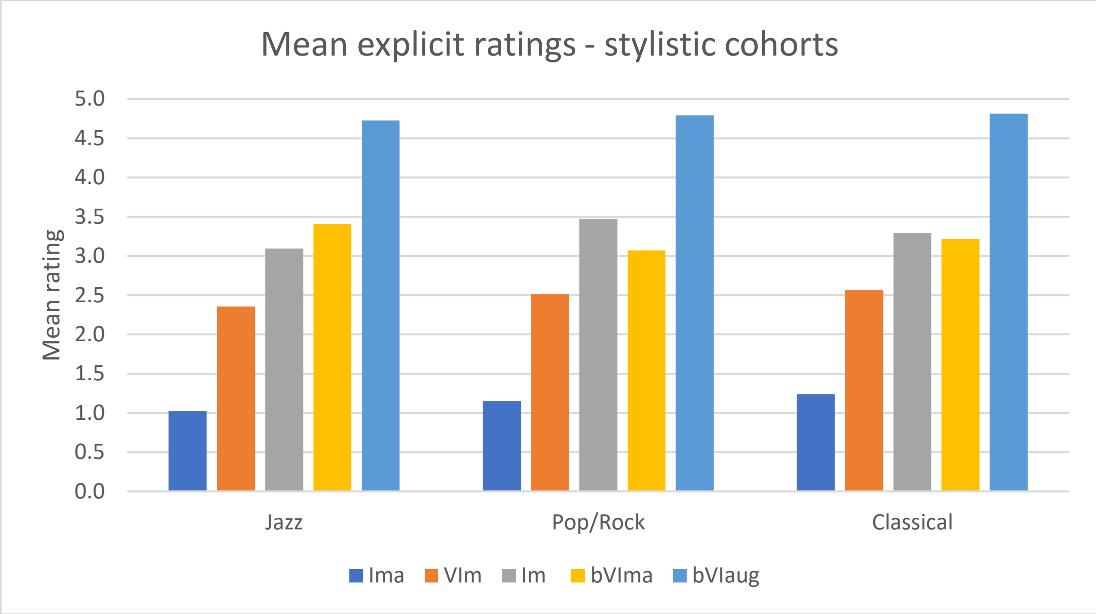

Fig. 46: Mean explicit ratings: stylistic cohorts

Cluster analysis supported this finding, revealing that pop/rock musicians clustered the ♭VI mostly with the VIm, and separated three of the Im chords into a separate subgroup. In contrast, jazz and classical musicians clustered the diatonic and chromatic deceptive chords into two distinct groups.

Pop/Rock musicians	
Group 1	I, I, I, I
Group 2	Im, ♭VI
	VIm, VIm
	VIm, VIm
	,♭VI
	♭VI, ♭VI
	Im, Im, Im
Group 3	♭VIaug, ♭VIaug, ♭VIaug, ♭VIaug

Table 4: Chord clusters for explicit ratings: Pop/Rock musicians

Although the LMM on chord ratings failed to show any distinction between the ♭VI and the Im for jazz musicians, it can be seen from the more nuanced picture of the cluster analysis that this group identified between these two types of chords, grouping the four examples of each in distinct subgroups within an overall group.

Given the prevalence of the ♭VIma in Delta blues, Chicago blues, and other progenitors of much rock music, it is perhaps not surprising that pop/rock musicians found this chord more expected than the Im. Although the Im is not unheard of as an MI chord in popular music, it is rare as a cadential chord in non-jazz contexts. These results may be seen as evidence that stylistic training influences harmonic schemas.

This conclusion is supported by the fact that no significant difference between Im and ♭VI was found for jazz musicians, within whose repertoire both cadential chords are commonly found. In addition, although the ♭VI is found in jazz, it does not comprise part of the fundamental tonal system, while popular music theorists have categorised the ♭VI within popular music frameworks (Biamonte, 2010).

Jazz musicians	
Group 1	I, I, I, I
Group 2	VIm, VIm, VIm, VIm
	♭VI, ♭VI, ♭VI, ♭VI
	Im, Im, Im, Im
Group 3	♭VIaug, ♭VIaug, ♭VIaug, ♭VIaug

Table 5: Chord clusters for explicit ratings: Jazz musicians

Classical musicians	
Group 1	I, I, I, I
Group 2	VIm, VIm, VIm, VIm
Group 3	,Im
	,Im
	♭VI, ♭VI
	♭VI, ♭VI
	Im, Im,
Group 4	♭VIaug, ♭VIaug, ♭VIaug, ♭VIaug

Table 6: Chord clusters for explicit ratings: Classical musicians

The distinction of jazz musicians' clusters may be related to their likelihood of having experience in improvising, as notable differences were found between the clusters of improvising and non-improvising musicians. Musicians who improvised were found to have grouped chords into distinctly differentiated clusters.

Improvising musicians	
Group 1	I, I, I, I
Group 2	VIm, VIm, VIm, VIm
Group 3	♭VI, ♭VI, ♭VI, ♭VI
Group 4	Im, Im, Im, Im
Group 5	♭VIaug, ♭VIaug, ♭VIaug, ♭VIaug

Table 7: Chord clusters for explicit ratings: Improvising musicians

Musicians who never improvised, on the other hand, showed much less differentiation in their responses for deceptive resolutions, grouping several separate chord types together in subgroups.

Non-improvising musicians	
Group 1	I, I, I, I
Group 2	Im
	Im, Im
	♭VI
Group 3	VIm
	♭VI, ♭VI
	VIm, VIm
Group 4	Im
	VIm, ♭VI
Group 5	♭VIaug, ♭VIaug, ♭VIaug, ♭VIaug

Table 8: Chord clusters for explicit ratings: Non-improvising musicians

The results of these analyses therefore support the results of intersubject correlations in that musical training, stylistic training, and training in improvisation appear to have effects on harmonic expectation. Specifically, musical training, and particularly training in improvisation, results in more differentiated and nuanced determinations of expectation.

In addition, the results provide initial evidence that harmonic schemas resulting from exposure to particular musical styles within Western tonal music may affect listeners' expectations, furthering the argument that CP stimuli are not representative of all Western tonal music. Jazz musicians were found to have more distinct clusters than other musicians and their results were highly intercorrelated. Another perspective on these results would note that both jazz musicians and classical musicians appeared to cluster deceptive chords based on diatonicism/chromaticism, separating the diatonic and chromatic deceptive chords into two distinct groups, while pop/rock musicians' clusters and surprise ratings appear to reflect the statistical likelihood of chords occurring within the popular music repertoire.

5.3.3. Other factors

Finally, a mixed model was fitted to the data in order to account for factors related to the audio files and to the participants and to check for interactions between these. Musical factors consisted of pitch height and chord type. Participant factors consisted of age, gender, training, theory knowledge, and musical proficiency. None of the participant or musical factors were found to influence the ratings.

5.3.4. Musical images

At the end of the listening test, participants were asked to indicate if they had experienced any musical images during the pauses in the preceding chord progressions. 50% of participants reported imagining a sound during every pause in the experiment. 30% imagined sounds on more than half of the pauses. 20% either imagined no sounds or did so only once or twice.

The highest proportion of musicians to imagine a sound on every pause were jazz musicians. The lowest proportion of musicians to do so were pop/rock musicians. Notably, proportionally more general listeners than pop/rock musicians reported imagining sounds on either every pause, or more than half of pauses, suggesting that the propensity to have predictions is not mediated by musical experience but rather an inherent aspect of general music listening.

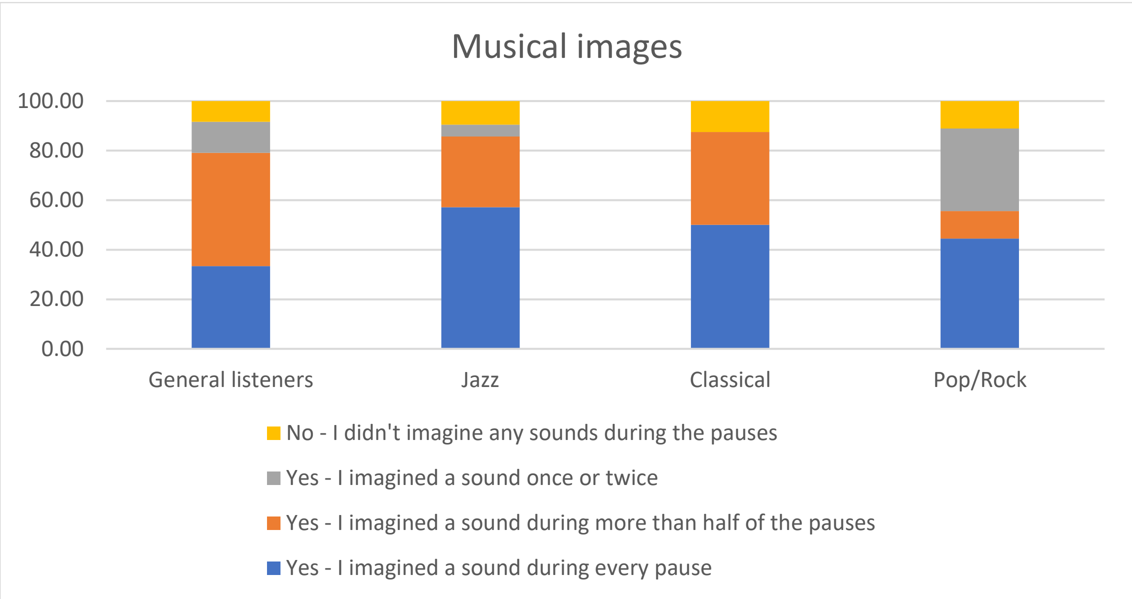

Fig. 47: Percentage of participants who experienced musical images

5.3.5. Qualitative results

Participants were keen to share their perceptions and opinions on musical expectation and surprising harmony in the optional comment section at the end of the experiment. This demonstrates that expectation is an important aspect of music listening to many people, and an element of music listening of which they are very aware. Of the 101 participants who took part in the experiments, 76 left optional comments on their experience taking the listening test. Some of the comments ran to 150 words. Terminology in the comments ranged from musically literate specialised language to broad, metaphorical generalist comments.

Many participants, particularly general listeners, were keen to give detailed descriptions of their methodology in selecting surprise ratings for the chords they heard. Many listeners thought carefully about how to interpret musical "surprise" and had strong feelings about how they went about determining surprise. For example:

> *"I imagined the final sound based on what came before, e.g. I would expect a slightly higher note based on the first three notes. My level of surprise was based on whether the final note seemed to 'fit' with the previous three."*
>
> General listener

> *"I imagined the scale always moving towards a climax, based on the tone of the first two notes."*
>
> General listener

> *"I found myself imagining which sound would be surprising/unharmonic as a final sound and which would be suitable. Then, when the final sound appeared, I compared it with my expectation and decided on that base in which degree the final sound has been surprising for me or not."*
>
> General listener

> *"I found it difficult to interpret the term 'surprising'. At the beginning I almost expected a scream or something. I eventually took it that you were questioning whether we thought the fourth chord 'belonged' in the sequence?"*
>
> Amateur musician, jazz
>
> *"I judged my 'slider' based on my instinctive reaction to what sound came next. Although in some cases I did think further about what that chord was / whether it was diatonic, etc. But that was more out of interest to see if I still*

knew how scales worked. I tried to be as instinctive as possible with regard to what 'felt surprising'."

Amateur musician, jazz

Many participants related surprise to dissonance/consonance:

"I found that there was tension in each musical phrase which needed to be resolved in the final chord. It seemed like a long wait for the final sound! If it seemed discordant or not to resolve the phrase, I noted surprise."

Amateur musician, folk

"…the progression was always a I II V and my ears were always expecting a resolution with the major I at the end (which i marked with expected everytime) anything else was 'unexpected' so i just marked the 'expectedness' based on how consonant the chords were."

Amateur musician, jazz

"I didn't imagine or predict, but I found myself waiting in suspense for the drop!! I think I based most of my choices on harmonic comfort. I am not a fan of dissonance, except for music of a horror movie ;-)"

Professional musician, classical

"Often the sounds were not the initial ones I had anticipated in the pause (mostly anticipated returning to the 1 chord) but were not surprising, especially when sounding consonant, reminded me of songs or pieces which take a slightly different direction using an unexpected cadence. Some of the more dissonant ones were surprising but not totally surprising as they had a relationship with the initial three chords, and it was understandable how they were reached, like continuing the rising sequence of bass notes, or returning to the minor version of the initial chord."

Amateur musician, classical

Several general listeners described the sounds they were hearing with unique and interesting accounts:

At every stage I imagined the next sound or tried to predict it and also a change in colour and temperature based on the original chord

General listener

"I have no musical background but I found myself 'playing' the next sound in my mind. The sounds that seemed 'off' didn't match what I had 'played' in my mind."

General listener

"I found myself predicting positive and uplifting notes in most cases, and so was surprised on the occasions when the final notes were less upbeat."

General listener

Several amateur musicians also came up with creative descriptions of their experiences, which they worked in with more traditional music theory-based descriptions:

Often, I found myself imagining the most 'comfortable' resolution chord - some kind of major root. Sometimes a minor resolution, less often other kinds of chords. I found it gave me something to gauge the 'unusualness' of the actual resolution chord.

Amateur musician, folk

"[I] always predicted the next chord as if I were practicing piano as a kid. Rarely were they the next major step and often minor which wasn't surprising but not what I had imagined. A few were jarring which surprised me."

Amateur musician, electronic

Many professional musicians and full-time music students were able to identify the chords used in the experiment and described their experience of the experiment using musically appropriate terminology.

"I was visualising the first 3 chords always in the key of C on the piano - even though I know the key was changing between the examples, which I find interesting - maybe I'm just a bit lazy! Having played lots of jazz and done a

lot of ear-training, I was able to 'map' the final chord onto the keyboard. I heard the final chord as being I, VI, ♭VI, ♭VIo and Im."

Professional musician, jazz

"Once I noticed that the final chord was always a I, ♭VI or VI, I was not surprised by the outcome, even when the chord qualities changed to melodic minor related extensions, though it is quite hard to gauge whether my opinion of my own level of surprise was objective."

Professional musician, jazz

"At first, I heard the V-vi with the same degree of surprise I might usually feel encountering an interrupted cadence in a piece of music; mild surprise. The V-i(minor) was less predictable given the major lead in. Once these (and the V-I) had been established as possible endings, my level of surprise dropped and I began to EXPECT something more dissonant. When it did appear, though, its harshness still triggered a 5 in my response. Once established as 'another possible conclusion' I think my level of surprise dropped. I began to wonder how else the tonic could be harmonised and if V- ♭VI might appear? I THINK it did toward the end, so I was only slightly surprised when that happened."

Professional musician, classical

"It's honestly ridiculous how conditioned my ear is to hearing or having the desire to hear a V-I. Even the minor V-Is caught me off guard a bit"

Music student, jazz

"I found myself imagining sounds, mainly going back to the tonic or to the relative minor - and was a little surprised when other chords took their place."

Music student, classical

Many listeners indicated that they were following the "melody", or top note of the progressions, and using whether that resolved to where they expected as a gauge for their surprise level. This indicates that it is important to factor in voice-leading when designing harmonic stimuli for experiments of this kind. Harmonic progressions in this experiment were designed so that each variation would have the same top-note voice-leading, i.e. so-la-ti-do.

> *"I imagined the sound I would hear - but it was always (I think) the doh in the top part."*
>
> Amateur musician, classical

> *"For the most part I sang over the preceding chord progressions and depending on the difficulty of changing tonality to sing over the last chord that is how I gauged how surprising it was."*
>
> Professional musician, jazz

> *"…my predictions were becoming narrower and narrower. It's like I'd developed a habit of improvising a neo-soul melody over the first three changes, and therefore expected a fourth chord that would fit my melody."*
>
> Professional musician, soul

Several participants related surprise levels to liking/disliking, which was notable as preference had been deliberately not mentioned at any point in the experiment. Listeners were not asked at any point for their preferences in terms of the progressions they heard, but the prevalence of comments regarding liking demonstrates that listeners link these two elements together themselves. Participants described positive feelings related to pleasant surprises, negative feelings related to unpleasant surprises, and positive feelings of anticipation in waiting for a resolution to the V chord:

> *"I caught myself waiting for a particular sound but not getting it most of the time, which was a pleasant surprise."*
>
> Amateur musician, pop/rock

> *"I particularly enjoyed the very surprising changes. I found them exciting and I wondered where they would go next. The unsurprising changes I found satisfying, but they closed things down, brought things to a close rather than opening up new ideas."*
>
> General listener

"A little surprising chords are my favourites: I must like being a little surprised."

Amateur musician, pop/rock

"I thought very tonally throughout, and enjoyed both the satisfaction of familiar progressions/endings and the difference/interest of unexpected endings."

Professional musician, classical

"I did find myself predicting points of resolution every time and I was nicely surprised when the resolution was not what I expected."

Professional musician, jazz

"I found it almost uncomfortable to listen to the fourth chord for many of them"

Amateur musician, pop/rock

"Surprised at myself how strongly I expect a resolution to major, and am weirded out by a minor chord."

Amateur musician, classical

"I like unexpected chords that change the entire mood, so I was often less satisfied with the many predictable sounds :-)"

Professional musician, classical

"I found myself waiting with great interest to see what the next sound might be…"

Professional musician, classical

"I found myself wanting the interval between the third and fourth note to be shorter, or to be exactly the same as between the first three. Impatient would be the wrong word as time is not an issue: maybe excited to hear what the fourth note would be."

General listener

Overall, the wealth of information volunteered by the experiment participants is evidence that musical surprise and prediction are important aspects of musical listening for professionals, amateurs, and general listeners. Even participants who described themselves as "tone deaf" volunteered erudite opinions on musical expectation and its effect on their listening experience. This suggests that this aspect of music listening is a valid and important topic worthy of research. Another important qualitative finding is that many participants described surprise in terms of pleasant/unpleasantness. This highlights the strong links between preference and expectedness.

5.4. Conclusions and discussion

This experiment aimed to address the following three research questions:

1) What are listeners own experiences of expectation and surprise.
2) Do listeners rate surprise on a gradient? That is, do different chords elicit different levels of surprise?
3) Does stylistic training and/or improvisation affect ratings of expectation and surprise?

The results of the experiment with respect to these questions are discussed below.

5.4.1. How listeners experience expectation and surprise

The results of the experiment suggest strongly that listeners have the ability to discriminate between chords in granular detail based on their own surprise levels, and that they both experience and perceive musical expectation and surprise as fundamental to musical listening. This is evidenced by the significant level of agreement between participants on the surprise levels of different chords. Given that no identification of any chords was provided for listeners, it is striking to note that all participants, including general listeners, delineated the different chord types, albeit to varying extents. This suggests that expectation and surprise are salient features of music listening for all listeners, and one that is easily understood and recognised within music. Qualitative results reinforce this, with many participants commenting on expectation and surprise in great detail in their written responses and noting their propensity to experience musical images. The prevalence of musical images, which can be considered tangible predictions in this context, lends weight to the idea that musical expectation and surprise are fundamental core processes in the experience of music.

The results of an LMM revealed that neither the participant factors of age, gender, training, theory knowledge, and musical proficiency, nor the musical factor of pitch height affected listeners' surprise ratings. The primary factor that influenced their surprise ratings was chord type, with stylistic expertise and training in improvisation found to be secondary factors.

5.4.2. A gradient of surprise

A clear gradient was found in listeners' surprise levels in response to the five different types of chords used in the experiment. All listeners distinctly rated the four Ima chords as least surprising, the VIm as the next least surprising and the four ♭VIaug chords as most surprising. These distinctions were verified by statistically significant differences in ratings. Im and ♭VI, although not differentiated between by all the participants, were placed in third. This suggests that Im and ♭VI, chords not traditionally used in music cognition experiments, are valid surprising resolutions, more unexpected than the traditional diatonic cadence, but rated by all listeners as distinctly separate from the invalid and incongruous ♭VIaug chord.

This reinforces the argument that research into harmonic expectation has neglected the wide range of means that composers use to elicit surprise within the category of deceptive resolutions.

5.4.3. Effects of musical training, stylistic expertise, and improvisation

Previous studies in harmonic expectation have found differences between the responses of general listeners and musicians (Loui & Wessel, 2007), (Przysinda et al., 2017). These results were verified in this experiment. In addition, differences were found between stylistic cohorts and between musicians who regularly improvised and those who didn't.

The primary difference found between groups was in their within-group consistency. Jazz musicians and musicians with formal improvisation training demonstrated the greatest within-group consistency, while general listeners demonstrated the lowest. This suggests that musical experience, particularly that of jazz and improvisation, leads to more definitive and consistent ratings of chords based on surprise and a more refined ability to quantify one's own experience of musical surprise.

As outlined in Chapter 2, many scholars have linked improvisation with expectation, noting that improvising musicians must constantly be ready to adjust to new musical information. It appears from these results that improvising musicians are better able to quantify their own expectations and to link them consistently with specific harmonic structures. Previous studies such as Vuust et al. (2012) and Tervaniemi et al. (2016) have found heightened responses to deviant auditory features in jazz musicians. Although these investigated only implicit sensory responses, their findings speak to a greater propensity among jazz and improvising musicians to quickly and accurately process deviant stimuli.

The results also suggest that while musicians overall are similar in terms of their explicit ratings of surprise, there are subtle differences related to harmonic language. This may be seen in the ratings for Im and ♭VI. While jazz and classical musicians were found to cluster the Im and ♭VI together and to rate them similarly, pop/rock musicians distinguished between them, rating the Im as more surprising than the ♭VI, clustering the ♭VI and VIm together and separating the Im into a distinct group. At first glance this may be related to root movement; perhaps the pop/rock musicians, who play a traditionally bass-heavy style, were influenced by the stepwise movement of the roots from V to ♭VI and VI, in contrast to the resolution down a fifth for Im. However, comparisons with the highly expected Ima, which featured the same root movement as the Im, and highly unexpected ♭VIaug, which featured the same root movement as the ♭VIma, demonstrate that this is unlikely to be the case. Rather, these listeners may be affected by their previous exposure, given the prevalence and centrality of the ♭VI in popular music contexts.

These results also point to the influence of diatonicism in ratings of surprise. Listeners, as a whole, appeared to differentiate the three deceptive chords based on their familiarity, with low surprise ratings given to the very common VIm chord, and higher surprise ratings given to the less common ♭VI and Im. However, these differentiations may also be based on diatonicism, given that the low surprise VIm is diatonic while the high surprise ♭VI and Im are both chromatic. This seems likely to be the case for general listeners who were found to cluster both the diatonic VIm and the diatonic Ima into a single group. Pop/rock musicians however, as noted above, clustered the diatonic VIm with the chromatic ♭VIma, suggesting that their ratings were based not on diatonicism but familiarity.

5.4.4. Summary

To summarise, the results of the Explicit Experiment confirm that listeners perceive and respond to harmonic surprise in nuanced and active ways and consider surprise to be an important factor in music listening. Listeners perceive harmonic surprise on a gradient, rather than as a binary phenomenon, and the ♭VIma and Im chords may suffice as valid chords with which to elicit harmonic expectation. Musical experience, jazz expertise, and training in improvisation refine listeners' abilities to quantify music based on surprise and lead to greater agreement within cohorts. Harmonic schemas may be different for different stylistic cohorts based on their musical experience and this may influence ratings of surprise. Diatonicism may be a factor in surprise for general listeners.

6. Experiment 2: Implicit reactions to deceptive cadences among stylistically diverse participants (Implicit Experiment)

6.1. Introduction

The Explicit Experiment (Experiment 1) demonstrated that listeners have distinct explicit responses to a range of cadences, and that these responses are mediated by musical training and stylistic expertise. The Implicit Experiment aims to further elucidate these results by investigating listeners' implicit responses and accounting for sensory factors, liking ratings, and voice-leading. In addition, the experiment aims to investigate a wider range of deceptive chords in order to expand the range of chords available to experimenters.

Through this investigation, the experiment aims to answer the following three research questions:

1) To what extent are listeners influenced by sensory and other factors in their reactions to deceptive harmony, and is this mediated by stylistic expertise?

   The extent to which sensory and cognitive factors affect expectation has been an ongoing debate in music cognition. No conclusive statements can be made, and it is likely that music listening features both. However, investigating this factor with a focus on stylistic expertise may yield interesting information about whether sensory processes are mediated by exposure to particular styles.

2) In what way is harmonic expectation and surprise related to liking and is this mediated by stylistic expertise?

   The question of whether expectation and surprise affect our experiences of music in positive or negative ways is an important one, and one that has been neglected to some extent in the research. Many resources have gone into determining the effects of expectation and surprise on our music listening, but if these factors have no effect on our enjoyment or appreciation of music, then this research is of little practical value. Determining how expectation affects preferences may yield useful information for composers and musicians, who may use such information in their compositions and performances.

Berlyne's inverted-U model suggests that there is a peak, or ideal, amount of deception that a musical stimulus can contain, beyond and before which liking will be reduced. However, it is likely that this zenith is not universal but rather will be dependent on musical experience. This is because, as the Explicit Experiment shows, although listeners from different cohorts have similar explicit expectations, differences exist. For example, general listeners were more surprised by the I chord, i.e. the most expected chord, than others, while pop/rock musicians were more surprised by the Im, a chord that is rare within their style of expertise, than others. Therefore, listeners' schemas, developed over time through exposure to particular music styles, are likely to mediate the point at which the zenith of harmonic surprise is reached.

3) Do listeners' reaction times (RTs) within the given experimental paradigm reflect chord expectedness and is this mediated by stylistic expertise?

The previous experiment demonstrated that participants, including general listeners, have concrete and specific ideas about the expectancy levels of chords. This experiment aims to find out if those explicit opinions extend to listeners' implicit reactions to deceptive and unexpected harmony.

6.2. Methodology

6.2.1. Material

As with the Explicit Experiment, the aim of this experiment was to determine listeners' surprise levels given a range of valid deceptive resolutions derived from the jazz/popular music repertoire. However, there were some important differences in the Implicit Experiment. Firstly, listener's implicit reactions were sought, rather than their explicit ratings of surprise. Thus, a different experimental paradigm was required. Secondly, a wider range of deceptive cadences were used. As detailed in Chapter 4, various deceptive resolutions can be justified through voice-leading, according to jazz and contemporary popular music theorists; Rochinski (2001) specifies any diatonically related chord containing the root, 3rd, 5th, or 7th of the I chord. These include the ♭VI and ♭II. In addition, Rochinski points out that the IIIm is a common deceptive resolution to V in jazz.

Therefore, to further explore deceptive cadences, several chords were added to the VIm, ♭VI, and Im used in the Explicit Experiment. The results of the Explicit Experiment demonstrated that diatonicism may be a stylistically mediated factor in expectedness, given that general listeners clustered the diatonic chords together in terms of their expectedness, jazz and classical musicians clustered the chromatic chords into a separate group to the diatonic deceptive chords, and pop/rock musicians did not appear to be affected by diatonicism at all. Therefore, to further investigate this phenomenon, a deceptive resolution to the diatonic IIIm chord was added. Progression from V to IIIm is commonly found in the jazz repertoire, for example in Jobim's "Chega de Saudade" (1958), and the Jimmy Van Heusen standard "But Beautiful" (1947).

Several additional chromatic deceptive resolutions were also added. These included the IVm. This chord is a commonly found modal mixture chord in Baroque and Classical music, as detailed in Chapter 3. This chord may also be found in the jazz repertoire, for example in the Jimmy Van Heusen standard "Darn That Dream" (1939). The ♭VII and ♭II, which may be found as cadences in many jazz and popular tunes, notably Mary Lou Williams' "Lover" (1954), and the ending of the Dan Fogelberg tune "Same Old Lang Syne" (1981), were also added. In addition to the ♭VIaug "unexpected" chord, three incongruous chords were added: the IIaug, ♭IIIdim and ♭IIdim. In addition, another set of incongruous, unexpected chords, with no theoretical justification, were added. These were the minor triads, ♭VIIm, ♭VIm, and ♭IIIm. Target chords used in the experiment, their categories and justifications are outlined in the table below:

No.	***Category***	***Resolution***	***Justification***
1-6	Expected	I major	Diatonic resolution
7	Diatonic Deceptive	VI minor	Traditional deceptive cadence
8	Diatonic Deceptive	III minor	Diatonic cadence common to jazz
9	Chromatic Deceptive	♭ VI major	Modal interchange
10	Chromatic Deceptive	IV minor	Modal interchange
11	Chromatic Deceptive	♭ II major	Modal interchange
12	Chromatic Deceptive	I minor	Modal Interchange
13	Chromatic Deceptive	♭ VII major	Modal Interchange
14	Unexpected	I augmented	Incongruous

15	Unexpected	II augmented	Incongruous
16	Unexpected	♭ III minor	Incongruous
17	Unexpected	♭ II diminished	Incongruous
18	Unexpected	♭ VI minor	Incongruous
19	Unexpected	♭ VII minor	Incongruous
20	Unexpected	VI diminished	Incongruous

Table 9: Harmonic material used in the Implicit Experiment

Since the experimental stimuli consisted of a wide range of different chords, voice-leading could not be controlled and so was factored in as an independent variable in the final analysis to determine its effects on listeners liking ratings and RTs.

6.2.2. Experimental paradigm

In the majority of previous experiments where listeners' implicit expectations were sought, RT priming paradigms have been used. These paradigms were initially used in the study of linguistic semantic facilitation (Meyer & Schvaneveldt, 1971), (Swinney, 1979). In an RT priming paradigm, participants are presented with a prime stimulus such as a word, sentence, or musical context, followed by a target. The target may be related or unrelated to the prime. Participants are asked to make a judgement on the target chord that involves some aspect of processing, and their RTs are measured. It has been found that when targets are related to primes semantically, syntactically, or physically, their processing is facilitated, and RTs are shorter (Bharucha & Stoeckig, 1986), (Draine & Greenwald, 1998). This is taken to be a measure of the expectedness of the target in relation to the prime, (Schmuckler & Boltz, 1994) given that less expected targets will result in an increased attentional requirement, leading to less attention available for the RT task (Kahneman, 1973).

Various aural processing tasks have been used to test facilitation in this paradigm. For example, multiple studies have asked listeners to detect mistuned notes within target chords (Bharucha & Stoeckig, 1986), (Justus & Bharucha, 2001), (Marmel & Tillmann, 2009). This is a popular paradigm, but it is not immune to criticism. Tillman et al. (2006) have pointed out that listeners may inadvertently associate the dissonance of the mistuning with the unrelatedness of the chord, causing what appears to be faster processing of related chords when they are in tune. Tillman et al. instead use a same/difference timbre discrimination task in order to avoid this potential confound. This task involves listeners discriminating between same/different timbres between the prime and target chords. However, it could be argued that there may also be a confound in using a same/difference task, as listeners will expect the target to continue with the same timbre as it began. In addition, where a same/different timbre task is used, there may be similarities between timbres based on their instrument family, i.e. primes heard with a violin timbre may be more similar to targets with a guitar timbre in comparison to targets with a piano timbre.

In this experiment, a novel discrimination task was used, in order to avoid confounds related to dissonance or timbre. A left-right spatial discrimination task was used. Prime progressions were held constant in their spatial position in the headphones, with equal volume in the left and right ears. In half of the cases, targets were played exclusively in the left headphone, and in the other half exclusively in the right headphone. Listeners were asked to press the left arrow on the keyboard if the chord was heard in the left ear, and the right arrow if it was heard in the right ear. This ensured no possible confounding effect of timbre, tuning, or same/difference effects. Since there is equal likelihood of the target being in either ear, there was no biasing effect either way. The independent variable was the expectedness of the target chord, and the dependent variable the RT to its spatial position.

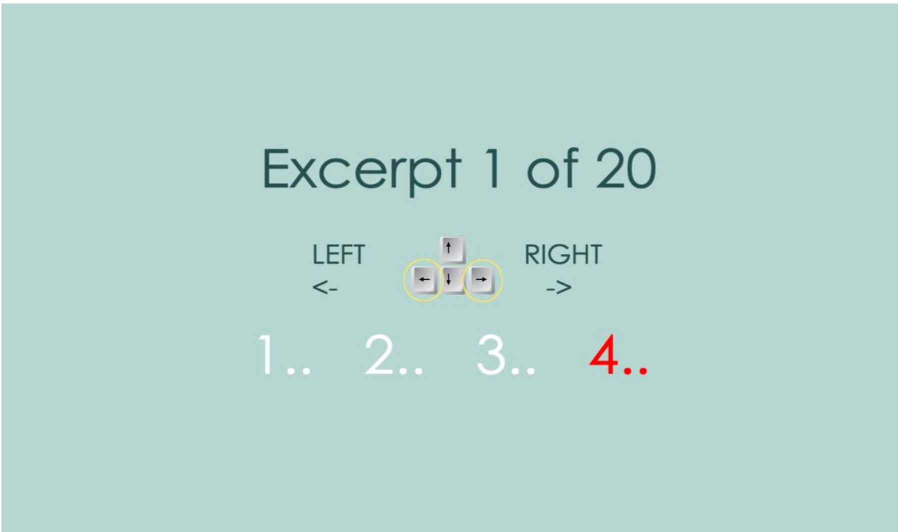

Fig. 48: RT question screen in the Implicit Experiment

It has been demonstrated that musicians may have slightly faster RTs to spatial discrimination tasks overall, but the effects are non-significant, therefore no significant difference in RT should be expected (Prior & Troup, 1988). However, this does raise the question of whether the groups may have different laterality effects, which could cause confounds within the paradigm. It has been suggested that musicians may have increased sensitivity to left ear stimuli and general listeners to right ear stimuli, as a result of differences in music processing lateralisation (Bever & Chiarello, 1974). However, other studies have found evidence that no such effects exist (Zatorre, 1979), or that they are alleviated by practice (Kallman & Corballis, 1975). In preliminary testing of results, no effect of left/right positioning was found through a one way ANOVA, suggesting that the paradigm was free of confounds relating to laterality effects.

In addition to gauging listeners' expectation levels for chords, liking ratings for each chord were also gathered. After each prime/target pair, listeners were asked to indicate on a sliding Likert scale how much they liked or disliked the progression they had just heard.

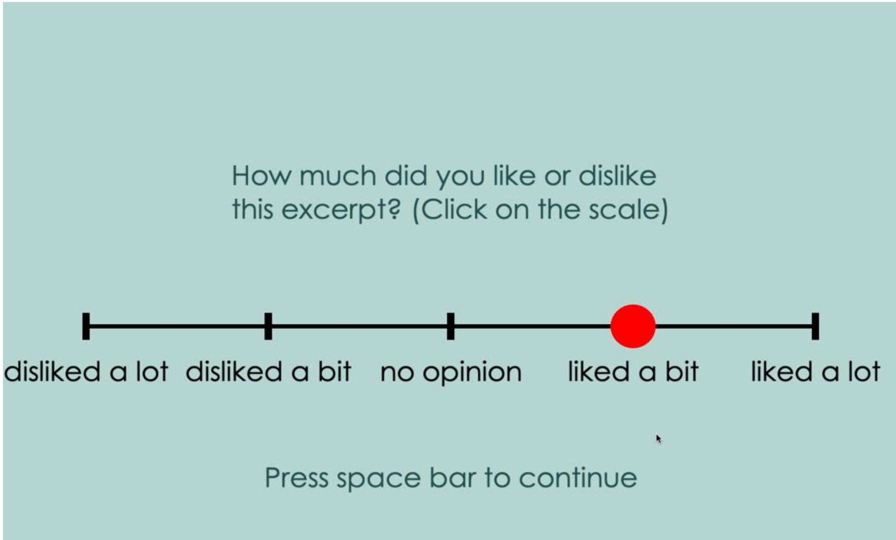

Fig. 49: Liking question screen in the Implicit Experiment

6.2.3. Procedure

The study was conducted at the Digital Media Centre in Technological University Dublin City Campus, and at the Centre for Jazz Performance Studies at Dublin City University. The experiment was implemented on the software PsychoPy, an open-source application for building interfaces for cognitive experiments, with RTs recorded through the PsychoPy software (Peirce et al., 2019). MuseScore ("MuseScore," 2002) an open-source music notation software with MIDI playback capabilities was used to generate the musical prime/target stimuli. Each prime was played at 120bpm and consisted of a 1-bar count-in heard on a clave, followed by a semibreve I chord on a stereo piano timbre to establish the tonal centre. This was followed by a minim IV chord and a minim V chord to set up an expectation for a return to I.

Targets then consisted of expected, deceptive or unexpected semibreve chords heard in either the left or right ear, using a piano timbre. Target chords followed precisely on beat 1 of the subsequent bar, to avoid any confounds related to unexpected temporal elements. Triads were voice-led in closed position, beginning in root position and ascending over the course of the sequence. In order to account for the effects of expectation for continuation of direction (Bregman, 1990) all resolutions ascended in the same manner, except in cases where ascending would cause a jump of greater than a minor third in the top voice. Tonal centres of the stimuli were randomised, as was the order in which they were presented.

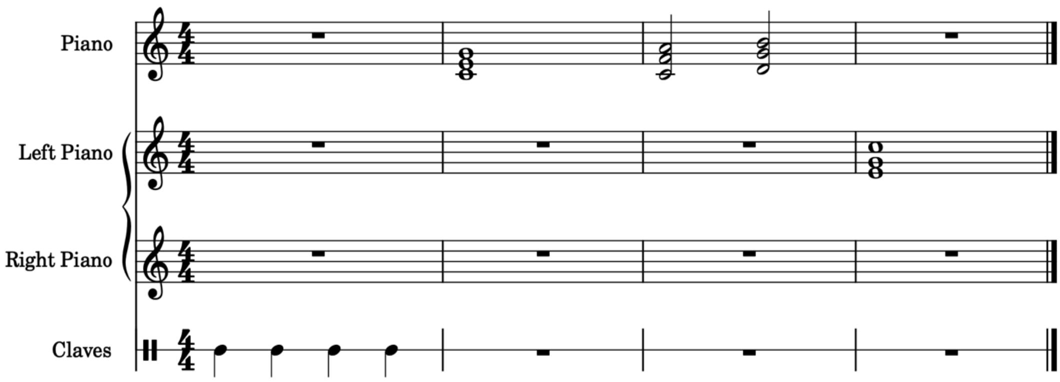

Fig. 50: Notated example of expected condition in Implicit Experiment

Participants were asked to complete a questionnaire giving details of their musical experience and education and the importance of music in their daily lives (See Appendix E). They were then asked to sit in a sound-isolation booth and wear headphones and undertake a short training session before the experiment began. In this training session, they were exposed to seven primes consisting of I-IV-V progression and targets as detailed in the previous section, consisting of expected, deceptive, and unexpected chords. This training session ensured that learning effects, whereby listeners' RTs increase over time due to familiarity with the paradigm, would be less likely to confound the experiment results. Participants then undertook the experiment, which consisted of 20 chord progressions.

6.2.4. Participants

58 participants took part in the experiment. 25 participants were female and 33 were male, and their ages ranged from "18-25" to "56-65", with the largest cohort of participants falling in the "26-35" age bracket (42%). One participant did not log any RTs due to a technical error, although their liking ratings were recorded. Three participants were found to have increased

their RTs significantly over the course of the experiment, suggesting a learning effect in spite of the training element of the experiment, and so their data were not included. Therefore, while data for 58 participants were included for the preference ratings, only 54 were included for RTs.

21 participants did not play a musical instrument (including voice) and had never studied music, and so were placed in the category of “general listeners”. Two participants played a musical instrument but rated themselves as beginners with less than two years of musical experience, and so these participants were also categorised as general listeners, to give a total of 23 in this category. The 35 remaining participants, all of whom played a musical instrument, were categorised as “musicians”. The majority of musicians had been playing their instrument for more than 10 years (n = 28), and/or had studied music full-time at university (n = 26). All but four had completed more than two years of formal musical training, with “>10 years training” as the mode value. Of the four musicians who had not received musical training, two described themselves as professional musicians, and two had been playing their instrument for more than 20 years.

Participants selected their primary style from a list. 17 musicians selected “jazz” as their primary style. This was by far the largest cohort. Six selected pop/rock, one selected traditional and one selected classical. 10 participants selected multiple styles as primary. Musicians were categorised into jazz, pop/rock, and other.

6.2.5. Data cleaning and test selection

1155 preference values on a Likert scale from 1 to 6 and 1137 RT values were recorded in total. 54 RT values were found to lie more than two standard deviations beyond mean individual RT. These values represent 4.75% of the total data, within the standard acceptable 5% cut-off for removal, and so were deleted from the dataset (Baayen & Milin, 2010) and replaced with data points calculated from the means of both participant RT and chord RT (Lachaud & Renaud, 2011). Three missing RT data points and five missing preference data points were replaced using the same method. The overall mean RT for all participants across all progressions was found to be 756ms. These values are broadly consistent with those typically found in research involving auditory choice RT paradigms (Donders, 1869/1969), (Surwillo, 1973), (Jain et al., 2015). Initial t-tests and correlation tests found no relationship between RTs and age, gender, left/right-handedness, or years playing.

Participant's RTs were normalised, within a range of 0 to 1, following Egermann et al. (2013), in order to account for varying general reaction delays between participants.

Data were again analysed using SPSS and R, and significance values of .000 in SPSS are reported as <0.001 (Cronk, 2018).

As with the Explicit Experiment, correlation tests were determined to be the most effective option to investigate participants' agreement with each other in their ratings.

Hierarchical clustering was used to investigate how participants grouped chords in terms of liking. This was initially also performed for RT values but was found to be an ineffective analysis method as no coherent groups could be determined. As with the Explicit Experiment, linear mixed models (LMMs) were used to determine factors influencing both RT and preference.

Due to the low number of participants in comparison to the Explicit Experiment, some planned statistical tests did not have the required power, and so finer details such as differences in RT to chord groups between participants of styles such as popular music and classical could not be investigated. However, differences could still be observed through the use of clustering algorithms and general patterns found through LMMs with power > 0.8.

6.3. Results

6.3.1. Implicit ratings

6.3.1.1. Intersubject Correlations

Mean intersubject correlations for normalised RTs approached 0 for all groups. This is suggestive of a lack of consensus among any group of participants in their RTs. This contrasts with the strong consensus between overall groups and individual cohorts in the Explicit Experiment.

6.3.1.2. RTs

A one-way ANOVA revealed that jazz musicians had faster RTs overall in comparison with both general listeners and musicians from the "other" category, $F(3, 1016) = 3.974$, $p = 0.008$. RTs, which had been normalised to a range between 0 and 1, were fastest in response to the diatonic deceptive chords of VIm and IIIm, with a mean of 0.305 (normalised value) for this category. The slowest RTs were found to be in response to the unexpected category at 0.393. Chromatic deceptive chords, consisting of IVm, Im, ♭II, ♭VI, and ♭VII, had the second slowest mean RT of 0.379, while the mean RT to expected chords was 0.358, the second fastest.

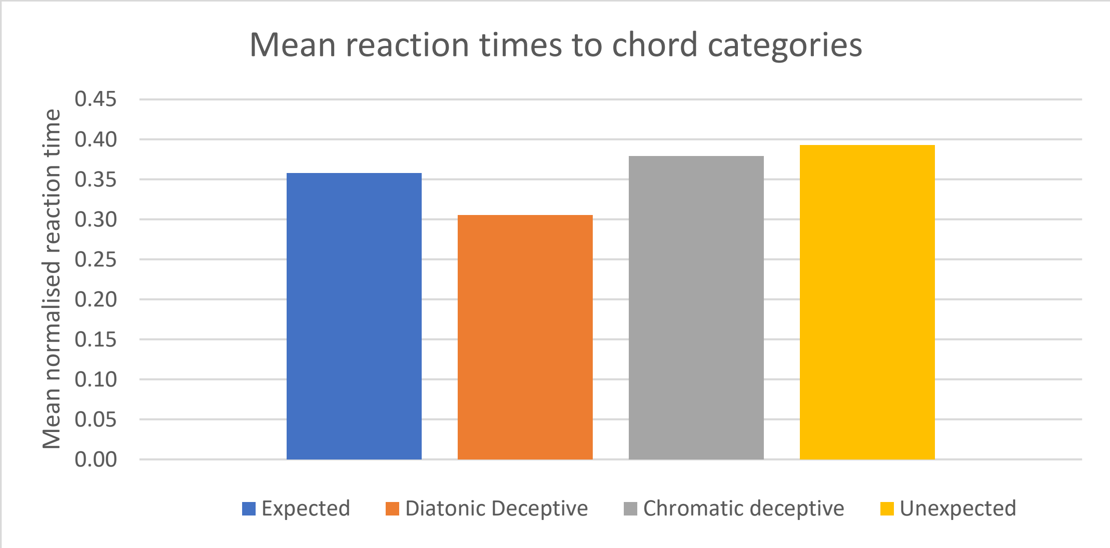

Fig. 51: Mean RTs: all participants

LMMs revealed that differences in RTs between chord categories for general listeners were statistically non-significant, meaning that general listeners did not differentiate between cadence types in their RTs. In contrast, significant differences between categories were found for musicians, who had faster RTs to diatonic deceptive chords and slower RTs to unexpected chords, $F(3, 567) = 5.047$, $p = 0.002$.

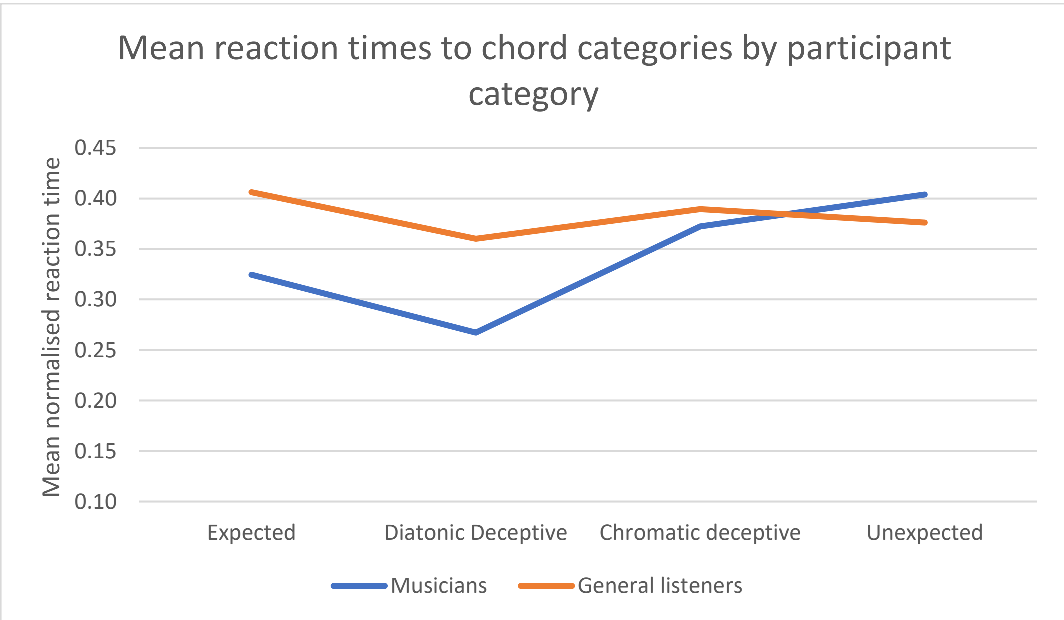

Fig. 52: Mean RTs: musicians and general listeners

Faster RTs for deceptive diatonic chords in musicians were primarily accounted for by musicians in the "other" category, who reacted significantly faster to these chords, and significantly slower to unexpected chords, $F(3, 187) = 5.159$, $p = 0.002$. In addition, pop/rock musicians were found to have significantly faster RTs to expected chords and significantly slower RTs to chromatic deceptive and unexpected chords, $F(3, 130) = 4.184$, $p = 0.007$.

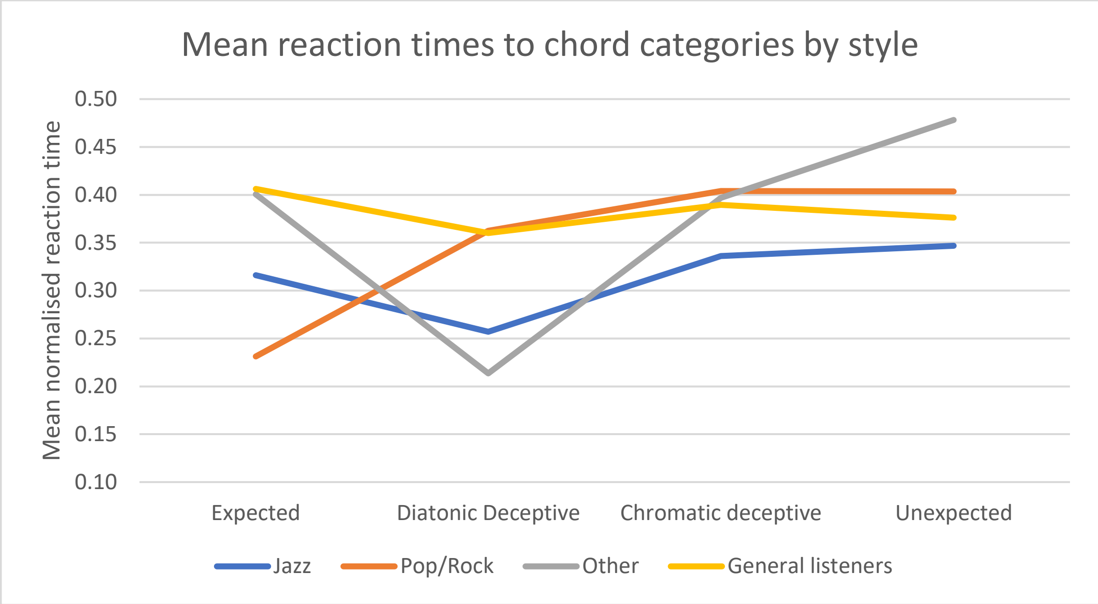

Fig. 53: Mean RTs: stylistic cohorts

Jazz musicians were found to have statistically significantly faster RTs overall, indicating facilitated processing of chords in every category in comparison to general listeners, while pop/rock musicians appeared to have facilitated processing for expected and diatonic deceptive chords, and inhibited processing for chromatic deceptive and unexpected chords.

Classification analysis was performed but did not reveal any useful information. Dendrograms may be found in Appendix E.

6.3.1.3. Sensory and other factors

Much of the discussion around harmonic expectation centres on the competing influences of sensory versus cognitive factors. Researchers have found evidence for the primacy of cognitive processing (Bigand & Pineau, 1997), sensory processing (Bigand et al., 2014), and for a combination of both types of processing (Tekman & Bharucha, 1998), whereby predictions are elicited based on sensory factors for short stimuli and cognitive for longer stimuli. Given that in this experiment listeners were asked to respond to stimuli as quickly as possible, it is likely that both sensory and cognitive factors influenced participants RTs. Therefore, a sensory model was used to determine how much of an effect sensory processes had for listeners.

The model chosen was Leman's IPEM model (Leman et al., 2001), as this is the only current model that has the capacity to both process harmony and to operate on raw audio files such as those used in the current experiment. This model has been proven effective at modelling sensory processes (Craton et al., 2021), (Goldman et al., 2021), (Bigand et al., 2014) The IPEM model processes audio signals through an "auditory periphery module" in which periodicity analysis is used to obtain a pattern of periodicity pitch. The resulting pitch images are then integrated in order to obtain approximations of echoic memories at both fast and slow decay rates. Correlation values between local and global pitch images are then calculated in order to determine the congruity between sounds and their current contexts. By obtaining correlation values for the targets of the progressions in this experiment, the acoustic signals may be compared to participants' ratings in order to determine how much influence sensory effects have on their answers. Meaned correlation values for each of the target chords in the experiment were gathered using the IPEM library within Matlab. These are listed below, with low correlation values reflecting low integration of the target chord into the given auditory context, and thus high potential surprise levels, and vice versa.

Chord	Key	Mean correlation
♭VIIm	C	0.6699
♭IIIm	F♯	0.6717
♭II	C	0.6903
♭VI	Db	0.7108
♭VIaug	D	0.7265
IIaug	G	0.7628
IVm	Bb	0.7700
♭VIm	E	0.7733
♭IIIdim	B	0.7958
♭VII	Ab	0.8143
VIm	F	0.8208
I	Bb	0.8238
I	Ab	0.8457
♭IIdim	Eb	0.8689
I	E	0.8690
Im	F♯	0.8695
I	F♯	0.8846
IIIm	A	0.8900
I	C	0.8942
I	D	0.8971

Table 10: IPEM correlation values for target chords in the Implicit Experiment

Linear regression with normalised RTs as the dependent variable and IPEM sensory values meaned over relevant chord windows revealed a significant effect of sensory mean values on musicians' RTs, F(1, 18) = 5.933, p = 0.025, although no effect was observed for general listeners.

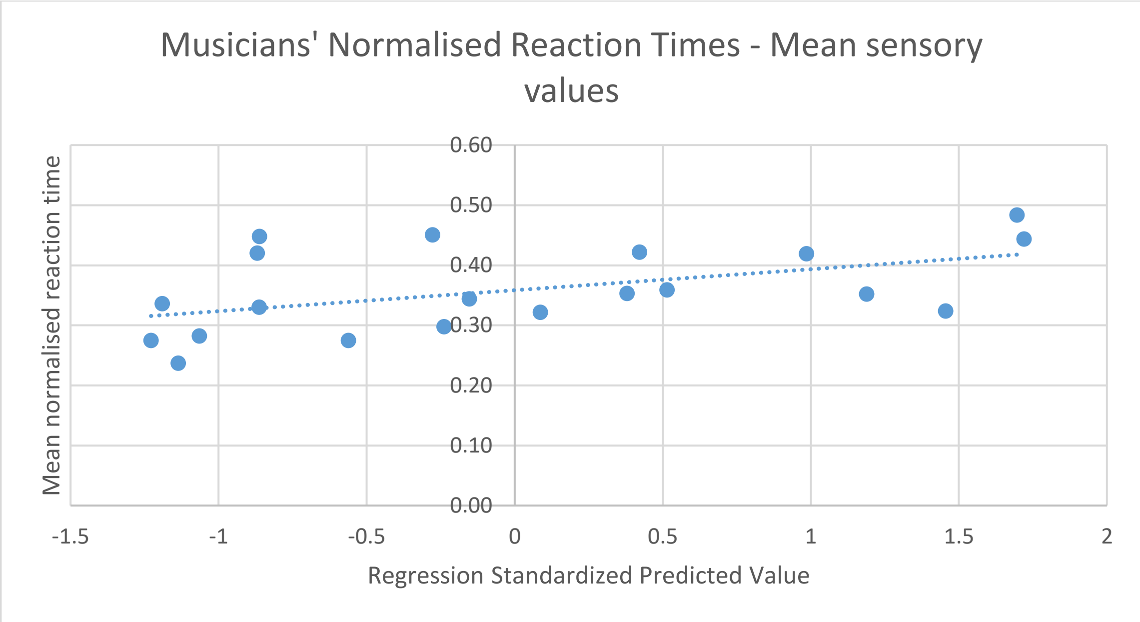

Fig. 54: Regression model of musicians' RTs and IPEM values

Further investigation revealed that this effect among musicians was primarily accounted for by the pop/rock musicians. This group were found to be significantly influenced by sensory factors, according to the regression model, F(1, 18) = 9.788, p = 0.006.

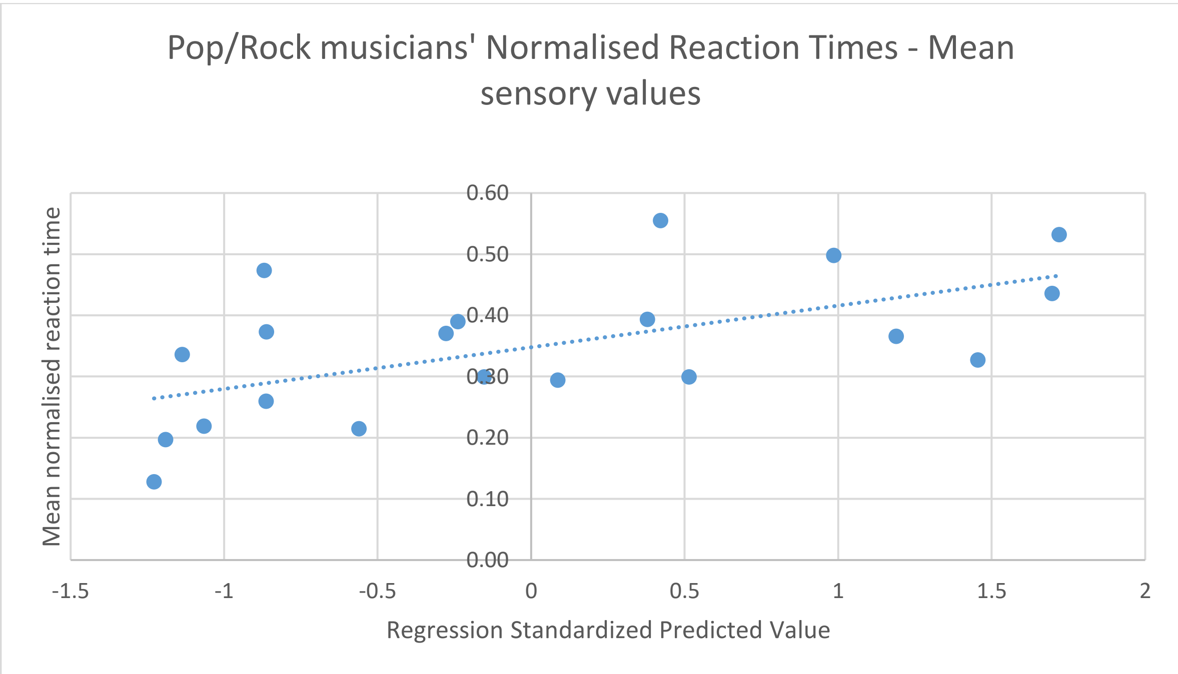

Fig. 55: Regression model of pop/rock musicians' RTs and IPEM values

Male participants were also found to be influenced by sensory factors, $F(1, 18) = 8.694$, $p = 0.009$. A significant influence was not found for female musicians. This may have been due to the fact that pop/rock musicians were predominantly male in the study, but accounting for this by excluding pop/rock musicians still found an effect of gender, suggesting that male participants in this context may have been more influenced by sensory than cognitive factors. An LMM with fixed factors of gender and sensory values found an interaction for sensory values and gender, $F(1, 967) = 5.268$, $p = 0.022$.

Additionally, professional musicians, in contrast to intermediate or advanced musicians, were found to be significantly influenced by sensory factors, $F(1, 18) = 16.389$, $p < 0.001$.

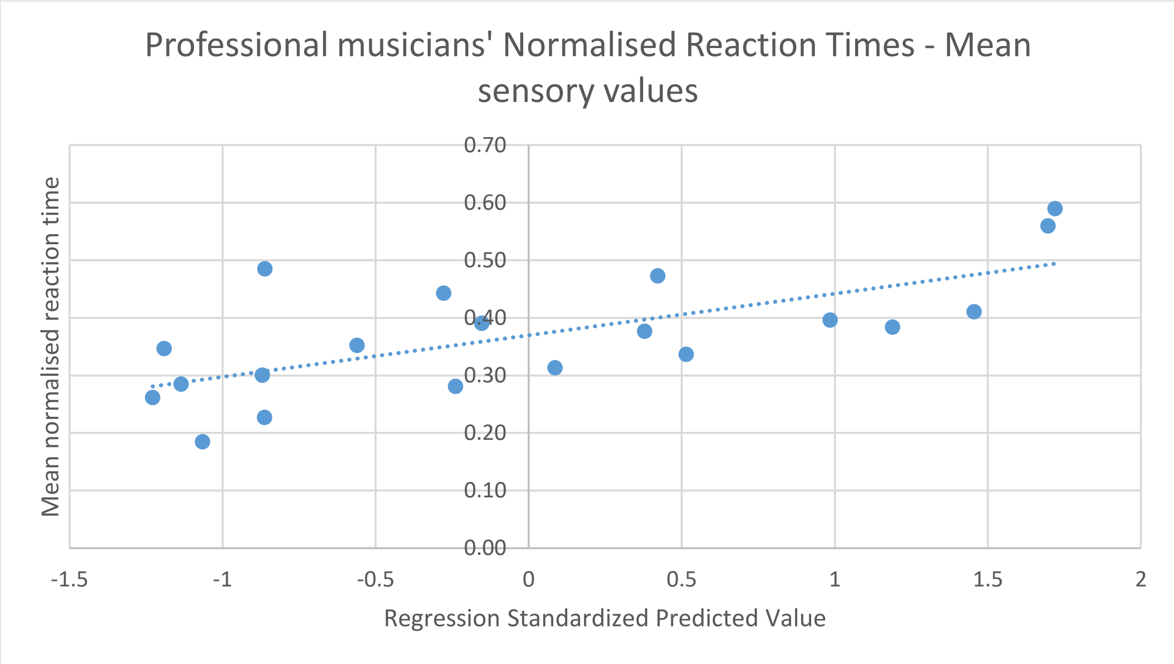

Fig. 56: Regression model of professional musicians' RTs and IPEM values

An LMM was fitted to the normalised RT data in order to account for factors related to the audio files and to the participant characteristics and to check for interactions between these. Musical factors consisted of voice-leading, pitch height, key distance, and chord type. Participant factors consisted of age, gender, propensity to be distracted by music, training, theory, experience, and proficiency. No effects of gender, age, pitch height, key distance, distraction, proficiency, training, or experience were found.

Voice-leading was found to have a significant effect on listeners' RTs, $F(3, 966) = 4.041$, $p = 0.007$. Post-hoc Tukey tests revealed that participants reacted significantly slower to chords that voice-lead up a whole tone or down a semitone. Voice-leading patterns for each chord quality may be found in the table below. No significant interaction was found between voice-leading and style, suggesting that voice-leading was a significant factor for all participants. This finding reflects the qualitative data found in the Explicit Experiment, in which several participants noted their own tendencies to follow the top-note of the chords in order to make judgements of expectedness.

Voice-leading	Chords
Same note	IIIm, ♭VIm
Up a semitone	Ima, ♭VI, ♭VIaug, ♭IIIdim, IVm, VIm, Im
Down a semitone	♭VII, IIaug, ♭IIIm
Up a whole tone	♭IIdim, ♭VIIm, ♭II

Table 11: Voice-leading patterns for each target chord in the Implicit Experiment

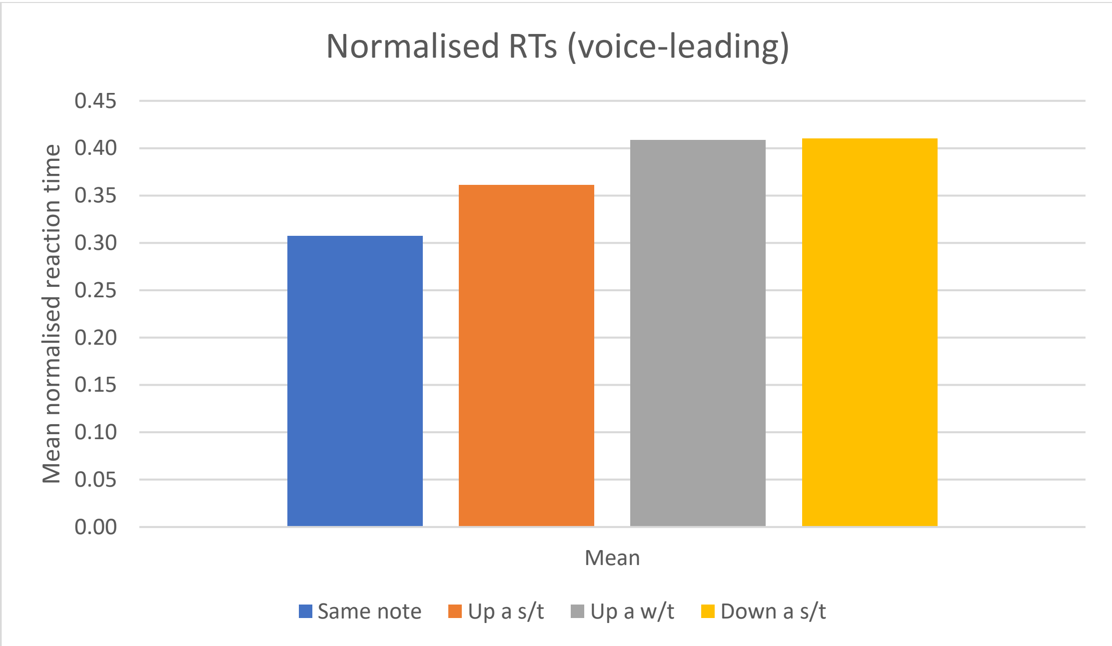

Fig. 57: Mean normalised RTs for voice-leading categories

6.3.2. Liking ratings

6.3.2.1. Intersubject Correlations

Mean intersubject correlations for liking ratings were weaker than those found in the Explicit Experiment, but substantially higher than those found for RTs. In contrast with the results of the Explicit Experiment, where general listeners had a lower mean correlation than musicians, general listeners were found to have higher mean correlations than musicians in terms of their preferences. This suggests that although trained musicians are more conclusive about what they find surprising, they have less consensus about what their preferences are. In contrast, while general listeners are less conclusive about what they find surprising, they are more consistent about what they like. While jazz and pop/rock musicians showed strong agreement in their explicit ratings of chords, they showed little agreement in the chords that they liked. Musicians from the "other" category appeared to be similar for both experiments.

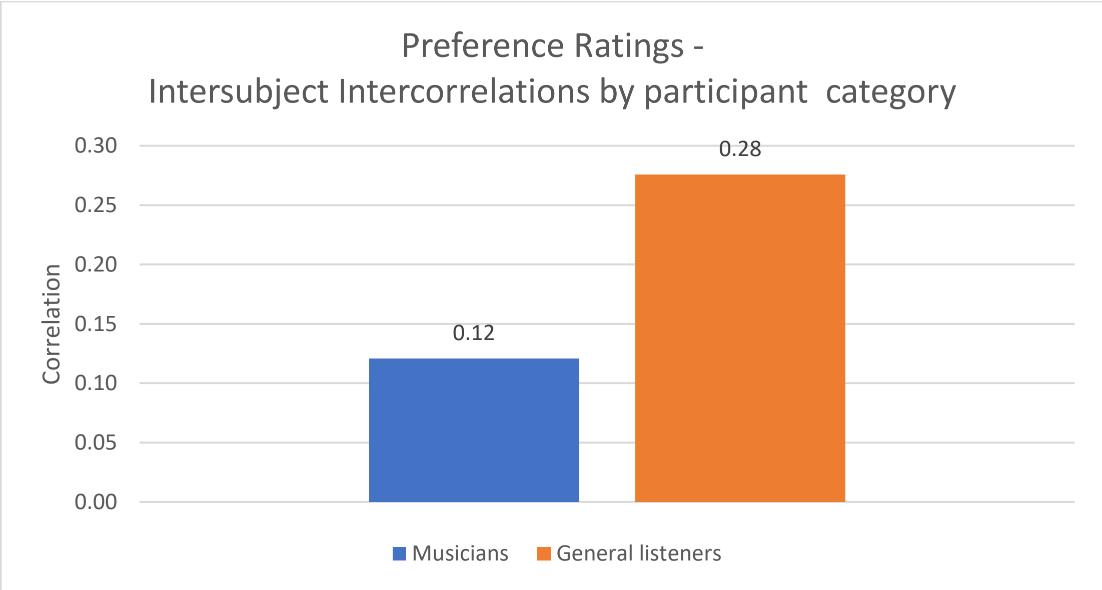

Fig. 58: Mean intersubject correlations: musicians and general listeners

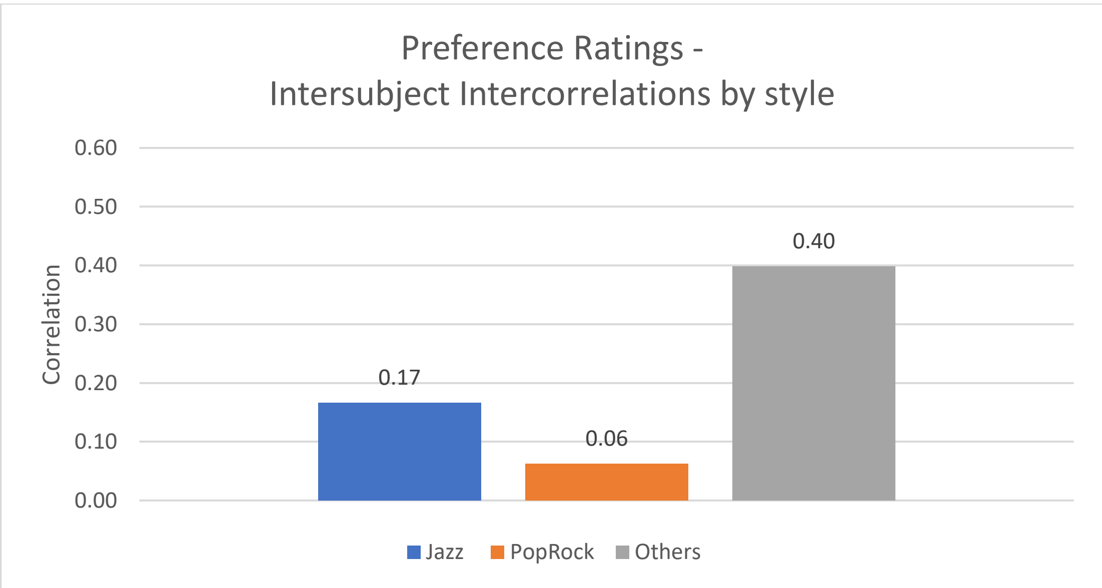

Fig. 59: Mean intersubject correlations: stylistic cohorts

6.3.2.2. Liking ratings and clusters

An LMM found that musicians had a significantly higher overall mean rating than general listeners, $F(1, 55.94) = 11.743$, $p < 0.001$, suggesting higher overall general preferences. No overall differences were found in the ratings of musicians of different styles.

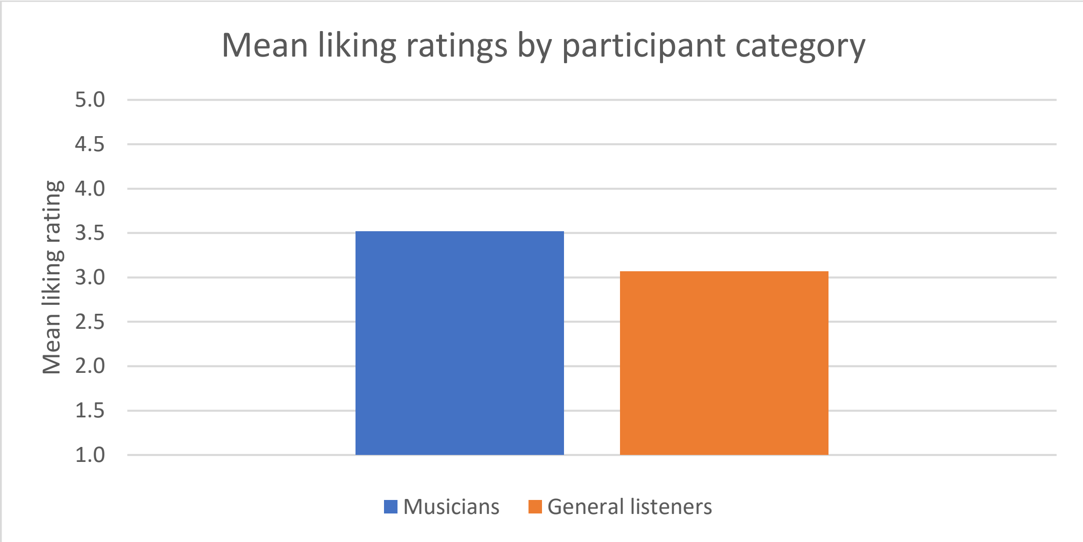

Fig. 60: Mean liking rating: musicians and general listeners

The most preferred chord category across all participants was found to be the diatonic deceptive category, with a mean rating of 4.01/5. The lowest rated category was that of the unexpected chords, with a mean rating of 2.91/5. The second most liked chord category was the expected category, with a rating of 3.66/5, while the chromatic deceptive category was rated 3.29/5. These differences were found to be statistically significant by an LMM, $F(3, 1094.22) = 50.452$, $p < 0.001$.

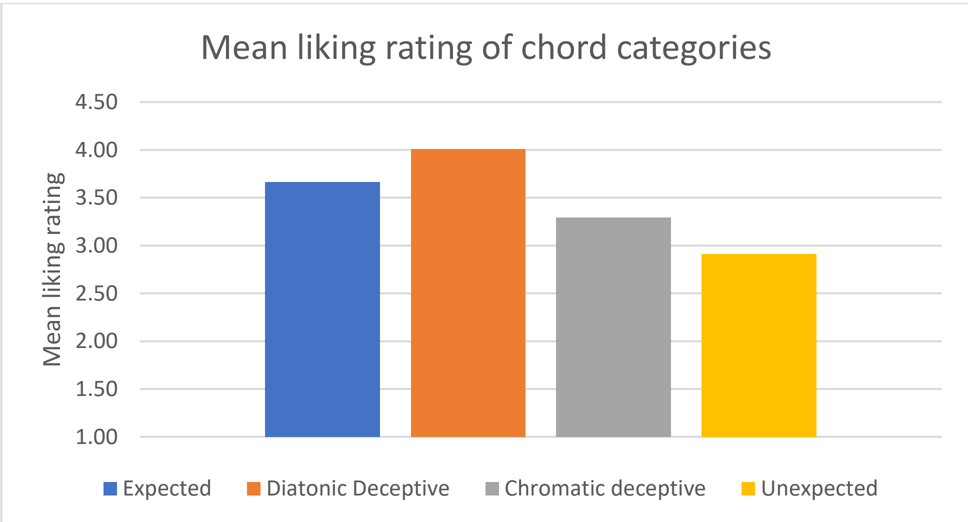

Fig. 61: Mean liking ratings: all participants

Further investigation revealed differences in liking ratings among the participant cohorts. For example, unexpected chords were the most disliked chord type across all groups except jazz musicians, who appeared to prefer unexpected chords to expected. Jazz musicians and musicians from the “other” category gave their highest preferences to deceptive diatonic chords, while pop/rock musicians and general listeners gave their highest preferences to expected chords. An LMM revealed a statistically significant delineation between two groups, one containing jazz musicians and “other” musicians, and one containing general listeners and pop/rock musicians, $F(9, 1085.14) = 8{,}767$, $p < 0.001$. Jazz and “other” musicians were found to have higher preferences for the more unexpected chords, i.e. those in the unexpected and chromatic deceptive categories, in comparison with pop/rock musicians and general listeners, who showed a general trend of preferring expected chords.

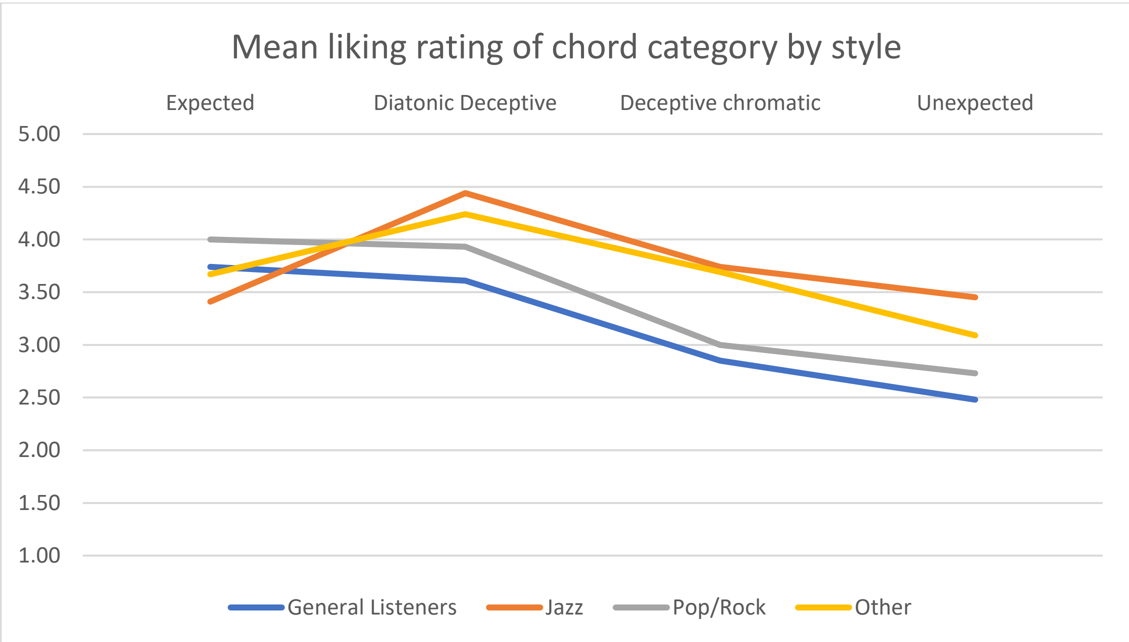

Fig. 62: Mean liking ratings: stylistic cohorts and general listeners

Participants therefore appeared to fall into one of two groups. The first group is one with a linear relationship between expectedness/complexity and preference. This group strongly preferred the most expected resolutions, showed a reduced preference for resolutions that were deceptive but within the key of the prime progression, and disliked resolutions that were outside of the key context and thus represented increased complexity. This group consisted of general listeners and pop/rock musicians.

The second group is one which demonstrated a more inverted-U relationship between expectedness/complexity and preference. This group showed strongest preferences for the deceptive diatonic chords, which could be considered as the most weakly deceptive, the most likely to be familiar, or the least complex. These groups were found to have lower preferences for both the least complex and most expected chords, i.e. the I chords, and the most complex and least expected chords. This group consisted of jazz and "other" musicians.

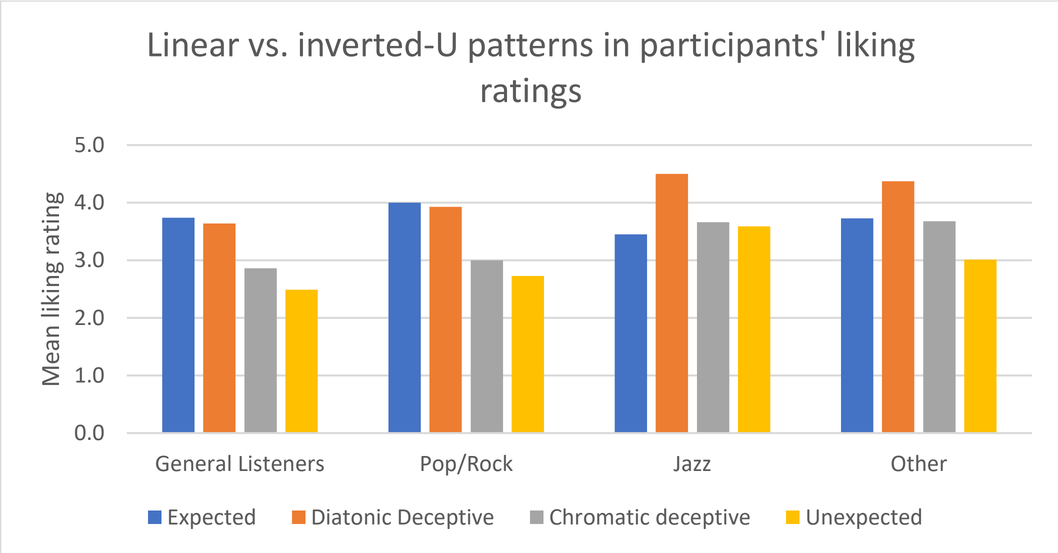

Fig. 63: Linear vs. inverted-U patterns in liking ratings

These differences between groups were further investigated through classification analysis and analysis of individual chord ratings. Dendrograms for all cohorts may be found in Appendix E. Cluster analysis revealed a tendency for general listeners to group diatonic chords together and sharply delineate between diatonic and chromatic chords, thus replicating patterns found in their explicit ratings in the previous experiment. This explains general listeners' high preferences for both expected and diatonic deceptive chords and their dislike of chromatic deceptive and unexpected.

General listeners	
Group 1	IIIm, I
	I
	I, I
	I
	I, VIm
Group 2	Im, ♭VIIm
Group 3	♭VI, ♭II
	♭VIm
	IIaug
Group 4	♭VII, ♭IIIm

Table 12: Chord clusters for liking ratings: General listeners

The ratings of pop/rock musicians, while similar to general listeners in that they also gave their highest preference to expected chords, demonstrated differences in how this group rated chromaticism in comparison to general listeners. While general listeners showed a delineation of preferences based on chromaticism, pop/rock musicians’ dendrograms revealed that they clustered both the ♭VIma and ♭VIm together with their preferred I chords, at the expense of the diatonic IIIm. This reflects pop/rock musicians’ results in the Explicit Experiment, where they were found to cluster the I chord with the ♭VI. Pop/rock musicians were also found to have clustered all of the augmented and diminished chords together, indicating, along with their mean ratings, a strong dislike of these chord qualities. General musicians showed similar dislike of these chord qualities. These results are notable when the rarity of these chord types in popular music is taken into account. For example, de Clercq and Temperley (2011), in a corpus analysis of popular music found that diminished chords accounted for only 0.7% of the total chords, and augmented even fewer, at 0.1%. In contrast, diminished chords are, according to Nettles, “characteristic of music that is fairly complex and often highly chromatic, such as jazz” (Nettles, 2007b, p. 45).

<table>
<tr><th colspan="2">Pop/Rock musicians</th></tr>
<tr><td rowspan="2">Group 1</td><td>I, I, I</td></tr>
<tr><td>I</td></tr>
<tr><td rowspan="2">Group 2</td><td>I, I</td></tr>
<tr><td>♭VI</td></tr>
<tr><td>Group 3</td><td>♭VIm, VIm</td></tr>
<tr><td rowspan="3">Group 4</td><td>Im, ♭VIIm</td></tr>
<tr><td>IVm, ♭II</td></tr>
<tr><td>♭IIIm</td></tr>
<tr><td rowspan="3">Group 5</td><td>IIIm, ♭VII</td></tr>
<tr><td>IIaug, ♭IIdim, ♭VIaug</td></tr>
<tr><td>♭IIIdim</td></tr>
</table>

Table 13: Chord clusters for liking ratings: Pop/rock musicians

The cluster analysis of jazz and “other” musicians’ results showed less differentiation, revealing a much less bifurcated classification of like and dislike based on diatonicism and chromaticism in comparison to general listeners. The liking ratings of overall categories for these groups revealed more of an inverted-U shaped pattern than a linear pattern, and this tendency was confirmed by liking ratings of individual chords.

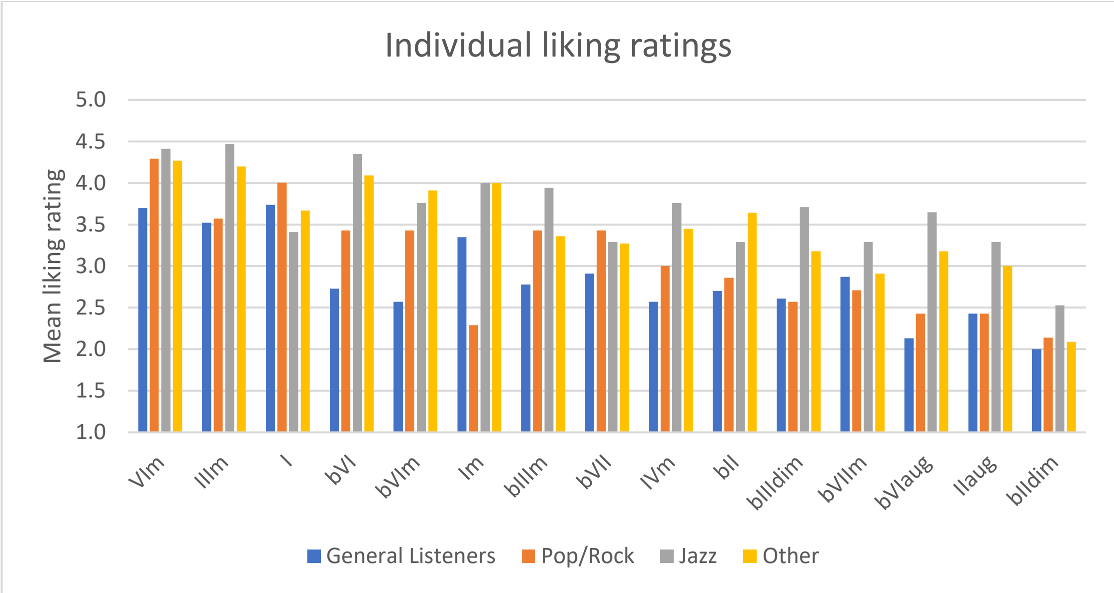

Fig. 64: Individual chord liking ratings: stylistic cohorts and general listeners

Like pop/rock musicians, jazz and "other" musicians showed strong preferences for the diatonic deceptive IIIm and VIm, and the chromatic ♭VIma and ♭VIm, but they were also found to like several other chromatic chords, such as the Im, ♭IIIm, IVm. In addition, jazz musicians did not show the strong dislike of the augmented and diminished chords that general listeners and pop/rock musicians had demonstrated.

To summarise, analyses of preference ratings show revealing differences between participant cohorts which demonstrate both the effect of musical training and stylistic expertise on music processing. Musical training appears to increase liking for chromatic/complex/deceptive harmony. However, for pop/rock musicians this effect appears to be insufficient to increase preference for unexpected harmony to a level beyond preference for expected harmony. Stylistic expertise in jazz appears to lead to a greatly increased preference for complexity and reduced liking for expected harmony, resulting in an inverted-U preference curve.

Evidence of the effects of musical schemata is also found, with jazz musicians and pop/rock musicians demonstrating increased liking for chords that appear more often in their repertoires, such as the ♭VI chord in popular music and diminished chords in jazz, and decreased liking for chords that appear rarely.

6.3.2.3. *Other factors*

An LMM was fitted to the data in order to determine whether participant characteristics or the properties of the musical stimuli affected preference ratings. Musical factors consisted of voice-leading, pitch height, key distance, and chord type. Participant factors consisted of age, gender, the extent to which participants are distracted by music in everyday life, training, theory, experience, and proficiency. No effects of gender, age, pitch height, key distance, distraction, proficiency, training, or experience were found. Differences were found between participants with different levels of training, but these were not found to be linear or meaningful.

As with RTs, voice-leading was found to have a significant effect on listeners' liking ratings, $F(3, 1094.15) = 29.822$, $p < 0.001$. Participants appeared to significantly prefer progressions that voice-lead up a semitone or stayed on the same note, in comparison to those that voice-lead up a whole tone or down a semitone. Post-hoc Tukey tests showed this to be the case in statistically significant terms.

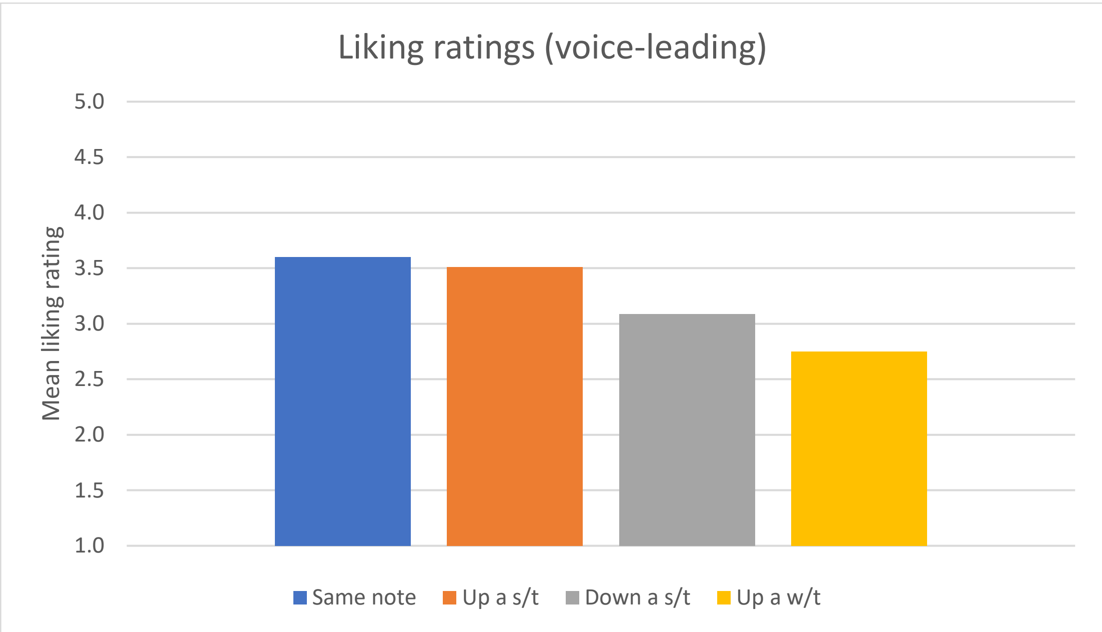

Fig. 65: Mean liking ratings for voice-leading

This was found to affect both musicians and general listeners, although the effect appeared to be stronger for musicians. General listeners did not have a preference for same note voice-leading over movement up a semitone, while musicians did.

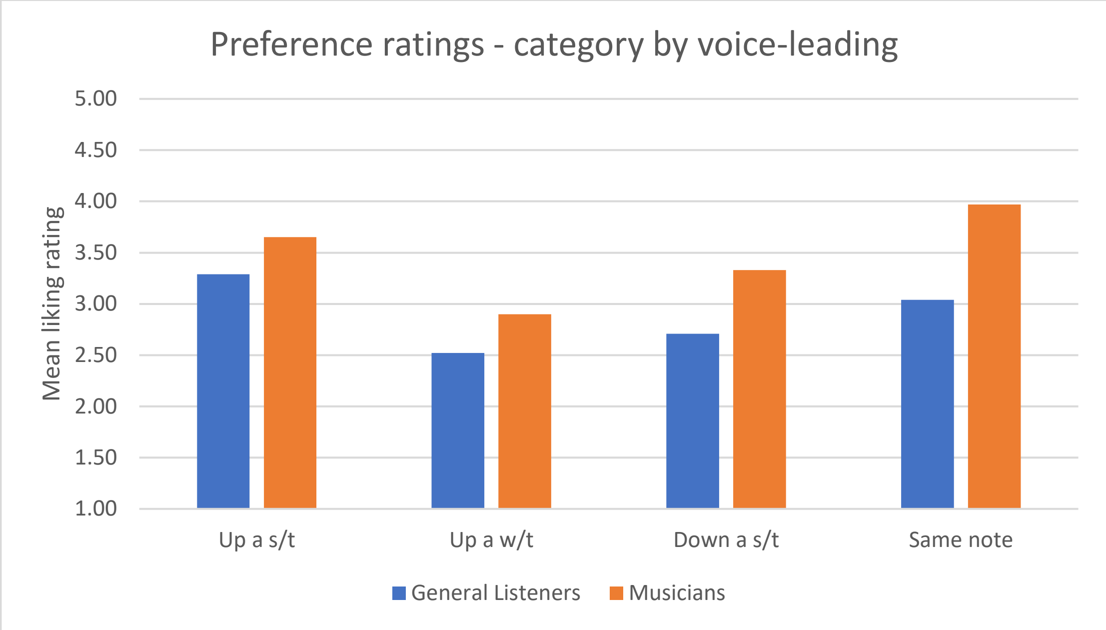

Fig. 66: Mean liking ratings for voice-leading: musicians and general listeners

Similar patterns were found between jazz and pop/rock musicians, with jazz musicians again being more strongly influenced by voice-leading in their preferences.

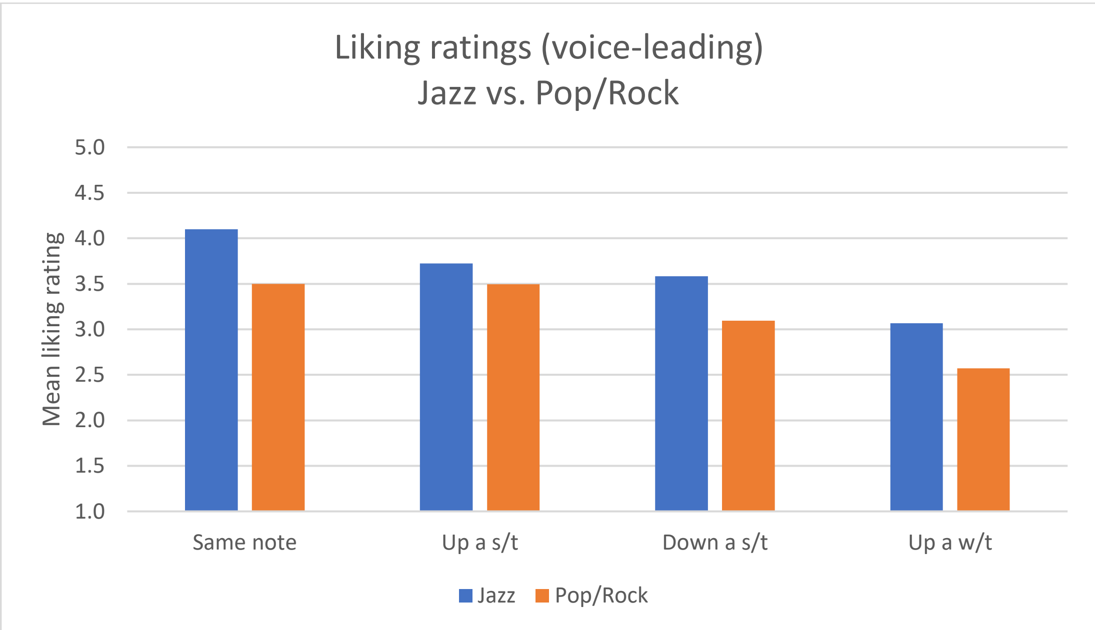

Fig. 67: Mean liking ratings for voice-leading: jazz and pop/rock musicians

6.4. Conclusions and discussion

This experiment aimed to address the following three research questions:

1) In what ways are harmonic expectation and surprise related to liking and are these mediated by stylistic expertise?
2) To what extent are listeners influenced by sensory and other factors in their reactions to deceptive harmony, and is this mediated by stylistic expertise?
3) Do listeners' RTs within the given experimental paradigm reflect chord expectedness and is this mediated by stylistic expertise?

The results of the experiment with respect to these questions are discussed below.

6.4.1. Participant preferences

The results of this experiment suggest that general listeners have strong, significant preference for expected cadences in comparison to unexpected cadences. This effect may be related to diatonicism: the most strongly preferred cadences for general listeners were those that were diatonic, and cluster analysis revealed that general listeners clustered chords in terms of their diatonicism. General listeners may have strong preferences for I chords, VIm chords and IIIm chords because they prefer diatonicism to chromaticism in general, regardless of the chord details.

Thus, these results demonstrate a clear contrast between musicians and general listeners. While general listeners strongly prefer diatonicism and expectedness, both jazz and pop/rock musicians embrace chromaticism and surprise, to varying degrees. While jazz musicians appear to have overall preferences for chromaticism, pop/rock musicians' chromatic preferences appear to be related to some extent to familiarity, given their high ratings for the ♭VI chord, a common chord in popular music, and low ratings for augmented and diminished chords, found much less frequently. Thus, pop/rock musicians' results show support for Zajonc's 'mere exposure' effect, whereby increased exposure to a stimulus increases liking towards it (Zajonc, 1968).

While pop/rock musicians demonstrated similarity with general listeners in giving their first preference to the most expected chord, this group nonetheless demonstrated a less linear pattern than general listeners, with highest liking ratings for their second-most expected chord, the traditional deceptive resolution to VIm.

Jazz musicians' liking ratings were markedly different from both general listeners and non-jazz musicians. Notably, the least preferred progression type for jazz musicians was the most expected, which was the most preferred type of progression for both general listeners and pop/rock musicians. Jazz musicians showed much higher preference for chromaticism than either general listeners or non-jazz musicians, indicating that they may have higher tolerances for unexpected harmony.

Overall, these data largely support the conclusions of Smith and Melara (1990), Orr and Ohlsson (2005), and Przysinda et al. (2017), which found that general listeners had higher preferences for low complexity chord progressions. In their study, Smith and Melara found that expert musicians prefer more complex chord progression, but the results of this study suggest that more granular detail may be found by investigating the details of this expertise. The current results show that liking of increased complexity may be related to stylistic expertise, with musicians preferring complexity that is found regularly within their styles of expertise.

General listeners were found to strongly prefer progressions with minimal complexity, with highest preference for the most predictable chords. Pop/rock musicians were found to have preference for moderate levels of complexity, with respect to the diatonic deceptive category, but overall demonstrated a linear relationship between liking and expectedness. Jazz musicians' liking data, in contrast, showed a distinct inverted-U curve. While pop/rock musicians maintained a preference for diatonic chords, jazz musicians were significantly more tolerant of chromaticism, with higher liking ratings for increased complexity, and significantly lower preferences for predictable resolutions.

6.4.2. Sensory and cognitive processes in RTs

Overall, RTs in this experiment appear to relate more to preferences, sensory effects, and voice-leading than to the expectedness of the target chords. The most preferred chord types, IIIm and VIm, were also those to which participants reacted the fastest. Jazz musicians across the board both had faster RTs and stronger preferences for chords in general. Previous RT experiments in harmonic expectation have generally found facilitated processing, i.e. faster RTs, for expected chords, with no effect of musical training found (Bharucha & Stoeckig, 1986), (Tillmann, Janata, et al., 2003), (Tillmann et al., 2008). In the current RT test however, differences were found in patterns of facilitation and inhibition for different cohorts of participants, suggestive of effects of stylistic training. These effects are summarised in the table below.

	General listeners	Jazz musicians	Popular musicians	"Other" musicians
Facilitated processing	None found	None found	Expected chords	Deceptive diatonic
Inhibited processing	None found	None found	Chromatic Deceptive Unexpected	Unexpected
Sensory effects	None	None	Yes	None
Voice-leading effects	Yes	Yes	Yes	Yes

Table 14: Processing effects for different cohorts

The effects of sensory factors, as indicated by Leman's sensory model, and effects of voice-leading significantly contributed to participant's RTs. The effects of voice-leading were found for all participants, while sensory effects were strongest for pop/rock, professional, and male musicians. Although the low ratings of pop/rock musicians for augmented chords may be explained to some extent by their relatively low integration values found by the IPEM model, these sensory effects do not account for pop/rock musicians' strong preferences for the ♭VIma chord, which showed low sensory integration values, nor their low ratings for diminished chords, which showed relatively high integration values. Thus, it is likely that these anomalous results are due to pop/rock musicians' exposure to these chords during the course of their performance/study.

6.4.3. Combined analysis of explicit, implicit, and liking results

In order to determine relationships between explicit ratings of surprise, implicit reactions to surprise, and preferences for surprise, the five chords used in the Explicit Experiment were separated out from the results of the Implicit Experiment so that they could be analysed with reference to the Explicit Experiment results. The results of the musician participants show a strongly linear relationship between theoretical surprise and explicit ratings, while liking ratings roughly suggest an inverted-U pattern. Normalised RTs (scaled by a factor of 10 for visualisation purposes) appear to follow an inverted pattern in comparison to preferences.

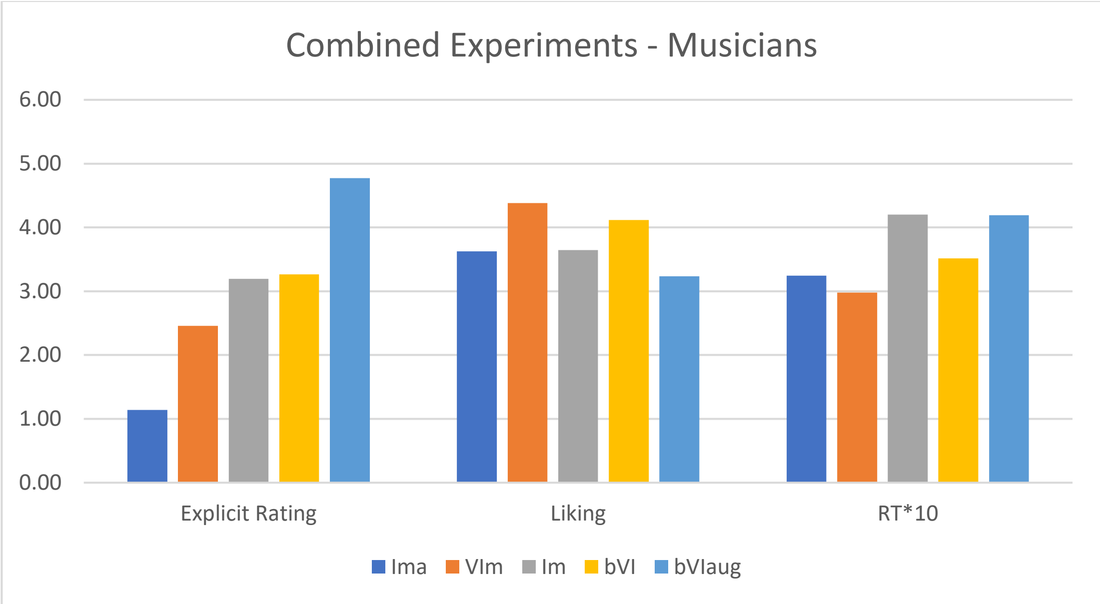

Fig. 68: Explicit ratings, RTs, and liking ratings: musicians

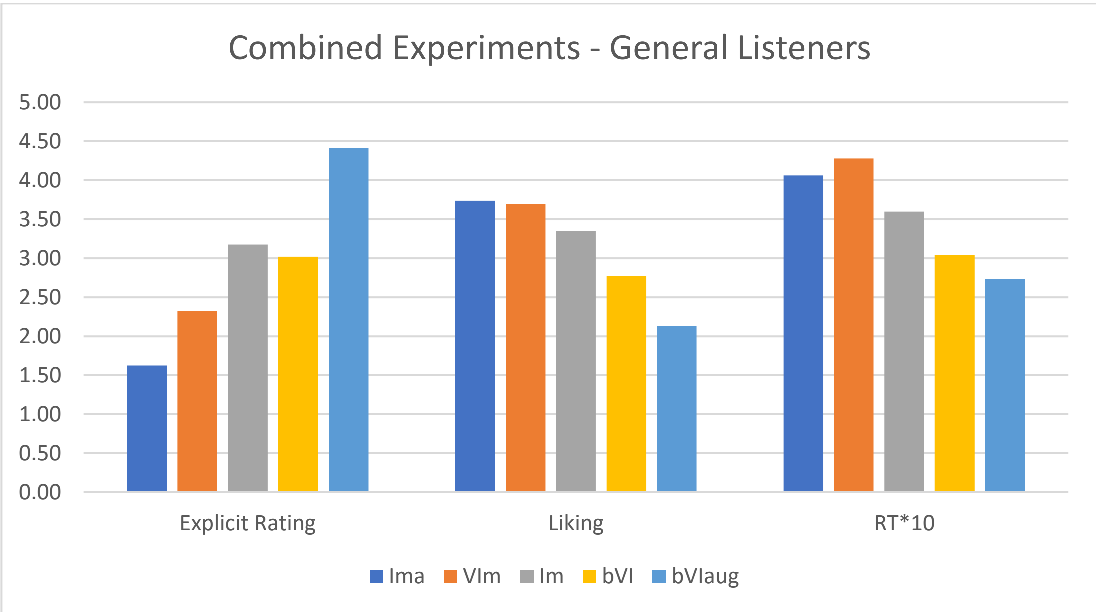

Fig. 69: Explicit ratings, RTs, and liking ratings: general listeners

General listeners appear to have linear relationships across the board. This cohort demonstrate a negative linear relationship between rating and liking, and a positive linear relationship between liking and RT.

Jazz musicians demonstrate again a linear relationship between theoretical surprise and explicit surprise, while their liking ratings appear to exhibit an inverted-U, and RTs an inversion of this.

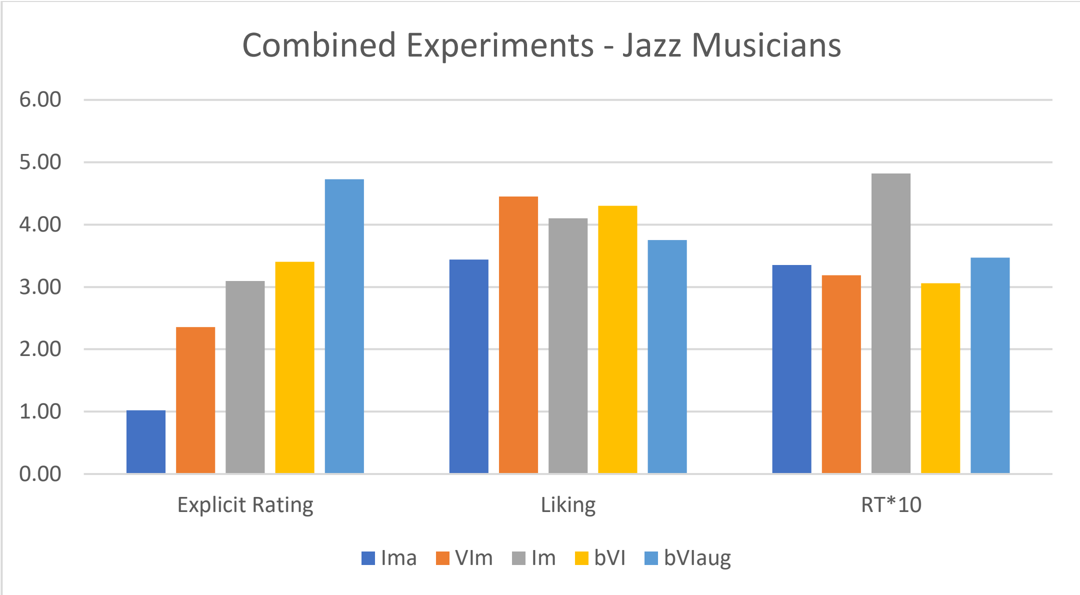

Fig. 70: Explicit ratings, RTs, and liking ratings: jazz musicians

Pop/rock musicians demonstrate similar results, albeit with the surprise ratings for the Im and ♭VIma reversed in comparison to other musicians.

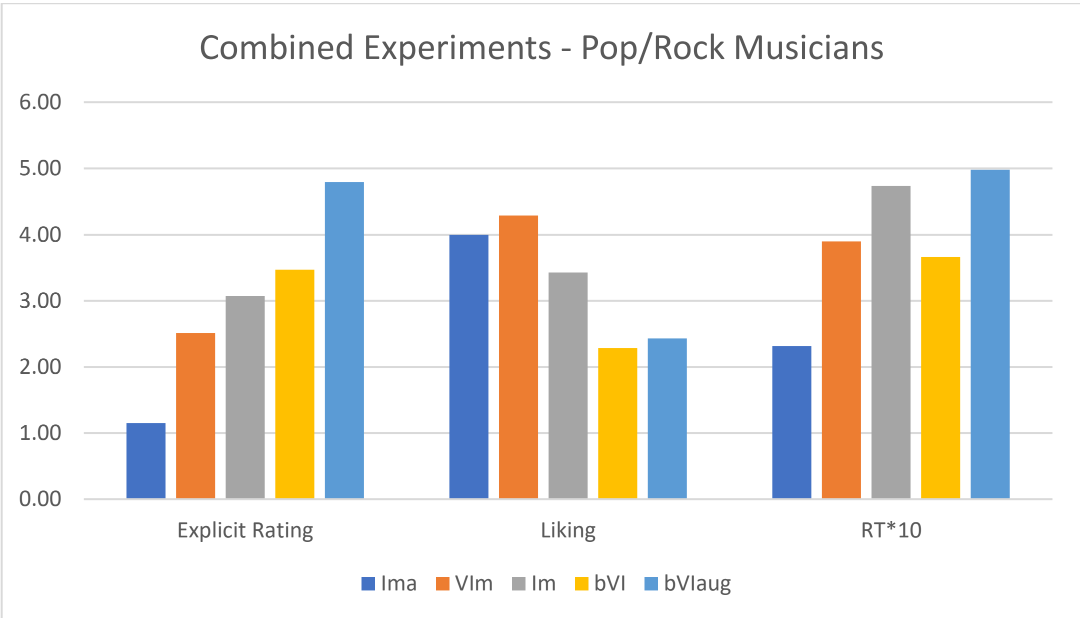

Fig. 71: Explicit ratings, RTs, and liking ratings: Pop/rock musicians

These relationships are verified by correlation testing. A very strong, significant negative correlation was found between liking ratings and explicit rating for general listeners, r = -0.914, p = 0.03. General listeners also had an extremely strong, significant positive correlation between normalised RTs and liking, r = 0.967, p = 0.007. However, no other group were found to have correlated values between explicit surprise and rating. Given that this is a negative relationship for general listeners, it appears that general listeners have strong preferences for predictable chords, and antipathy towards surprising chords.

6.4.4. Summary

The results of the Implicit Experiment, when considered in tandem with those of the Explicit Experiment, provide further evidence that listeners experience surprise in nuanced ways. Again, analysis shows a strong mediating effect of musical experience, with general listeners preferring diatonicism while jazz musicians prefer to be surprised by chromaticism, and pop/rock musicians prefer diatonicism but respond favourably to chromatic chords from their genre. Implicit expectations, as indicated by RTs to the spatial discrimination paradigm were found to relate strongly to preferences, sensory effects, and voice-leading, while the theoretical expectedness of the chords did not appear to be a significant factor. Sensory effects were strongest for professional musicians and pop/rock musicians.

Combined analysis revealed notable patterns in listeners' explicit ratings, liking ratings, and RTs. Patterns in liking ratings in comparison to explicit ratings of surprise were found to vary between groups. General listeners were found to have a strong inverse linear relationship between rating and preference, while musicians, both jazz and pop/rock, demonstrated inverted-U patterns in their preferences. These patterns reinforce Berlyne's theory of aesthetic preferences, where listeners prefer a moderate amount of complexity, but dislike overly or insufficiently complex stimuli (Berlyne, 1971). However, in this case, this pattern appears to apply only to expert listeners, with general listeners preferring simplicity.

7. Experiment 3: Surprise responses to ecological popular music among stylistically diverse musicians (Ecological Popular Music Experiment)

7.1. Introduction

Several notable results, such as the ability of different deceptive cadences to elicit a gradated range of surprise levels, the mediating effects of musical training, stylistic experience, and improvisational training on expectation and surprise, and strong relationships between surprise and preferences, were found through the Explicit and Implicit Experiments. However, these results were derived from a purely experimental context. This means that these results, while they give an important baseline and reveal significant information, cannot be extrapolated to explain listeners' reactions to real world listening experiences. In order to understand listeners' real-world reactions, these factors must be accounted for using ecologically valid stimuli. This is particularly important in the case of popular music, as this style dominates Western music listening (Lex et al., 2020), and thus reflects the contemporary musical vernacular in Western society.

Therefore, the following two experiments attempt to further elucidate the results of the previous two experiments within ecologically valid contexts by asking the following four research questions:

1) Do surprise ratings in response to cadences found in Experiments 1 and 2 extend to real life ecologically valid popular music conditions?

Cadences, and the expectations they elicit on both global and local levels, provide an important means of building structure and momentum into many CP forms. However, Chapter 3 revealed that there are fundamental differences in how narrative is built between CP and contemporary popular styles. Composers of popular music are less likely to use cadences as structural marker points, and less likely to use deceptive cadences as an integral part of musical form. Thus, listeners' experiences of cadences, and the chords that comprise them, may be very different depending on the stylistic context.

2) Are these surprise ratings related to cadence, or to chromaticism, within an ecological popular music context?

An argument could be made that the results of Experiments 1 and 2 were derived not from the cadential context of the chords, but rather by the fact that they were chromatic. In order to investigate this possibility, this experiment aims to extricate these factors by comparing ecological examples of the chromatic deceptive resolutions used in the Implicit Experiment, i.e. the Im, IVm, ♭VII, and ♭VI, with the same chords in ecological non-cadential contexts. Comparison of these chords in both contexts will elucidate the effects of chromaticism versus cadence.

In addition, the placement of cadential chords in terms of hypermeasure is another way in which CP cadences tend to differ from those in popular music. Cadences in CP music tend to resolve, both melodically and harmonically, onto a weak hypermeasure, thereby concluding a section. In popular music and jazz, cadences more typically resolve onto a strong hypermeasure, indicating the beginning of a new section rather than an end. The cadences in the Explicit and Implicit Experiments resolved onto strong hypermeasures, but the experimental context made it impossible to account for the effect of a cadence beginning, rather than ending a section. This will be explored in this experiment.

3) Are these results mediated by tonal context within an ecological popular music context?

The discussion in Chapter 3 revealed that tonality in contemporary popular styles is rarely as clear-cut and unambiguous as it is in CP music, due to the influence of modal and blues harmony, and the blending of both parallel and relative major and minor harmony often found in these styles. Tonality is often ambiguous, veering between major and minor, or encompassing multiple different tonal systems within the same song. Thus, chromatic chords, such as the N^6 chord, cannot be defined as easily in popular music as they may be in a CP context. Participants' responses in the Explicit and Implicit Experiments were based on the establishment of a strong major tonal context prior to the target stimuli. However, the surprising or unsurprising effects of these chords may not be the same if they were found in a more ambiguous or modal context, such as is commonly found in popular music.

The chords of ♭VII, ♭VI and ♭III, with roots in blues harmony and triad-doubled systems, are regularly found within popular music contexts. These chords are often treated as diatonic by popular songwriters but would be considered chromatic within traditional CP-based music theory. This experiment aims to determine whether these chords are considered chromatic or diatonic, i.e. surprising or unsurprising, in popular music, and whether that determination is mediated by context.

4) What additional features may be related to expectation and surprise?

In addition to cadences and non-cadential examples of MI chords, the stimuli in this experiment also contain several techniques theorised to be related to expectation and surprise as detailed in Chapter 4, such as secondary dominants, tritone substitutes, and extensions.

7.2. Methodology

7.2.1. Experimental paradigm

Given the exploratory nature of the research, the decision was made to rely on the expertise of trained musicians to determine the harmonic elements they found surprising, and then explore the resulting data to find patterns in the elements chosen. Since harmonic surprises can be easily confounded with melodic, rhythmic, or textural surprises, participants were required to be professional musicians or music teachers, or to have undertaken at least two years of full-time music training at university level. They were given explicit instructions to respond only to harmonic surprises, and to ignore surprises of any other nature, thus minimising confounds related to melodic, rhythmic, or textural surprises to the extent possible.

Participants listened to musical excerpts and were asked to click a button on-screen as quickly as possible if they heard anything that they found harmonically surprising. They were also asked to indicate whether they had liked, disliked, or neither liked nor disliked the surprise. To control for effects of familiarity and dislike, participants were asked to indicate if they were already familiar with, or particularly disliked the excerpt in question.

7.2.2. Material

Ecologically valid musical stimuli were taken from a corpus of ~500 popular songs, transcribed by the author. These are listed in Appendix B. Tonal centres were determined using Jonathon Kramer's definition of tonal centre, i.e. a tone that is "likely to persist longer than temporally adjacent chords, is likely to begin or end a pattern and is likely to receive an attack more emphasized than its temporal neighbours" (Kramer, as quoted by Moore, 1992, p. 77).

Excerpts were chosen to include a mixture of diatonic chords, cadences, and chromatic chords. In terms of cadential material, cadences to IIIm, VIm, IVma, IVm, Im, ♭III, ♭VI, and ♭VII were identified in the corpus. The same cadence chords were then found in non-cadential contexts. Tellingly, no examples could be found of cadences onto weak hypermeasures, the traditional point for closure in common practice cadences. In total, 29 excerpts were chosen, each ranging in length from 20 to 40 seconds. Five excerpts containing no cadential or chromatic harmonies were also selected as controls. Details of root movement, hypermeasure placement, tonal context and melodic context were gathered for each chord. Details of the excerpts and links to audio files may be found in Appendix F.

Chords in the excerpts were contextually analysed and grouped using categorisations. Chords were first designated as diatonic or chromatic. Chromatic chords were then further subdivided based on the criteria outlined in the Berklee Core Harmony textbooks and described in Chapter 4. These chromatic subgroups consisted of secondary dominants, MI chords, tritone substitutes, SFDs, modulations, and non-diatonic related II chords.

Given Miles et al.'s (2017) results suggesting that extensions may serve as a surprising feature in popular music contexts, all chords were categorised by whether they were triads or contained an extension of the 7th or above. Chords in popular music are also found to be almost always root position triads (Temperley, 2018) in contrast to CP music where inversions are an important aspect of musical analysis, and in jazz, where slash chords feature heavily. In their corpus analysis, de Clercq and Temperley (2011) found that 93.9% of chords in their corpus were in root position. This allows for the potential for inversions and slash chords to be perceived as surprising, since these chords are rare, but not unprecedented, and so chords were analysed with respect to their inversion.

7.2.3. Procedure

The experiment was implemented and hosted online using Gorilla Experiment Builder (Anwyl-Irvine et al., 2019). It consisted of two parts. In the first, listeners were asked to give details of their age, gender, and musical experience. As the experiment was only open to professional musicians, music teachers, and full-time music students, general listeners were redirected. Once participants passed the initial stage, they were then asked for further details of their musical experience and stylistic specialisation in a questionnaire which may be found in Appendix F. Participants were then invited to watch a video giving details of how the experiment proper would work and given two practice exercises to complete.

The second part consisted of the experiment proper. In this section, listeners were presented with 34 randomised excerpts consisting of 20-30 seconds of music. They were asked to listen to the excerpts and click a button on screen as soon as they heard something in the harmony of the stimuli that surprised them. They could indicate positive surprise by clicking a green button, negative surprise by clicking a red button, and neutral surprise through a yellow button. Participants were given two opportunities to listen to each excerpt and told they could "re-record" their answer(s) if they felt they did not accurately reflect their surprise on the first listening.

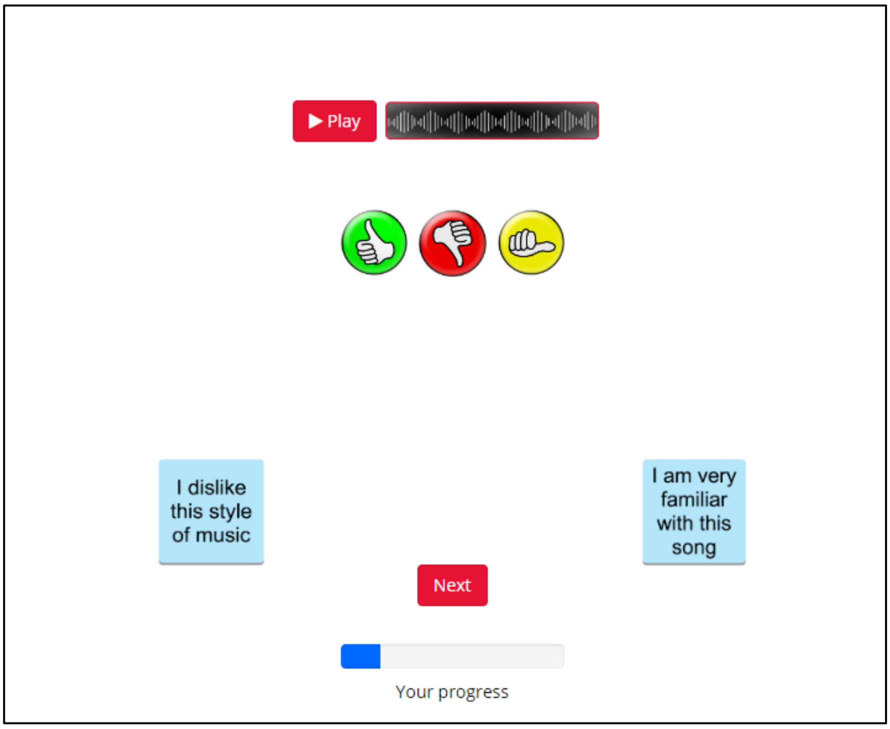

Fig. 72: Question Screen in the Ecological Experiments

At the end of the experiment, participants were invited to give feedback on their experience and given the opportunity to enter a draw to win a €100 voucher for the online music store Thomann.ie.

7.2.4. Participants

46 people participated in the experiment. 15 of these were female and 31 male. Participants were asked to identify the musical style in which they specialised. 15 participants selected classical, 17 selected jazz, and 14 selected popular music. The majority of participants with

classical specialisation were female (60%), while those specialising in jazz (88%) or popular music (71%) were mostly male.

14 participants identified their musical status as full-time music students (3rd year or above), while eight identified as full-time music teachers. The largest cohort of participants (52.2%, or 24 participants) identified as professional musicians. For jazz and classical music, there was a roughly equal split between professional musicians and full-time music teachers, with a small number of full-time students within each status category (two jazz, two popular music, and four classical). Most participants specialising in popular music identified as professional musicians. This category numbered 11 participants. Henceforth, all participants will be referred to as "musicians", regardless of their status, unless status is explicitly being discussed.

Participants were asked about their professional/educational musical experience. The mean value in years of experience was 27.3, with a standard deviation of 13.3. The range of participant experience was 4 – 60 years. Pop/rock musicians were found to have the most experience of the participants, with a mean of 33. Jazz musicians averaged 24 years of experience and classical musicians 25 years. This difference was not found to be statistically significant. The most experienced musicians were found to be professional musicians with a mean of 31 years, and full-time music teachers with a mean of 27. Music students had less experience, with a mean of 17 years.

When asked if improvisation was an important aspect of their musical practice, most participants maintained that it was, with 29 answering "yes", while 17 answered "no". Jazz musicians were the most likely to say that improvisation was an important part of their practice, with only two out of 17 jazz musicians stating that improvisation was not an important part. Classical musicians were the least likely to have improvisation as an important part of their practice, with nine out of 16 stating they did not improvise. This was reflected in the improvisation by status (i.e. professional, student, or teacher) statistics, with only two of eight music teachers, a category dominated by musicians with classical specialisation, stating that they improvised. Musicians who improvised had a slightly higher mean of years' experience in comparison with musicians who did not, but an ANOVA revealed that the relationship between experience and improvisation was not statistically significant.

7.2.5. Data cleaning and test selection

No paradigm for the analysis of continuous, ecologically valid stimuli with button click responses existed within the literature, and so a novel analysis method was required. The method chosen incorporated previous related methodologies to such an extent as was possible.

The primary issue with the analysis of these data was reaction time delay, whereby the timestamp of button clicks may not reflect the actual time that participants were intending to mark. Studies have found that test participants exhibit delays in response to aural and musical stimuli. These delays are mediated by participants' musical experience, and by the type of stimuli being tested. A minimum RT delay of 500ms for participants was assumed. This value was determined based on the following studies.

Landry and Champoux (2017) found that musicians react to non-musical auditory stimuli in a mean time of 193.9ms, while the mean RT for general listeners to the same stimuli is 250.13. These extremely fast RTs may be accounted for by the fact that the stimuli in the experiment could be responded to using bottom-up sensory processing mechanisms. On the other end of the processing spectrum, Sloboda and Lehmann (2001) described delays of two to four seconds when listeners were asked to rate the "emotionality" of musical excerpts using a continuous response interface via a computer mouse. The longer RTs here may be a result of requirement for cognitive top-down processing, incorporating high level factors such as musical emotionality, and as the authors put it, "response latencies that have to be expected when subjects are asked to manipulate a mouse pointer" (Sloboda & Lehmann, 2001, p. 112). Indeed, multiple studies investigating continuous responses to musical stimuli have found delays between one and three seconds when participants are required to manipulate a continuous interface using a mouse (Gregory, 1995), (Krumhansl, 1996).

The paradigm in the current experiment required listeners to make continuous cognitive judgements, but in contrast to a physically unwieldy mouse slider, listeners used a button click to indicate their responses. Studies involving button clicks in response to harmonic deviants show delayed response times of around 500 to 1000ms. For example, Proverbio et al. (2016) found that the mean RT in response to dissonant chords within progressions, where the participants did not know when the targets would be heard, were 588.7ms for musicians, and 598.8 for general listeners. Koelsch, Schroger, and Gunter (2002) found a mean RT for general listeners of between 567 and 596 in response to deviant chords in progressions, again where participants did not know where the targets would occur. Kung et al. (2014) in a similar setup but using dyads rather than triads found a mean RT of 656 for musicians, and 642 for general listeners. Similar studies have found behavioural response ranges of 750-950ms (Atalay et al., 2006), and a mean of 616ms (Koelsch et al., 2007) for musicians.

In order to determine the chords to which participants' RTs were referring, each excerpt was divided into "chord windows". Onset times for each chord were determined, and windows began 500ms after each onset. Windows ended at the onset of the following chord, or in the case of the final chord, 2000ms after its onset. Timestamps and chord details of these series of windows for each excerpt may be found in Appendix F. Given the differing durations of the chords, there were a wide variety of time windows for each chord, which could lead to misinterpretation of button click RTs. However, it was assumed that participants' button clicks would be contained within the required windows for several reasons. All participants within the experiment were trained musicians, either professional working musicians, music teachers, or full-time music students in the latter part of their studies. This meant that they had a thorough understanding of harmony, chord changes, and where these events occurred. At the beginning of the experiment, participants were given detailed instructions on what was required, and asked repeatedly to make their judgements "as soon as the chord is heard". Thus, it can be assumed that participants would be unlikely to press a button to indicate surprise related to one chord after another chord had been heard. In addition, participants were given two chances to "redo" their answers, ensuring that should they press a button late, they could then fix their error by anticipating the chord the second or third time and ensuring that their button click fell within the correct window.

The resulting data consisted of 14,582 data points: 317 chords heard by 46 participants. The initial distribution of results followed a Bernoulli distribution, with either a 1 indicating a surprise button hit, or a 0 indicating no hit, for each chord and for each participant. An initial decision was thus made to perform a regression on the data. However, an imbalance in the ratio of 1 values versus 0 values (401:14181) meant that a model could not be accurately fit.

For that reason, count values were therefore summed for each chord, resulting in a roughly Poisson distribution for the outcome variable. However, testing revealed the data to be overdispersed, thus violating the assumption of equal means and variance required for a Poisson regression. For this reason, the decision was made to analyse the data using a negative binomial regression, with an estimated dispersion parameter. This reduced the means/variance ratio from 1:5.112 to 1: 1.095 and allowed for a model to be accurately fit.

The first of the predictor variables was the tonality of the excerpt. Another predictor variable was whether the chord had an extension or not. Chords with extensions included 7th and 9th chords, plus sus4 and sus2 chords. Root movement was also described, and a predictor variable created from these data, in order to determine whether root movement was a factor in surprise. Chord category was also used as a predictor variable. This included information about how each chord would be categorised within the Berklee system of harmonic analysis. Categories included diatonic, diatonic with extension, diatonic slash chord, MI, secondary dominant, tritone substitute.

Information about whether the chord acted as a resolution to a cadence was also included. This variable was used to compare cadence chords with their equivalents in non-cadential conditions, in order to determine if surprise levels found in the Explicit and Implicit Experiments had been influenced primarily by cadential structure, or by the chromaticism of the chords.

Multicollinearity was found between tonality, cadence and category, and so these were analysed in separate models.

In this, and the following experiment, all of the audio excerpts were analysed in Matlab using Leman's IPEM model (Leman et al., 2001). Resulting correlation values were meaned across the chord windows described above, to give approximate correlation values for each chord. These values were input as a continuous variable in order to determine whether there was a relationship between participants' surprise levels and the sensory contextuality levels of each chord, as determined by the IPEM model.

For this and the Ecological Jazz Experiment to follow, chord duration was configured as an offset variable in order to ensure that durations did not confound the results. That is, setting this variable as an offset would account for higher amounts of button presses in chords of longer duration, due purely to the longer amount of time in which they were heard.

Button-presses to indicate surprise will be hereafter referred to as "votes".

Regression analyses were performed in SPSS and R.

7.3. Results

7.3.1. Like/dislike/familiarity

Participants were given the option to press a button if they were familiar with a song in the experiment, or if they disliked the style of a song. Chi square tests revealed a significant relationship between these variables, reflecting current thought on the mere exposure theory. Participants were much less likely to dislike the style of songs they were familiar with, and more likely to dislike styles of songs they were unfamiliar with, χ^2 (1, N = 17777) = 134.223, p < .001. This relationship held when controlling for style, with all style groups less likely to dislike familiar songs than unfamiliar ones. However, there were differences in how pronounced this effect was, with pop/rock musicians having a much higher adjusted residual of 9.7 in comparison to classical musicians 5.7 and jazz musicians' 4.9, suggesting that this effect of disliking unfamiliar music and preferring familiar is stronger for pop/rock musicians than for jazz or classical musicians. This tallies with results found in the Implicit Experiment, where pop/rock musicians had strong preferences for chords commonly found in pop/rock contexts, and lower preference for chords that were not commonly found.

A statistically significant relationship between familiarity and style was found, $F(2, 45) = 82.824$, $p = 0.042$. This significance was primarily accounted for by the difference between classical musicians, who had a mean of 2.27 familiar button clicks per participant, and jazz and pop/rock musicians, who had means of 5.64 and 4.06 respectively, suggesting that the classical musicians were much less familiar with the popular music excerpts overall in comparison with jazz and pop/rock musicians. No outliers were found in the data.

No significant relationships between experience and familiarity, dislike and gender, age and dislike, or familiarity and gender were found. However, a positive correlation between experience and familiarity was found, with participants with more experience recognising more of the songs in the experiment, $r = 0.308$, $p = 0.038$.

No statistically significant relationship was found between surprise and familiarity. This verifies theories related to veridical expectations, in that participants were no more likely to be surprised by unfamiliar songs than familiar songs.

A moderate correlation was found for participants who marked a song disliked, and the number of negative surprise votes the song received, $r = 0.574$. This suggests that dislike votes for surprise chords were more strongly influenced by overall dislike of the song style than by the chords themselves.

7.3.2. Surprise votes

Chi square tests revealed a relationship between genre and surprise, χ^2 (2, N = 19509) = 16.29, $p < .001$. Post-hoc analysis revealed that this was accounted for primarily by differences between classical and jazz musicians. Significantly fewer jazz musicians rated chords as surprising in comparison with classical and pop/rock musicians (adjusted residual -3.0), and significantly more classical musicians rated chords as surprising in comparison to jazz and pop/rock musicians (adjusted residual 3.9). Research has shown that familiarity has limited effects on surprise due to compartmentalisation between schematic and veridical expectations (Tillmann & Bigand, 2010), but neuroscience studies have shown reduced brain activity in response to harmonic surprises in familiar excerpts. Therefore, controls for familiarity and dislike were introduced and thus this relationship was no longer found to be significant, suggesting that differences in surprise are more likely due to differences in familiarity or dislike. Further chi square tests revealed that classical musicians were significantly more likely to rate chords from familiar songs as surprising, which may account for the difference.

It should be noted that the classical musician group was primarily made up of female participants while the other groups were primarily male. There was a significant relationship between gender and surprise, with female participants more likely to rate chords as surprising, and males more likely not to, χ^2 (2, N = 19509) = 8.72, p =.013 (adjusted residual 2.7). This difference remained significant when controlling for dislike song votes, but significance was reduced when controlling for familiarity. Male participants were found to be more likely to indicate that they were familiar with songs than female participants, χ^2 (1, N = 19126) = 13.36, p < .001 (adjusted residual 3.7).

7.3.3. Individual chords

A negative binomial regression analysis was run on the full set of chords within the dataset, with Ima serving as the reference chord. Several chords were found to positively influence the amount of surprise votes made by participants. The most influential of these were MI chords and secondary dominants. Of the top 10 most influential chords in the model, only one was diatonic. Conversely, all the chords that were found to be non-significant were diatonic chords. This highlights the effects of chromaticism and diatonicism on surprise suggested by both the implicit and Explicit Experiments. The model found the most surprising chord to be the ♭VI, followed by III7, IVm6, IIIsus, and Im. All chords in the stimuli and their total surprise votes may be found in Appendix F.

7.3.4. Factors influencing surprise

The results of the negative binomial regression model indicated that several factors, in addition to chord type, contributed to the surprise levels of chords. The largest statistically significant contribution came from the sensory values output by the IPEM model. This verifies the effect of sensory influence found in the Implicit Experiment, which was particularly salient for professional and pop/rock musicians. This thesis does not aim to extricate sensory and cognitive processes, but rather to understand how their effects may be expressed in music theory terms, while acknowledging and allowing for their confounding effects.

The next most significant factor in the model was cadential structure. This suggests that chords that functioned as deceptive cadence resolutions were significantly more surprising than other chords. MI cadences were found to lead to greater surprise, with an estimate of 1.75, suggesting that MI cadences had almost double the number of surprise votes than non-cadential chords. Diatonic cadence chords were found to affect the outcome, but at a lower level of 1.006. MI chords in non-cadential contexts also had a high statistically significant estimate of 1.23.

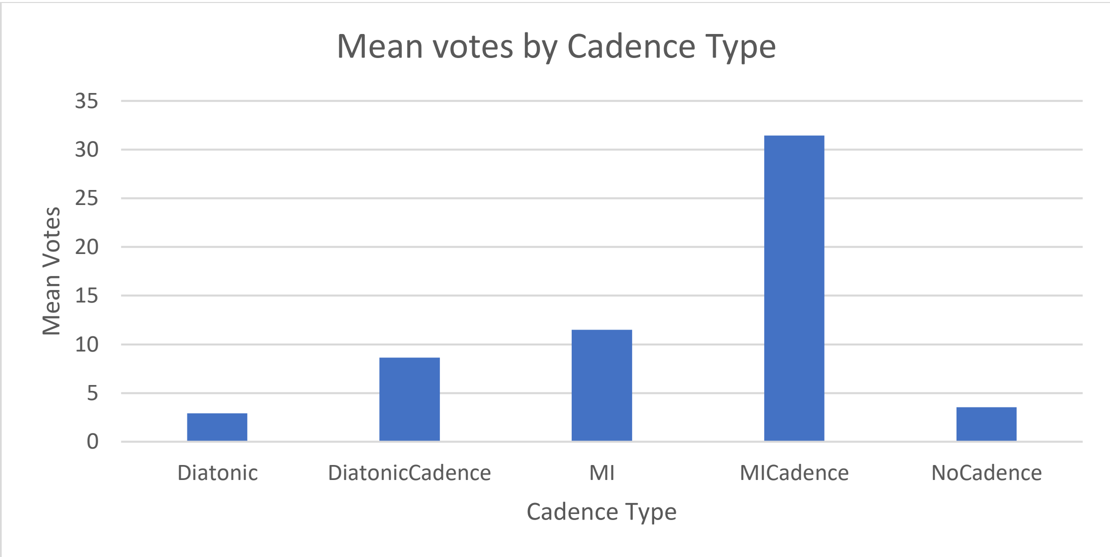

Fig. 73: Mean surprise votes by cadence type

Also highly significant was the diatonic factor, indicating that chords that were chromatic were more likely to have higher surprise levels, with an estimate of 1.39.

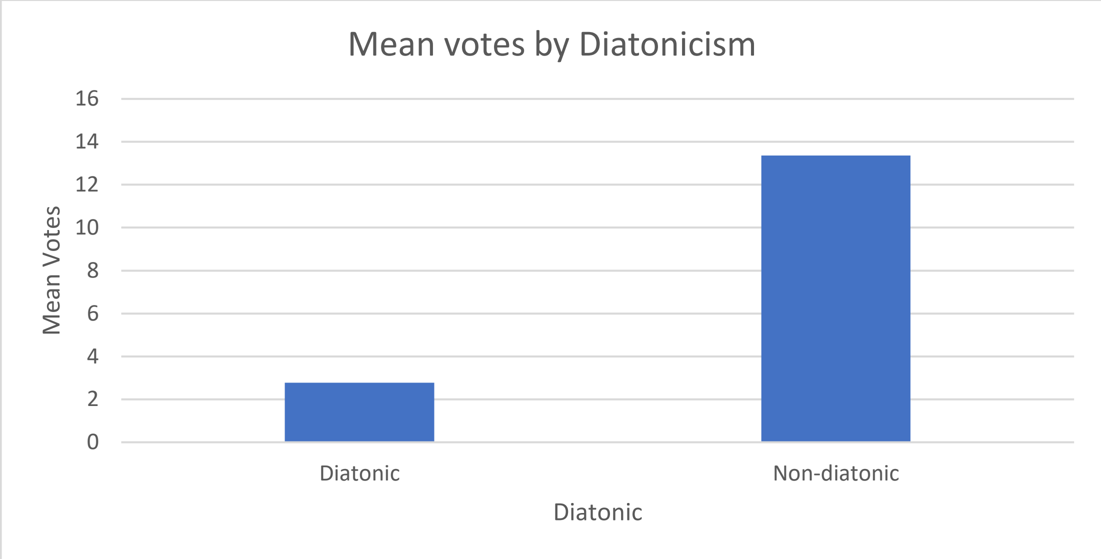

Fig. 74: Mean surprise votes: diatonic and chromatic

Two non-cadential chord categories were found to influence outcomes. These were MI chords and secondary dominants. Other categories, including chromatic passing chords, diatonic extensions, diatonic slash chords, and related II chords were not found to have an effect on surprise levels. Modulation was found to have a high number of votes, but as this category consisted of only a single chord, it was not found to be contributory by the model.

Root movements in thirds were also found to have significant effects, particularly those down a minor third and up a major third. Familiarity and dislike were not found to be contributory, nor were extensions or hypermeasures. Tonality was also not found to contribute to the model overall, in that listeners did not appear to find particular tonalities surprising in general, but tonal context did appear to strongly affect surprise in another way.

7.3.5. Tonal context

Further investigations revealed some notable findings regarding the tonal contexts of surprising chords. For example, a post-hoc one-way ANOVA revealed a significant effect of tonal context on whether the ♭VII was perceived as surprising or not, $F(3, 23) = 7.408$, $p = .002$. In the case of a definitive major context, the mean surprise level for ♭VII chords was 24 votes. However, for definitive Mixolydian contexts, this value dropped to a mean of 1. A similar effect was found for the ♭III chord. The mean surprise level for a ♭III chord in a major context was 28. For a Mixolydian context, this dropped to 8.75, a difference revealed to be significant by a one-way ANOVA, $F(1, 7) = 10.228$, $p = .019$. Within the context of the Mixolydian excerpts, the second most surprising chord was found to be a V chord. This is notable as this chord is non-diatonic to Mixolydian. Also notable is the fact that the diatonic V chord was found to be more surprising than the ♭VII in this context.

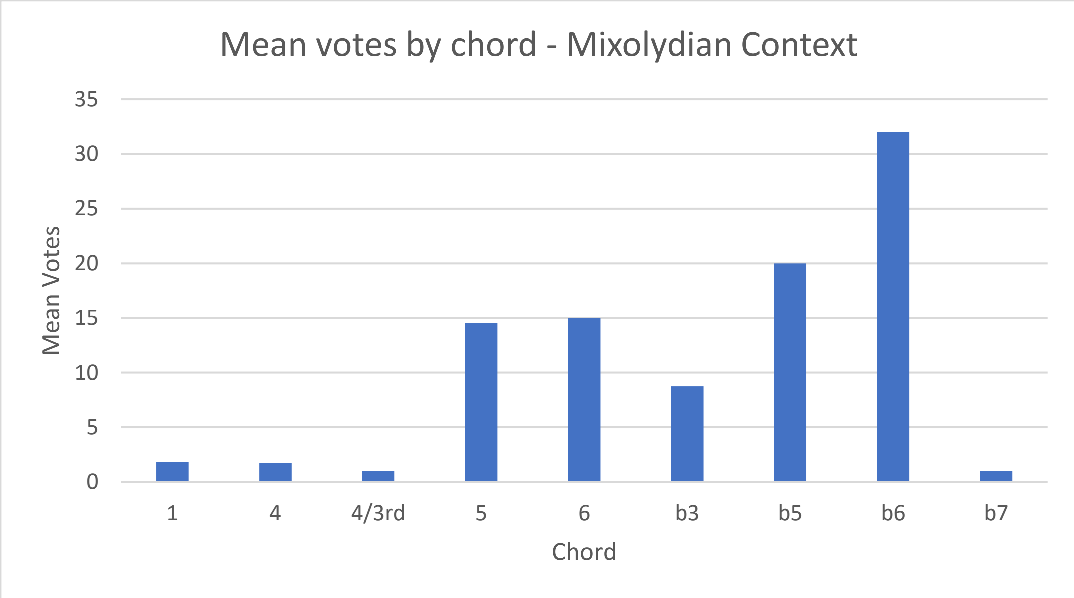

Fig. 75: Mean votes by chord within a Mixolydian context

In contrast, within a major key context, the ♭VII chord had the highest mean surprise value for participants, while the V chord had one of the lowest.

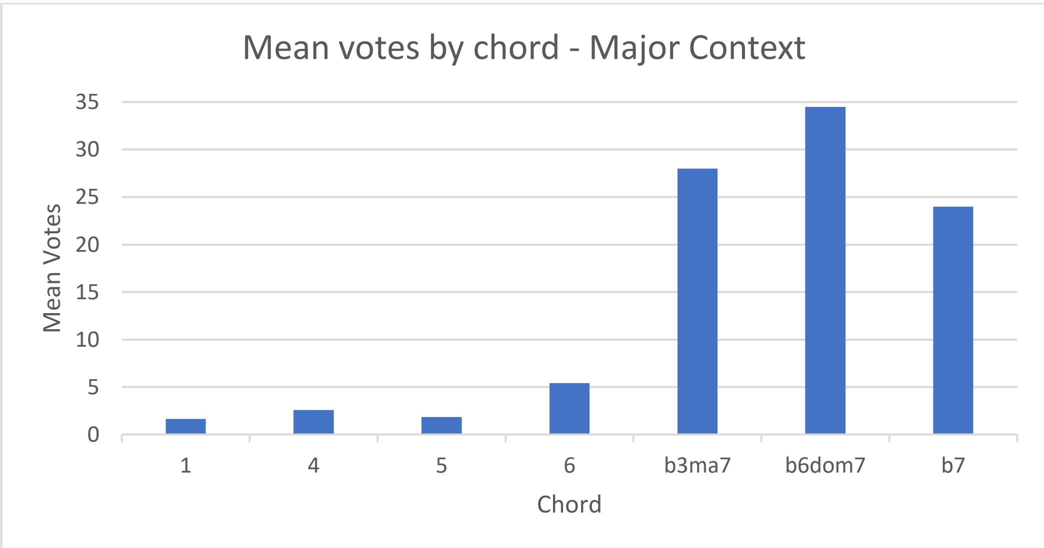

Fig. 76: Mean votes by chord within a Major context

These results suggest that surprise level is significantly mediated by tonal context.

7.3.6. Cadences

Mean surprise rating for each chord categorised by cadential structure show that MI cadences elicited significantly more surprises than other chords. These were followed by MI chords not found within cadences, which suggests that although some of the surprise factor for MI cadence chords can be explained by the surprisingness of the chords themselves, a significant proportion must be attributed to cadential structure. Diatonic deceptive cadences had a mean of nine votes, in comparison with these same diatonic chords, VIm and IIIm in non-cadential contexts which had a mean of 3. Non-cadential VIm and IIIm chords were found to be less surprising than other non-cadential chords, suggesting that the surprise factor of these chords within cadences is directly attributable solely to their cadential context. Finally, the lowest surprise values were found for authentic cadence resolutions, suggesting that, as in CP music, these are the most predictable of progressions. This also provides evidence that although popular music authentic cadences are structured in fundamentally different ways to CP cadences in terms of their hypermeasures and section contexts, they have similar effects on listeners.

7.3.7. Preferences

Participants were given three options for demonstrating surprise in their reactions: a green button to indicate a pleasant surprise, red to indicate unpleasant, and yellow to indicate neutral. Most button clicks were indicative of pleasant surprises, while a small minority were for unpleasant surprises. A negative binomial regression model with counts of down votes as outcome indicated that these votes were strongly related to participants' dislike judgements of the song styles. In other words, participants were more likely to rate their surprises as unpleasant if they found the overall style of music unappealing, and less likely to rate surprises unpleasant if they did not dislike the overall style. Therefore, positive and negative ratings of surprises were less likely to reflect participants' feelings about the chords themselves, and so were not further analysed in relation to preferences for surprises.

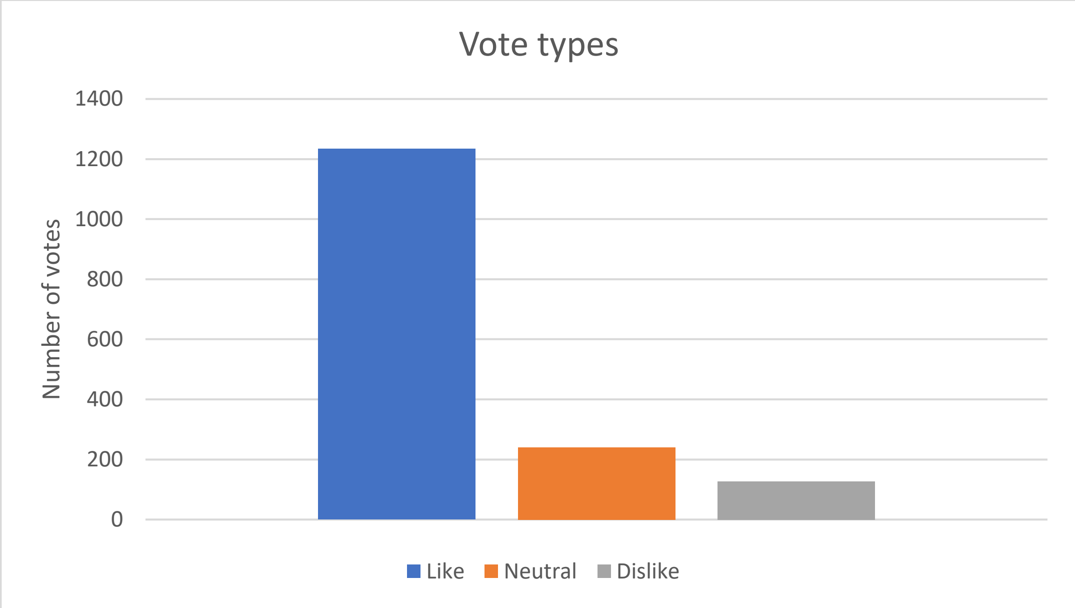

Fig. 77: Like, dislike, and neutral ratings of surprising chords

7.3.8. Differences between groups

Some relevant differences were found between stylistic cohorts. For example, classical musicians were more surprised by related II chords than other groups, while jazz musicians were more surprised by diatonic extensions. However, all groups were primarily surprised by MI.

The stylistic cohorts were generally very consistent in terms of their highest voted surprise chords, with no significant differences between the chords that the different cohorts found surprising. This finding contrasts with results found by the Explicit and Implicit Experiments but may be an indication that ecologically valid conditions are experienced differently by participants in comparison to experimental conditions.

7.3.9. Improvisation

There were no statistically significant differences in general for improvisation, but a relationship was found between surprise and pop/rock musicians who improvised. These musicians were found to register more surprises than pop/rock musicians who did not improvise, χ^2 (1, N = 6457) = 22.02, p < .001.

Notably, musicians who improvised were found to be more likely to vote surprises as liked than were musicians who did not improvise, even when they disliked the song.

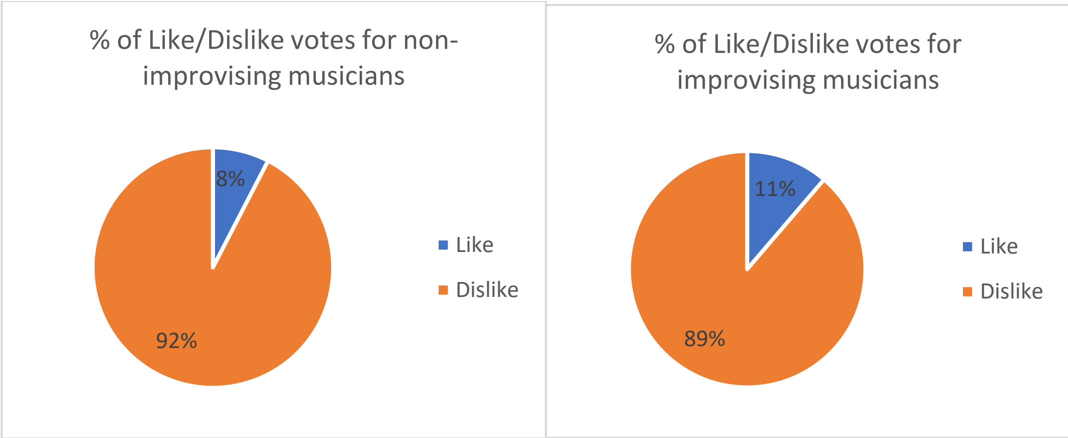

Fig. 78: Proportion of like/dislike votes for improv and non-improv musicians

Musicians who improvised were also found to register fewer dislike song votes than those who did not improvise, χ^2 (1, N = 19509) = 23.32, p =0.021.

7.3.10. Qualitative results

Participants were given the option to leave comments outlining their thoughts on the experiment. 19 of the 46 participants left feedback. These comments demonstrated an in-depth understanding of expectation, surprise, and how it relates to both music theory and listening experiences. Many participants linked surprise to specific harmonic techniques, identifying chromaticism, deceptive cadences, and progressions in thirds as techniques that evoked surprise in them.

> *"I noticed myself identifying interrupted cadences and chords that lay outside the key signature/needed accidentals"*
>
> Classical musician

> *"It's interesting how just any non-diatonic chord makes me go 'ooh'"*
>
> Jazz musician

> *"I think I like the chord progressions that go to minor keys and then resolve to the major keys - also I like suspension chords, that then resolve - something very satisfying to my ear"*
>
> Classical musician

> *"I think some of the ones I liked were '3rd relations', e.g. tonic of one chord becomes the third of the next resulting in a sudden key change"*
> Classical musician

Several participants commented on the difficulty of determining whether they "liked", or "disliked" specific surprises, reinforcing results that showed that listeners were far more significantly influenced by their stylistic preferences than by the specific chords in terms of their preferences. When compared with preference results from the previous experiments, where participants showed marked dislike of incongruous resolutions without any theoretical basis, it can be seen that once surprises are grounded in theory, their effect is more global than local. That is, listeners appear to enjoy the overall effect of harmonic surprises, rather than specific resolutions.

> *"I found it difficult to 'dislike' any of the harmonic changes. I either felt they were good, or I didn't have a strong opinion on them"*
> Jazz musician

> *"I found it difficult to place preference whether I 'liked it' or not. Hence, largely selecting the 'thumbs up' option"*
> Jazz musician

Other points made by participants include the link between style and surprise, with one participant noting:

> *"At times it is difficult to separate the 'surprise' elements of chordal progressions with the overall production and genre... for example it really works in the soul, groove, motown, jazz examples, but not so much in the pop, country, rock stuff. I found the examples that crossed over very interesting"*
> Jazz musician

This point is notable as it demonstrates the further refinement that could be made within the area of harmonic surprise in popular music. Stimuli chosen were from an array of styles within popular music, however, a corpus analysis of subgenres may reveal further patterns that may make particular chords more or less surprising within these subgenre contexts.

7.4. Conclusions and discussion

Participants in this experiment were found to be remarkably consistent with one another in their rankings of surprise within the excerpts, even accounting for stylistic expertise. This demonstrates that within a real-world musical context, surprise and expectation are valid, identifiable musical attributes that are clear and consistent, at least for professional musicians. This can also be seen in voluntary comments left by participants at the end of the experiment; as with the Explicit Experiment, many took the time to leave thoughtful and considered remarks that demonstrated that expectation and surprise are key factors in their music listening experiences.

This experiment aimed to address the following three research questions:

1) Do surprise ratings to cadences found in Experiments 1 and 2 extend to real life ecologically valid popular music conditions?
2) Are these surprise ratings related to cadence, or to chromaticism within an ecological popular music context?
3) Are these results mediated by tonal context within an ecological popular music context?

The results of the experiment with respect to these questions are discussed below.

7.4.1. Popular music cadences

Results demonstrate clearly that the traditional deceptive cadence to VIm does not appear to have the same primary surprise function in popular music as it does in CP music, although there are similarities. This finding is supported by the results of the Explicit Experiment, where the resolution to VIm was ranked the least surprising of the three deceptive resolutions in the experiment.

Notable results can be found from the comparison of surprise ratings for diatonic chords, diatonic deceptive cadences, deceptive cadences to MI chords, and MI chords themselves. The negative binomial regression model found that MI chords, and particularly MI cadences are far more significant in contributing to surprise than traditional deceptive cadences. This suggests that although the traditional deceptive cadence is used in popular music, and does have a surprising function to some extent, its function is much weaker in a popular music context than it may be in a CP context.

MI chords are more surprising when they occur as part of a cadential context than otherwise. This suggests that cadences do function within the context of popular music in the traditional way. What is different in comparison to CP is the importance of chromaticism in eliciting surprise in these contexts.

7.4.2. The effect of chromaticism

The primary factor in eliciting surprise within this experiment appeared to be chromaticism. Almost all the chords rated highly surprising by listeners were chromatic, and few diatonic chords garnered high votes.

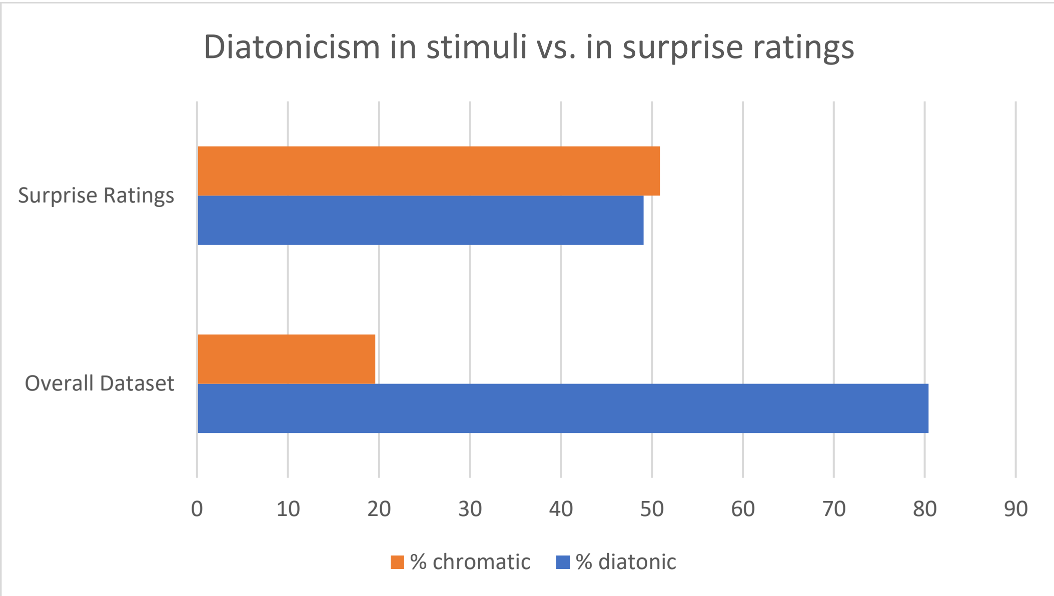

Fig. 79: Comparison of chromatic and diatonic chords in dataset and in results

This was the case regardless of hypermeasure, cadential context, or any other factor. It was also irrespective of the stylistic expertise of the participants. This is an important factor, and one that could have implications for how musical stimuli may be used in future harmonic expectation research. Researchers have used chromatic chords in experiments before, such as the N^6 chord, but this is not a chord that is common in contemporary popular music, especially in major key music. The results of this study provide a clear set of common chromatic chords from the popular music repertoire that can be relied on to provoke surprise in experienced listeners within an authentic modern musical context.

7.4.3. The effect of tonal context

Another important finding is that surprise is dependent on tonal context, which is varied in popular music. This is demonstrated in results that show that the ♭VII chord was voted highly surprising within a major key context but elicited low votes within a Mixolydian context. The reverse can be seen in results for the V chord, which was voted low in a major key context, but high in a Mixolydian context, where it would be considered chromatic. These results suggest a highly significant mediating effect of tonal context on surprise, and they highlight the importance of expanding the range of tonal contexts used in harmonic expectation experiments from major and harmonic minor to include contexts commonly found in the popular music repertoire.

7.4.4. Other sources of surprise

The most surprising chords structures found in this experiment were MI chords. MI chords tested as part of these stimuli were IVm, ♭VII, ♭VI and ♭III. All four were found by listeners to be surprising, both within and outside of cadential contexts. Secondary dominants included V/IV and V/V, and both were considered surprising to listeners. Modulations were also found to elicit surprise, although this result must be tempered by the fact that only one modulation was included in the stimuli. However, it should be noted that this one event elicited a notable number of votes from listeners, and therefore will feature significantly in the next experiment. This finding supports results found by Berent and Perfetti (1993) that musically trained listeners' reaction times to audible clicks were slower when a modulation co-occurred, in comparison to reaction times to clicks before and after a modulation, suggesting that modulations are a source of harmonic surprise.

Neither diatonic extensions nor slash chords were found to elicit significant surprise from listeners. This again reinforces the fundamental importance of diatonicism and chromaticism in surprise: these chords may be unusual within the repertoire, but their diatonicism reflects the overall tonality, and thus they are not surprising.

7.4.5. Stylistic Expertise

In contrast to the Explicit and Implicit Experiments, little difference was found between musicians with different stylistic expertise. Initial results appeared to show higher surprise levels overall for classical musicians and lower for jazz musicians. However, further investigation revealed that this relationship was mediated by familiarity and dislike. Once these factors were excluded, then all style specialisations had similar levels of surprise.

7.4.6. Summary

The results of this experiment reveal that although cadences are associated with surprise in a popular music context, they do not function in the same way as in CP. The traditional CP cadence is not considered by participants to be surprising, but deceptive cadences to chromatic chords elicit significant surprise. The results of the Explicit and Implicit Experiments raised the question of whether surprise reactions to chromatic deceptive resolutions were down to chromaticism or cadential context; the current results suggest that chromaticism is a strong factor, but surprise reactions are increased when chromatic chords are cadential. Overall, chromaticism appears to be the primary factor in eliciting surprise, while tonal context is important in mediating the surprise levels of chords.

8. Experiment 4: Surprise responses to ecological jazz music among stylistically diverse musicians (Ecological Jazz Experiment)

8.1. Introduction

The Ecological Jazz Experiment was designed and implemented almost identically to the Ecological Popular Music Experiment, with the exception of the stimuli used. In this experiment, the following research questions will be asked:

1) Do surprise ratings to cadences found in the Explicit and Implicit Experiments extend to real life ecologically valid jazz conditions?

One of the main findings of the Ecological Popular Music Experiment in terms of cadences is that the primary deceptive cadence within CP music does not have the same primary surprising effect when used in a popular music context. Chromatic MI deceptive cadences were found to have a more surprising effect than the traditional deceptive cadence. This may be due to the weakened global effect of cadence in popular music, as well as its reduced functionality in comparison to CP. In jazz however, functionality, although less globally used, is strong, as evidenced by the prevalence of the functional II-V-I progression that is ubiquitous in standard repertoire. Thus, it is likely that the perceptual effects of deceptive cadences will differ in an ecologically valid jazz context. Within CP music, cadences are generally used to end a phrase or section of, in most cases, four bars duration (Kostka & Payne, 2009). Within jazz, this may not always be the case, however. Although many of the Tin Pan Alley classics and musical theatre songs that form much of the jazz repertoire utilise traditional four to eight bar diatonic cadential structures, compositions written by jazz musicians often do away with these traditional structures. The IIm7-V7-I progression so common to these compositions is often used by composers as a compositional "cell", to be sequenced, substituted, and rhythmically manipulated.

In these compositions, the harmonic rhythm of the progression is often contracted and sometimes elongated; it can be found extending over an entire 8-bar section, such as in the John Coltrane composition "Dear Lord" (1970), or only four beats, such as in "Ecaroh" (1952), composed by Horace Silver, or Coltrane's multitonic systems, exemplified in his pioneering compositions “Giant Steps” (1960) and “Moment’s Notice” (1957), which contain several sequential II-V-Is moving at a famously fast tempo and harmonic rhythm. In addition, this progression is often tritone substituted; while the subdominant-dominant-tonic functions remain, root movement descends in semitones and chromaticism is introduced within the cadence. Thus, the traditional structure of the cadence is manipulated.

Cadences are often manipulated in other ways in jazz performances. Chromaticism is also often introduced in the final cadence of the piece, through the tendency of jazz musicians to improvise deceptive cadences to end performances. This is often achieved through the use of MI, and most commonly features ♭II as the deceptive resolution, but ♭VII, ♭III and ♭VI also feature (Mulholland & Hojnacki, 2013). Hypermeasure placement is again different from that of CP, as cadences invariably end on a strong hypermeasure, and very often a new section, within jazz. Overall, although many cadential structures follow similar patterns to those of CP, important differences in harmonic rhythm, root movement, MI, and hypermeasure mean that cadences in jazz may not be perceived in the same way as cadences in CP.

2) Are these surprise ratings related to cadence, or to chromaticism, within an ecological jazz context?

The Ecological Popular Music Experiment demonstrated that chromaticism was the primary driver of surprise in popular music. Within that context, secondary dominants were found to be one of the chromatic techniques that elicited surprise in participants. These types of chords are much more common in jazz than in popular music, as revealed by the survey in Chapter 4, and so their surprising effects may be diminished in a jazz context given their omnipresence. MI chords were also found to be surprising within a popular music context and may remain surprising within a jazz context. However, these chords are more common within jazz than within popular music. The Ecological Jazz Experiment therefore aims to explore whether chromatic techniques such as secondary dominants and MI have the same surprise effect in jazz as they do in popular music.

Extensions were not found to be surprising within a popular music context, and this is likely to remain unchanged for jazz, as the default voicing for any chord in jazz is one containing a 7^{th}. The use of extensions beyond the 7^{th}, i.e. the 9^{th}, 11^{th}, and 13^{th}, is also common, and so these will be investigated as potentially surprising. Dominant chords are often altered in jazz (Santisi, 2009), and so the surprising effects of alterations will also be investigated.

3) Are these results mediated by tonal context within an ecological jazz context?

Tonality in jazz is similar in many ways to that of popular music, but there are also important differences. For example, the tonic I chord in minor key jazz tunes is often a minor 6th or minormajor7 chord, in contrast to the minor triad or minor 7th often found as the minor tonic chord in popular music. The use of a minor 6th or minorMajor 7th emphasises a melodic or harmonic minor origin, as opposed to the natural minor origin suggested by the popular music minor triad or m7. Thus, where the same tonal structure underpins both major and minor in popular music, a contrast is implied between the major and melodic/harmonic tonalities of jazz. This suggests that the tonal ambiguity featured in popular music may not be so prominent in jazz.

Another important potential difference between jazz and popular music in terms of tonality is that non-Aeolian modal tonalities are more common than in popular music, although they of course exist in popular music. Examples include the Dorian modal compositions “Little Sunflower” (1967) by Freddie Hubbard, “Impressions” (1963) by John Coltrane and “So What” (1959) by Miles Davis. In addition, chromatic harmonies derived from these modal contexts, such as quartal voicings, are commonly found within the standard jazz repertoire. Commonalities between jazz and popular music in terms of tonality also exist, such as the use of the Mixolydian tonality, or the omission of the 7th in the major key, creating an ambiguity between major and Mixolydian common to both styles. The Ecological Jazz Experiment investigates whether tonal context has the same strong mediating effect in jazz as it does in popular music. It also explores the effect of additional modal contexts such as Phrygian, and the chromatic effects of modal-derived voicings such as quartal harmonies.

8.2. Methodology

In terms of the experimental paradigm, implementation, and statistical test selection, the methodology of the Ecological Jazz Experiment was identical to that of the Ecological Popular Music Experiment. However, there were important differences in the stimuli used, the data cleaning process, and the makeup of the participants. These are outlined below.

8.2.1. Material

Excerpts to be used as experimental stimuli were taken from a corpus of harmonic transcriptions listed in Appendix A. All of the selected examples were in major keys or modes, with the exception of a single Phrygian context. Tonal centres were again determined using Jonathon Kramer's definition of tonal centre, as outlined by Moore (1992).

Diatonic deceptive cadences to IIIm, VIm, IV, and I/3rd were identified within the excerpts. Several resolutions to different chord qualities of III chord were identified, including resolutions to IIIm6, IIIm7♭5, III13sus, and III7alt. In terms of chromaticism, MI cadences to Im, ♭VI, ♭VII were found, with resolutions to several different chord qualities. Two exceptions were noted: a cadence to Idim7, a common voice-leading ornamentation of a I chord found often in reharmonisations of jazz standards. Although this is not an MI cadence, it could still be considered surprising because of its chromaticism, and so was included in the analysis.

Additionally, several V chord modulations were identified. Although these progressions would be retrospectively perceived as modulations, the initial resolution from the diatonic V to a non-diatonic I may be considered a deceptive resolution of a V chord (Nettles, 2007a). Within the chosen excerpts, these V chord modulations consisted of a modulation up a minor third, giving a resolution to what would be considered ♭IIIma7 in the original key, and I of the new key, and two V chord modulations down a major third, with V chord resolution to the ♭VIma7 in the original key.

As in the previous experiment, these chords were then identified in non-cadential contexts within the stimuli, for comparison.

In addition, secondary dominants, SFDs, tritone substitutes, modulations, extensions (past the 7th), alterations, and slash chords were included in the excerpts.

33 excerpts were chosen, ranging in length from 20 to 49 seconds. Two excerpts containing no cadential or chromatic harmonies were also selected as controls. Details of root movement, hypermeasure placement, tonal context, and melodic context were gathered for each chord. Details of all chords in the excerpts and links to audio files may be found in Appendix G.

8.2.2. Participants

45 people completed the experiment. Unfortunately, eight of these participants were found to have not played the audio excerpts and so were excluded from the analysis and results. One

participant listened to the excerpts in full but did not record any responses and so left no usable data. This left 36 valid participants. Eight of these were female and 28 were male. Participants were asked to identify the musical style in which they specialised. Eight participants selected classical, 12 selected jazz, and 16 selected popular music. 75% of participants with classical specialisation were female, while those specialising in jazz and pop/rock skewed heavily male, at 92% and 94% respectively.

13 participants identified their musical status as full-time music students (3rd year or above), while seven identified as full-time music teachers. Most participants (44.4%, or 16 participants) identified as professional musicians. Half of pop/rock musicians indicated that they were professional musicians, with the other half consisting of one music teacher and seven full time music students. Half of classical participants were music teachers, with an equal split for the rest between professionals and students. Half of jazz participants were professional musicians, with the rest consisting of one sixth teachers, and two sixths students. As in the previous chapter, all participants will be referred to as "musicians", regardless of their status, unless status is explicitly being discussed.

The mean value in years of experience was 20.8 years, a drop of approximately seven years in comparison to the participants of the Ecological Popular Music Experiment, with a standard deviation of 11.394. The range of participant experience was 5 – 47 years. In contrast to the previous experiment where pop/rock musicians had the most experience, this cohort were found to have the least, with a mean of 15.75 years. Classical musicians averaged 23.75 years of experience and the most experienced were jazz musicians, with a mean of 25.6 years. This difference was not found to be statistically significant. In contrast to the previous experiment, where the most experienced musicians were found to be professional musicians, in this case teachers had the most experience, with the same mean of 31 years. Professional musicians had a mean of 24.25 years and students 11.2 years.

When asked if improvisation was an important aspect of their musical practice, most participants maintained that it was, with 24 answering "yes", while 12 answered "no". All jazz participants answered that improvisation was an important part of their practice, while only one classical musician answered in the affirmative. The majority of pop/rock musicians (69%) improvised. Musicians who improvised and those who did not improvise had roughly similar years of experience.

8.2.3. Data cleaning

As in the previous experiment, count values were summed for each chord, resulting in a roughly Poisson distribution for the outcome variable. Again, testing revealed the data to be overdispersed. Therefore, a negative binomial regression model with an estimated parameter was again used, reducing the means/variance ratio from 1:2.766 to 1:1.191 and allowing for a model to be accurately fit. The same predictor variables were used as in the previous experiment. However, due to the different nature of the musical style, there were differences in the levels within some of these variables. These included quartal chords and diatonic alterations added to the chord categorisation variable.

8.3. Results

Participants were familiar with 14.6% of the songs, and disliked 3%, less than half of what was disliked in the previous experiment. In the previous experiment, a significant relationship was found between participants' likelihood to indicate familiarity or dislike. However, this test did not reach significance for this experiment, χ^2 (1, N = 1260) = 4.542, p = 0.058 with continuity correction. In a binary logistic regression, no factors were found to significantly affect the outcome variable of dislike. This is expected, as dislike ratings were much lower for this experiment than for the previous experiment.

Chi square tests revealed that, unsurprisingly for an experiment using jazz stimuli, jazz musicians were more likely than popular music or classical musicians to be familiar with the stimuli, χ^2 (1, N = 1260) = 222.693, p < .001. In terms of overall votes, jazz participants indicated surprise on 507 occasions, with a mean of 42 votes per participant over the course of the experiment. Classical musicians had slightly more surprise votes per person, at 43, with a total of 347 votes. Pop/rock musicians made the most indications of surprise, with a total of 881, for a mean per participant of 55.

8.3.1. Like/dislike/familiarity

8.3.2. Individual chords

A negative binomial regression analysis was run on the full set of chords within the dataset, with the diatonic I chord as reference. Several chords were found to positively influence the amount of surprise votes made by participants. 43 chords reached statistical significance. Of these, only seven were diatonic, or 16%. For reference, in the total datastet, 28.5% of chords (not counting repetitions) were diatonic. Within the chords that did not reach significance, 65% were diatonic.

Quartal chords were found to be among the chords with the highest estimates. These included the ♭IIIm11, IVm11, ♭IIm11, Vm11, and ♭VIm11. Other prominent chords of statistical significance were MI chords, including the ♭VIsus2, the IVmiMa9, ♭VI, and the Im. Modulations also featured, as did tritone substitutes. Several of the MI chords were found to be cadential. All chords and their surprise votes may be found in Appendix G.

8.3.3. Factors influencing surprise

In the previous experiment, the greatest contribution to the negative binomial regression model came from the IPEM sensory values corresponding to each chord. However, this was not the case for the Ecological Jazz Experiment. In this case, IPEM sensory values were not found to be a statistically significant factor in the model. This suggests that cognitive factors, rather than sensory, were behind listeners' voting decisions.

Instead, the most significant contribution to the model in this case came from the chord categories, with chromatic categories being particularly influential. The category with the highest estimate was the category of quartal harmonies, with an estimate of 1.8, followed by MI with an estimate of 1.64. MI had also been found to significantly influence surprise levels in the Ecological Popular Music Experiment. Modulations, only one of which had featured in the musical stimuli of the Ecological Popular Music Experiment, were found to be significant, with an estimate of 1.6. Diatonic chords with alterations, as well as secondary dominants, tritone subs, related II chords, and SFDs were also found to be significant. Of these categories, only secondary dominants had been found to be significant in the previous experiment. The Berklee categories of diatonic, diatonic extension, diatonic slash chord, line cliché, and passing chromatic, as in the Ecological Popular Music Experiment, were not found to be significant.

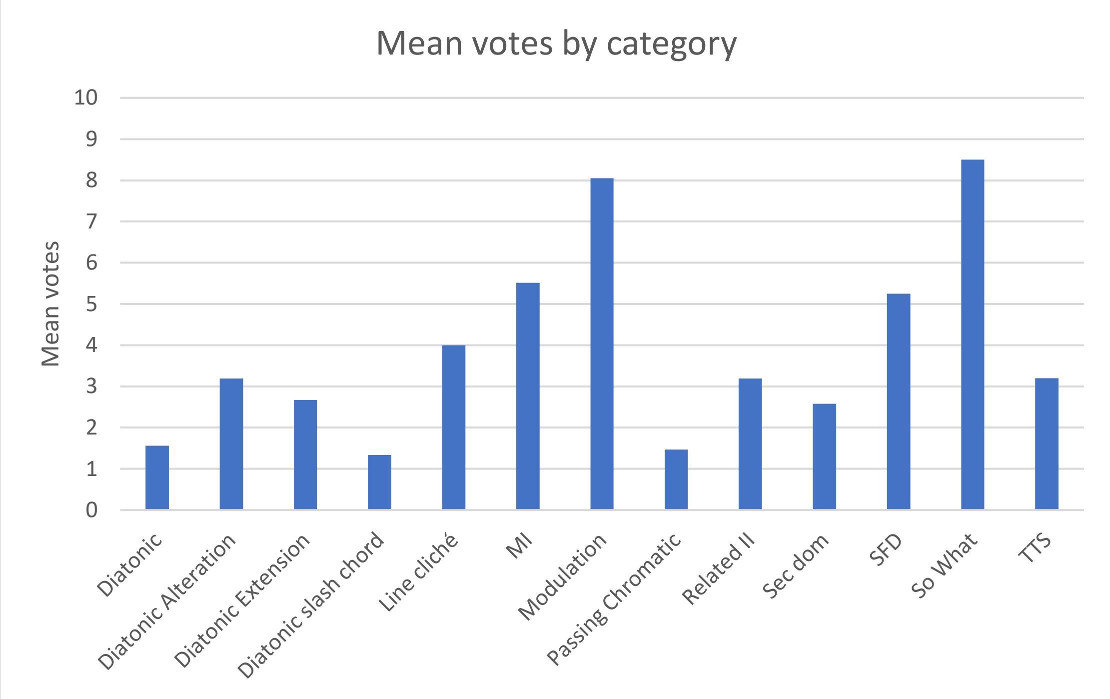

Fig. 80: Surprise levels for chord categories

Familiarity was found to be a significant factor, with a negative relationship between participants' familiarity with the songs in the experiment and the surprise votes they gave to the chords within them.

Several root movements appeared to influence ratings of surprise. Movements of a tritone and down a major third were found to be significant. In the previous experiment, movements up a major third and down a minor third had been found to be significant. Diatonic cadences appeared to influence surprise votes, although MI cadences did not. However, MI cadences had the highest mean rating of surprise votes.

Overall, as in the Ecological Popular Music Experiment, diatonicism appeared to be an important factor in surprise levels, with a significant result for chromaticism as a model predictor.

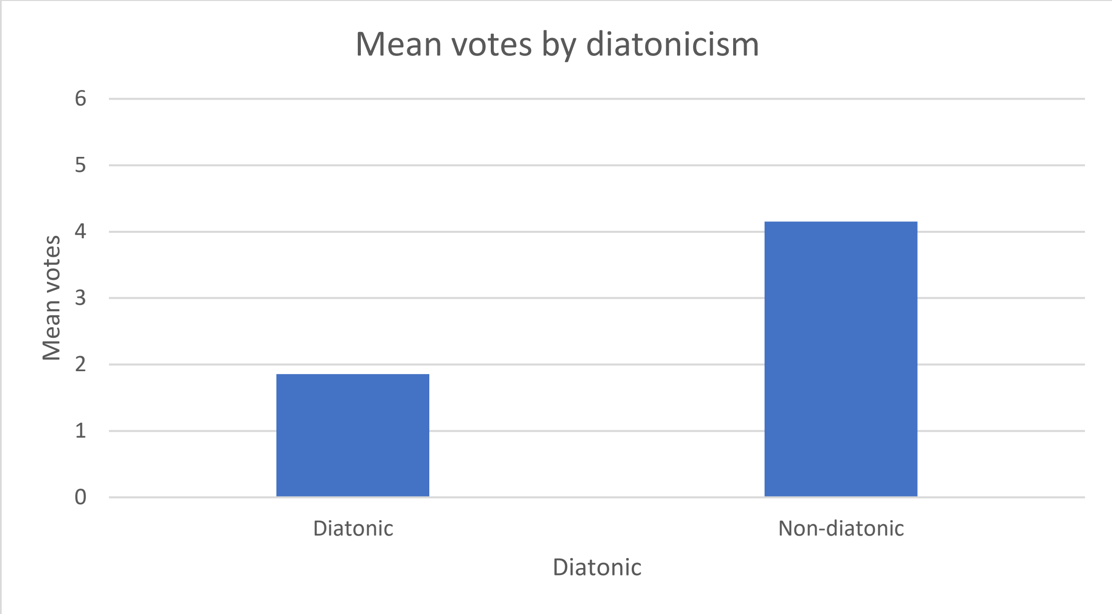

Fig. 81: Mean surprise votes: diatonic and chromatic

8.3.4. Tonal context

Harmonic context again appeared to have a strong effect on the expectedness of chords. As in the previous experiment, a one-way ANOVA revealed a significant effect of tonal context on whether the ♭VII chord was heard as surprising or not, ANOVA, $F(3, 34) = 4.897$, $p = .014$. The mean surprise level for ♭VII chords was 7 in a definitive major context, and reduced to 1 for definitive Mixolydian contexts. In the previous experiment, the V chord was found to be significantly less surprising in a major context than it was in a Mixolydian context. This was verified by this experiment, with the addition of information about Phrygian contexts. A one-way ANOVA revealed a statistically significant difference between surprise ratings for V chords (with no extensions or alterations) in major and modal contexts, $F(3, 45) = 3.894$, $p = .015$.

For the ♭II chord, a one-way ANOVA revealed a significant effect of context, but only between Phrygian and major without a 7th present. ♭II chords were found to be more surprising in the context of major without a 7th than they were in the context of major or Phrygian. This may be related to the fact that several of the ♭II structures were dominant 7th chords, which contain the ♮7th as a chord tone.

It may also be worth noting that the most surprising chord within the context of Mixolydian was found to be a VIIm7 chord, which emphasises the ♮7th. This chord received 14 votes within a Mixolydian context, but only four votes within a major context. As there were only one instance of each chord, no statistically significant measurements could be taken.

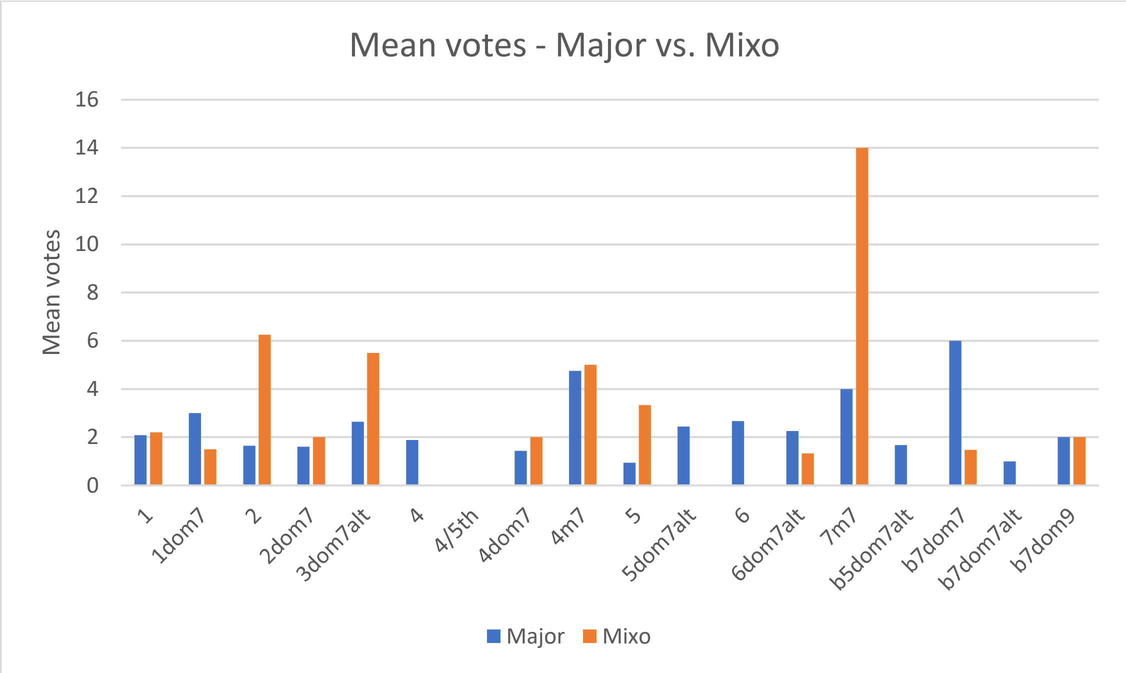

Fig. 82: Mean surprise votes: major and Mixolydian

Overall, a one-way ANOVA found tonal context to be a significant factor in participants' surprise votes for MI chords, $F(3, 65) = 5.699$, $p = .002$. These chords were found to be significantly less surprising in Mixolydian contexts than in major, or major without a 7th contexts.

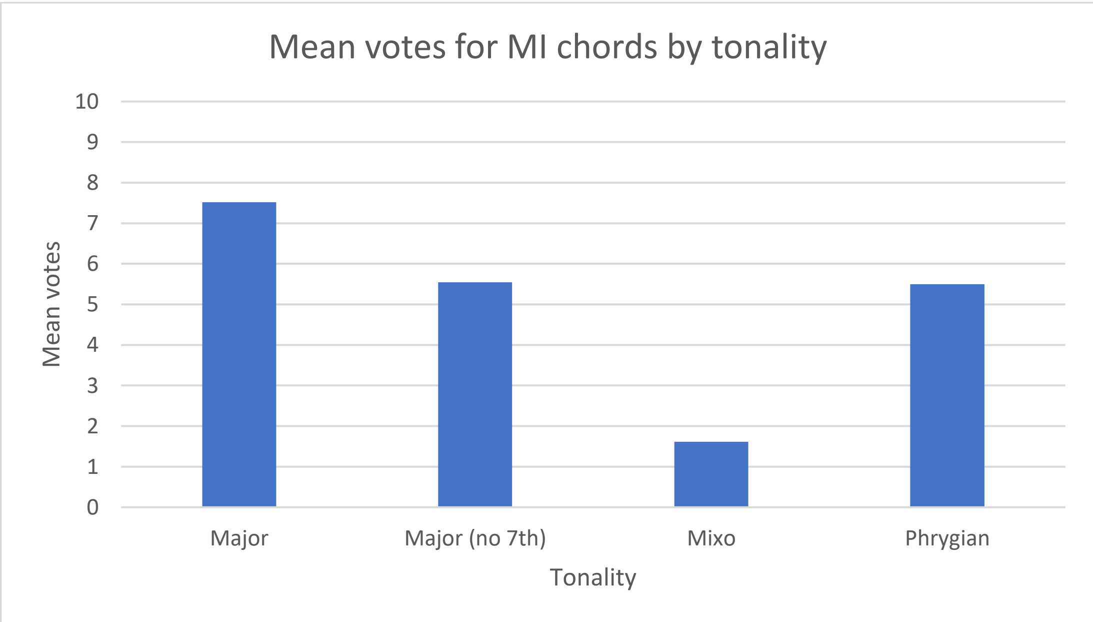

Fig. 83: Mean votes for MI chords by tonality

8.3.5. Cadences

Results of a negative binomial regression model suggested that deceptive cadences, particularly those with resolutions to MI chords, are an important contributor to surprise levels in jazz music.

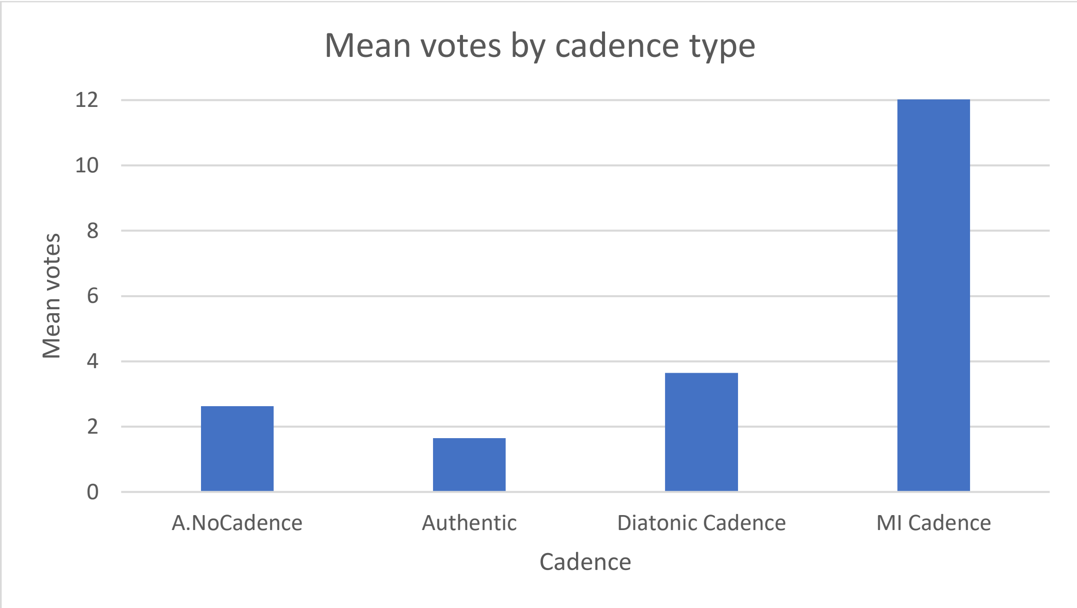

Fig. 84: Mean votes by cadence type

Surprise results for cadences were similar to those found in the Ecological Popular Music Experiment. As with that experiment, mean surprise ratings for each chord categorised by cadential structure show that MI cadences elicited significantly more surprise votes than other chords. MI chords not found in cadential contexts had the same mean as diatonic cadence chords. Authentic cadences and non-cadential chords had the lowest means of these groups.

Although MI cadences were not found to contribute significantly to the negative binomial regression model, a one-way ANOVA found that this category had a significant effect on surprise levels, when compared to other chord types, $F(5, 611) = 28.481$, $p < .001$.

This also provides evidence that although popular music cadences are structured in fundamentally different ways to CP cadences in terms of their hypermeasures and section contexts, they have similar effects on listeners, notwithstanding differences in chord types.

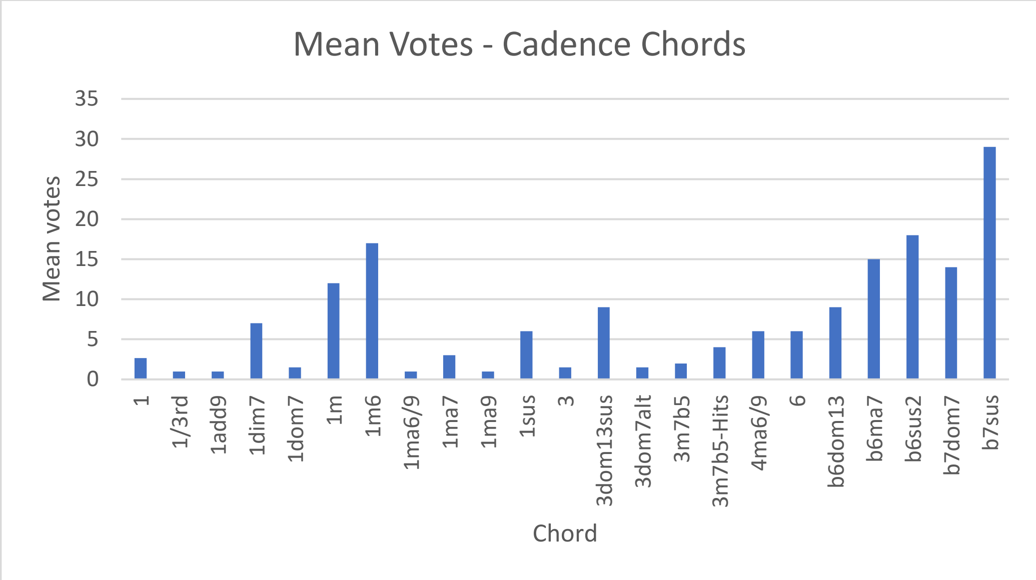

Fig. 85: Mean votes by cadence chord

8.3.6. Modulation

The negative binomial regression model revealed that listeners found modulations particularly surprising. This was hinted at in the results of the Ecological Popular Music Experiment, when the single modulation included in the stimuli garnered high surprise ratings. In an unexpected finding, no difference in surprise level was found between prepared and unprepared modulations. Neither did hypermeasure seem to affect the surprisingness of modulations. It appears that modulations, regardless of their finer details, are surprising to most listeners.

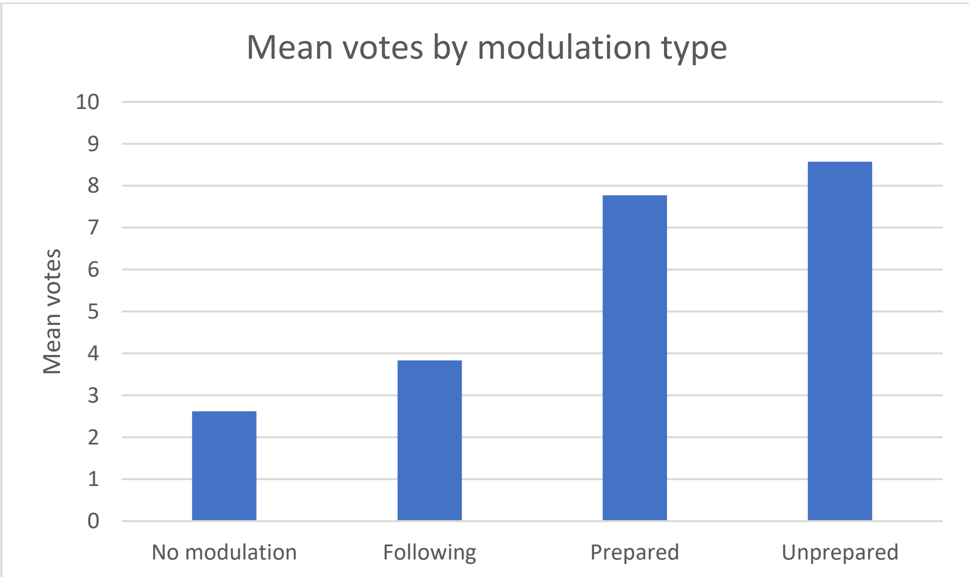

Fig. 86: Mean votes by modulation type

8.3.7. Preferences

As with the previous experiment, participants were given three options for demonstrating pleasant, unpleasant, and neutral surprise in their reactions. Most votes were indicative of pleasant surprises, while a small minority were for unpleasant surprises. The previous experiment revealed a significant effect of dislike on unpleasant surprise ratings, that is, participants were more likely to indicate an unpleasant surprise if they disliked the style of the excerpt. This suggested that positive and negative votes were less related to the specific surprises in question, and more to the overall style of the music. In this experiment, dislike was not found to significantly influence negative voting. This may be related somewhat to the fact that there were relatively few dislike votes, in comparison to the previous experiment.

Of a total of 1735 votes made by the participants, only 109, or 6.3% were negative. 91 of these negative votes were made by the same five participants, and 27 of these were made by the same single participants who clicked the dislike button on almost every song. A multinomial regression analysis, with pleasant/unpleasant/neutral votes as the outcome variable, found that the most significant factor in which rating was chosen by participants was the participants themselves. This suggests that listeners' personal preferences were important factors, and thus their votes of pleasant, unpleasant, and neutral were peripheral to their perceptions of surprise.

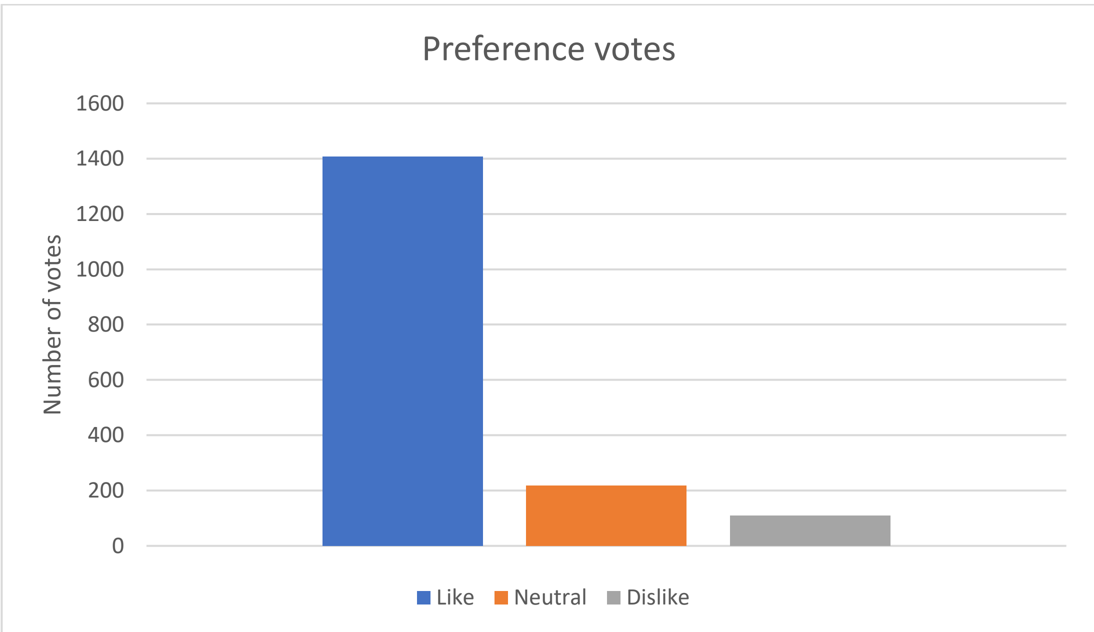

Fig. 87: Like/dislike/neutral votes

8.3.8. Differences between groups

Results demonstrated that jazz musicians were significantly less likely to experience surprise in this experiment in comparison to classical or pop/rock musicians. Other relevant differences were found between groups. As in the previous experiment, classical musicians were more surprised by related II chords than were jazz musicians. All groups were primarily surprised by the same factors though: MI, quartal chords, and modulation. Some root movements also played a part for jazz and pop/rock musicians, but not for classical musicians. Movement down a major third was surprising for jazz musicians, but not the other groups. Movements up a tritone and down a major second were surprising for pop/rock musicians only. Movement up a major third was also marginally significant for pop/rock musicians ($p = 0.051$) and for jazz musicians ($p = 0.058$). No root movements were significant for classical musicians.

Diatonic cadences were surprising for classical and jazz musicians, but not pop/rock musicians, which further supports results suggesting that cadence to the VIm is not an important progression in popular music. MI chords were highly significant for all stylistic cohorts, but MI cadences did not reach significance for any cohort. None of the three cohorts were particularly surprised by the sensory ratings of the chords, nor by extensions, although both jazz and pop/rock musicians were surprised by alterations in the diatonic chords.

In terms of individual chord surprise levels, there was again strong consistency between participants. Some differences were found in how participants interpreted cadences. Pop/rock participants found diatonic cadences less surprising than the other groups, while they found diatonic chords in non-cadential progression more surprising. Otherwise, participants were very consistent between groups.

	Classical %	Jazz %	Pop/Rock %
Authentic cadence	12.21	10.10	11.22
Diatonic Cadence	12.98	12.12	8.58
MI Cadence	25.95	28.28	28.38
Diatonic - no cadence	10.69	11.62	15.51
MI - no cadence	38.17	37.88	36.30

Table 15: % of participant votes by cadence type

8.3.9. Qualitative results

Participants were again given the option to leave comments describing their thoughts on the experiment. 18 of the 46 participants left feedback. What was striking in these comments was the recurring theme in the responses of jazz musicians that they found very little surprising. This is reflected in the surprise votes of the experiments; the mean number of votes per jazz musician was 16.5, in contrast to the mean number of votes per pop/rock musician of 20.3.

> *"I found very few harmonic surprises in general in these songs, presumably because they are so familiar to my ear."*
> Jazz musician

> *"In quite a few examples I did not find anything surprising."*
> Jazz musician

> *"I was very familiar with most of the tunes, most of the harmony was expected, so difficult to hear any surprises."*
> Jazz musician

Notably, classical musicians had a relatively close mean to the jazz musicians, with 17.4 per participant. It is interesting that no classical musicians reflected a lack of surprise in their comments, with one participant noting that they were unfamiliar with the majority of the samples:

> *"…I only recognised one…"*
> Classical musician

One jazz musician reflected that they indicated surprise at points they assumed that other people would indicate surprise:

> *"In a lot of the examples I hit the green button where I thought most people would find the chord surprising"*
> Jazz musician

However, others indicated that they had taken the opposite approach:

> *"This prior knowledge made me internally acknowledge the presence of interesting chords changes but not mark my reaction to them in the experiment as they didn't feel unexpected enough to 'surprise me'"*
> Jazz musician

> *"I think there was one or two audio samples where none of the harmony seemed unexpected to me so I would have left them blank"*
> Jazz musician

One jazz musician, who appeared to have also participated in the previous experiment, noted explicitly that their familiarity with the style reduced any surprises they could take from it, in comparison to more unfamiliar styles:

> *"I think that because I knew I was listening to jazz, I didn't find the harmonic surprises as surprising as in the previous experiment, when we were listening to more than just jazz."*
> Jazz musician

As in the previous experiment, participants demonstrated an in-depth understanding of expectation, surprise, and how these factors relate to both music theory and listening experiences. Many participants linked surprise to specific harmonic techniques, including specific jazz techniques such as MI:

> *"I would always expect key changes, modal interchange etc and would quite often guess what that would be even if I didn't know the tune."*
> Jazz musician

> *"…I found if [the chords] were leading to what felt like a cadence that they didn't finish, it was the most unexpected…"*
> Pop/rock musician

Notably, one participant noted a link between functional harmony and a lack of surprise, suggesting that perhaps for some jazz musicians, surprise is unlikely to occur except in non-functional contexts:

"Nothing sounded unexpected to me, almost every example was functional harmony..."

Jazz musician

In the same vein, another noted that surprise might be more likely to come from more contemporary jazz:

"...perhaps you could have chosen some new jazz, more angular and challenging?"

Jazz musician

Finally, one participant reflected on the aesthetic value of unexpected harmony:

"Deceptive chord changes, love them!"

Jazz musician

8.4. Conclusions and discussion

As with the previous experiment, participants were extremely consistent with each other in their surprise ratings, demonstrating that these effects are most likely universal for musicians trained in jazz, classical, and popular music. Comments left by participants demonstrate further that expectation and surprise are important attributes of music listening experiments. Thus, overall results show important differences between how cadences and chromaticism are perceived in jazz, CP music, and popular music, and important differences in how surprise is elicited in these styles.

This experiment aimed to address the following four research questions:

1) Do surprise ratings to cadences found in Experiments 1 and 2 extend to real life ecologically valid jazz conditions?
2) Are these surprise ratings related to cadence, or to chromaticism within an ecological jazz context?
3) Are these results mediated by tonal context within an ecological jazz context?
4) What additional features may be related to expectation and surprise?

8.4.1. Cadences in jazz

Similarly to the Ecological Popular Music Experiment, the traditional deceptive cadence to the VIm chord does not appear to have the same primary surprise function in popular music as it does in CP music. This deceptive cadence was ranked low in terms of surprise by participants, particularly in comparison to chromatic deceptive cadences. Regression models demonstrated that diatonic deceptive cadences were an important factor for participants' surprise levels, but these were primarily accounted for by resolutions to III, rather than VI.

Participants appeared to find resolutions to MI chords much more surprising than those to diatonic chords. This was particularly relevant for the ♭VI chord, which was generally rated high in surprise. As with the previous experiment, participants rated MI cadence chords as more surprising than MI chords outside of a cadential context, suggesting that deceptive cadences are effective in jazz in terms of generating surprise. What is different in comparison to CP is that the resolution chords need to be chromatic in order to elicit high surprise levels. These results also demonstrate similarities between jazz and popular music in terms of cadences.

8.4.2. The effects of chromaticism and tonal context

The main finding of this experiment is that chromaticism appears to be the primary driver of surprise within jazz music. This is consistent with the results of the Ecological Popular Music Experiment. Tonal context was again found to be a mediator of surprise with respect to chromaticism. Several chords that were rated surprising within a major context were rendered less surprising when heard within a Mixolydian context and vice versa.

8.4.3. Other sources of surprise

Several techniques with the potential to elicit surprise within jazz were also investigated. These included quartal harmonies, modulations, tritone substitutes, SFD chords, altered chords, slash chords, and line cliches. Results show that quartal harmonies were found to be the most surprising type of chord in the dataset, with statistically significant ratings also found for secondary dominants, tritone subs, related II chords, and SFDs. Altered chords, extensions beyond the 7^{th}, and slash chords were, as in the previous experiment, found to be non-surprising.

8.4.4. Stylistic Expertise

As with the previous experiment, little difference was found between the types of harmonic techniques that listeners found surprising. What was found to be different between the stylistic cohorts, however, was the amount of surprise they experienced. This was validated by the comments left by participants, which indicated that jazz musicians generally were less surprised by the stimuli.

8.4.5. Summary

Stylistic expertise appeared to mediate surprise to some extent in this experiment, with jazz musicians demonstrating lower surprise overall. Otherwise, similar results were found to the Ecological Popular Music Experiment, particularly with reference to cadences. Again, cadences to the traditional VIm were not found to be particularly surprising to participants, although cadences to chromatic resolutions were. As with the previous experiment, the main finding is that chromaticism appears to be the primary driver of surprise within jazz music, for musicians, and that tonal context is an important factor. Quartal harmonies, secondary dominant, tritone subs, related II chords, and SFDs were all found to be surprising by participants.

9. Conclusions and Discussion

9.1. Overall findings

The aim of this thesis was to fill the knowledge gap in music cognition caused by the exclusion of jazz/popular music and musicians in harmonic expectation research due to the assumption that CP is paradigmatic of all Western music styles. This was to be achieved through two objectives: discovering the ways in which expectation and surprise differ between CP and contemporary popular styles, and determining the musical techniques that elicit expectation and surprise in jazz/popular music. This project has resulted in four primary findings which together serve to introduce new information into the study of harmonic expectation and surprise.

9.1.1. Expectation in CP is not paradigmatic of jazz and popular music.

The literature review in this thesis revealed fundamental differences between the narratives, tonal frameworks, functionality, and harmonic languages of CP, and of jazz and popular music, due to the influence of blues and other factors. It also revealed that these elements are strongly associated with the techniques used to elicit expectation and surprise in CP, i.e. cadence, chromaticism, and modal mixture. For example, the surprise reaction garnered by the VIm deceptive resolution in CP is dependent on goal-oriented structure and the functionality of the dominant V chord. The experiments in this study therefore aimed to investigate if these differences in narratives, tonal frameworks, functionality and harmonic language between CP and jazz/popular music led to differences in cadences and chromaticism, and therefore differences in how expectation and surprise are elicited. The results of the experiments demonstrated that the differences described above do bear out when empirically tested, and thus it can be concluded that CP harmony is not paradigmatic of all Western tonal styles.

9.1.1.1. Narratives and tonal frameworks

CP narrative is large-scale and goal-oriented, with expectation at its core. Composers elicit both expectations for local cadences, and global expectation throughout large-scale forms. In contrast, forms within popular music tend to be cyclical. Narrative, in terms of harmony, is based on local fulfilment of harmonic goals. Within jazz, narrative is tied to the goals of the improviser and the ensemble. These goals may be melodic, harmonic, rhythmic, or textural. Song form serves as a cyclical structure over which to build a larger scale narrative. However, local harmonic goals, such as II-V-I progressions, occur more regularly in jazz than within CP.

Tonal frameworks within CP are, for the most part, strictly delineated into major and minor. Modulations between these are clearly distinguished. Modality is uncommon. In contrast, tonal frameworks within popular music are malleable and amorphous, in part due to the influence of blues. Both natural and flattened 3rd, 7th, and 6th scale tones are tolerated within a diatonic context, and modalism is common. Within jazz prior to the post-bop period, tonal frameworks are generally delineated as major or minor, but chromaticism is extremely common, and blues harmonies are regularly incorporated into diatonic frameworks, particularly within the hard-bop style.

The corpus analyses of jazz and popular music repertoire carried out in this study revealed a wide variety of tonal contexts in both styles. Some of these did not reflect traditional tonal or modal frameworks. For example, several major key contexts devoid of 7th tones were found. This speaks to the flexibility of tonality within popular music described throughout this thesis and highlights differences in tonal frameworks between popular music and CP. It also highlights the variety of contexts that are found in the jazz repertoire but unaccounted for in jazz theory.

The results of both Ecological Experiments demonstrated the importance of tonal context in defining and determining harmonic surprise. For example, within the clearly articulated major key context, the ♭VII chord is found to be surprising, but in contexts without a 7th it is not. Given the variety of tonal and modal contexts found in jazz/popular music, as well as the non-traditionally tonal contexts of triad-doubled systems, chords cannot be relied upon to have universal effects. Instead, the perceptual effects of chords must be understood with respect to their tonal contexts.

9.1.1.2. Functionality and cadence

Functionality within CP is based on diatonicism, with strict dominant functionality applying to the V chord, subdominant to the IV, and tonic to the I. Functionality is inherent to narrative in CP.

Popular music, however, is generally less functional, for several reasons. These include the elevation of the IV chord to a level on par with the V, the divorce of melody from harmony and of cadence from CP hypermeasure norms, the prevalence of non-goal-oriented cyclical forms, and the reduction in importance of the leading tone due to the ubiquity of the ♭7th. Cadential points may be signposted using chords other than the V, such as the ♭VII.

Jazz could be considered locally hyper-functional in comparison to CP, due to the prevalence of the II-V-I structure. It features an elevation of the II chord as the primary subdominant in place of the IV, although the IV maintains subdominant function in Great American Songbook contexts. As with popular music, the ♭7th tone is elevated in importance, thus reducing functionality related to the leading tone.

Functionality in CP music is primarily manifested in the cadence. The V chord elicits strong expectations for resolution to I through its dominant function. Theorists such as Daube and Türk have described multiple types of deceptive cadences available within CP, with gradations of surprise elicited by them. Over time, these were reduced by theorists and practitioners to the VIm, currently considered the exemplar. Resolution to the VIm traditionally results in surprise, as described by theorists and evidenced by harmonic expectation experiments in the literature.

However, this effect appears not to hold in the case of jazz/popular music. Although cadences were found to be surprising in both the Ecological Jazz Experiment, and the Ecological Popular Music Experiment, the traditional deceptive cadence to VIm was not, and chromaticism in the form of MI is required for a deceptive cadence to be surprising.

In addition, MI chords do not need to be part of a deceptive cadence to be surprising, in the way that the VIm is generally considered unsurprising outside of a cadential context. MI chords were found to be significantly surprising on their own, thus lessening the importance of cadential context in eliciting surprise. This suggests a reduced effect of the V chord to elicit expectation purely through its function. Within the context of popular music, this finding supports the conclusions of Biamonte, Moore, and others that functionality within popular music does not follow the same rules as CP.

Although the effect of the cadence appears to be reduced in comparison to CP contexts, it is not eliminated, and the wide range of chromatic colour chords available within jazz and popular music allows for more deceptive cadences than are traditionally found in CP. Deceptive cadences to IIIm, ♭VI, ♭VII, ♭III, ♭II, IVm were found in the corpus analyses carried out for this thesis. This range of cadences suggests a gradation of surprise, such as that described by Daube and Türk.

9.1.1.3. *Harmonic language*

Harmonic language in CP is primarily diatonic, with chromaticism introduced mainly through secondary dominants, modal mixture, N^6 and $^+6$ chords.

A wide variety of chromatic chords were found in the corpus analyses, and harmonic analysis of these chords demonstrated that those that overlap with chromatic CP chords were used in functionally different ways. The results of the Explicit and Implicit Experiments demonstrated a wide range of acceptable chromatic chords with gradations of surprise elicited by them. These gradations of surprise were further reflected in the results of the Ecological Experiments. This finding highlights the variety of chromaticism found in both jazz and popular music, and the gradated nature of surprise in these contexts.

Tonal language in jazz before post-bop is fundamentally diatonic, but due to the innovations of swing and bop musicians, incorporates a wide range of functional chromaticism as well as chromatic colour chords. These include altered secondary dominants, non-diatonic related II chords, tritone substitutes, modal interchange and SFDs.

Within popular music, the prevalence of modalism and the reduced distinction between major and minor has allowed for many additional chords considered chromatic in CP, such as the ♭VI, ♭VII and ♭III, as part of the tonal language. In addition to these chords, secondary dominants and modal mixture can be found. Modal mixture is expanded from the traditional IVm chord to encompass the ♭VI, ♭VII, ♭III, and ♭II. Although these chords may overlap with chromatic CP structures such as the N^6 and $^+6$ chords, their functions are often different. Rather than functioning as pre-dominants, these chords in popular music usually feature as colour chords.

9.1.2. Stylistic expertise, improvisation training, and musical training affect expectation and preferences.

The literature review revealed promising results of experiments on the effects of improvisation and stylistic diversity on music processing. These results were suggestive of an effect of these factors on harmonic expectation. The four experiments carried out in this study revealed significant effects of these factors on harmonic expectation.

9.1.2.1. Musicians vs. general listeners

Differences between general listeners and musicians suggest significant effects of musical training and experience on expectancy, preferences, and interactions between these. Although general listeners were in strong agreement with each other on their surprise ratings, their intersubject correlation levels were significantly lower than those of musicians. This suggests that musical training leads to more definitive abilities to delineate chords based on surprise. This effect appears to be strongest for jazz and improvising musicians. General listeners were not found to have either facilitated processing for expected cadences, nor inhibited processing for deceptive or unexpected cadences.

General listeners appear to delineate and cluster expectancy and preference based on diatonicism, with lower surprise levels and higher preference for diatonic chords, and higher surprise levels and lower preference for chromatic chords. These participants demonstrated an inverse linear relationship between liking and surprise. This contrasts with musicians, particularly jazz musicians, who tended to be less surprised by and have higher preferences for chromatic chords in comparison. Previous experimental results have found that general listeners both are less surprised by and have higher liking for expected chords, but this has not previously been linked to any specific musical techniques, such as diatonicism or chromaticism. This finding may be of use in describing the results of harmonic expectation studies in the language of musicians in order that they may be used to further the understanding of musical expectation for the benefit of its practitioners.

9.1.2.2. Pop/rock musicians

Within all four experiments, pop/rock musicians showed significant differences with regard to both general listeners and other musicians. This cohort appeared to be the only group whose reaction times (RTs) related to chord expectancy. They demonstrated inhibition for deceptive and unexpected chords, and facilitation for expected chords. They were the only group to explicitly differentiate between the surprise levels of the Im and the ♭VI, and this was reflected in their preferences, where they rated the ♭VI significantly higher. Their preferences appear to relate more strongly to exposure than to surprise. These results echo those of Craton et al. (2016), who found that general listeners preferred chromatic chords typically found in contemporary popular music, but not found in CP music. Given that it is likely that the style to which general listeners are likely to have the most exposure is pop/rock, this suggests a general trend for those familiar with it to have preferences for its harmonic language. Pop/rock musicians demonstrated the highest sensory influence of all groups, and the lowest likelihood of imagining sounds. This suggests that mental predictions are less of a factor for pop/rock musicians than for other musicians. This appears to be borne out by analysis of the qualitative results of the experiments; pop/rock musicians were the least likely to leave comments discussing their expectations and reactions to surprising harmony.

Pop/rock musicians appeared to be the least affected by the diatonic VIm cadence, clustering it with the Ima in the Explicit Experiment, and ranking it low in the surprise ratings, although they gave this chord their highest preference rating. This is reflected in the results of the Ecological Experiments, where pop/rock musicians were less surprised than classical musicians by diatonic cadences.

Taken together, the results demonstrate that although pop/rock musicians are influenced by chromatic cadences, the traditional deceptive cadence to VIm has little effect on their surprise levels. These musicians show significantly higher liking for chords within their repertoire, and lower liking for chords outside it. Prediction appears to be less of a factor, and sensory effects of greater importance than for other cohorts.

9.1.2.3. Jazz and improvising musicians

Prediction appears to be a very strong factor for jazz musicians, who demonstrated the highest likelihood of imagining chords and submitted many comments discussing their expectations. The RTs of jazz musicians were found to be faster than other participants, and they showed facilitated processing for all types of chords, expected and unexpected. Their facilitated processing was further demonstrated by the results of the Ecological Experiments, where they were less surprised by stimuli in both jazz and popular music contexts.

Jazz musicians were notable in their preferences for chromatic chords. This cohort had low liking levels for predictable harmonies and stronger preferences for chromaticism than other musicians. Their preference data showed a distinct inverted-U curve. Like other musicians, jazz musicians were most surprised by MI cadences, and modulation, but were least surprised of all groups by quartal voicings, demonstrating that familiarity with a style lowers surprise levels for harmonies idiomatic to it. These results demonstrate that training in jazz significantly increases the propensity to make predictions, the ability to discriminate based on expectedness, and it appears to increase preferences for the unpredictable and dislike of predictability.

It is likely that these results are linked to improvisation, given that the overwhelming majority of jazz musicians in these studies improvised regularly. Przysinda et al. (2017), found that the preferences of improvising musicians followed an inverted-U curve. Similar results are found here, with highest preferences for medium complexity and lowest for both high and low complexity among jazz musicians. The results of the Explicit Experiment demonstrated that improvising musicians had enhanced abilities to differentiate chords based on their expectedness levels, lending weight to arguments that improvising musicians have enhanced abilities to respond to unexpected musical stimuli due to the nature of the music they play. While musically experienced participants in previous studies have been consistently found to have inhibited response to unexpected harmony (Tillmann et al., 2008), and this is indeed the case for non-jazz musicians in the current study, jazz musicians show no such effect, further evidencing their ability to deal with unexpected harmony. These results suggest that jazz/improvising musicians are more comfortable with deceptive and unexpected harmony than general listeners and pop/rock musicians, and that experience in jazz and improvisation appear to have significant effects on expectation, resulting in increased abilities to predict and react to unpredictable stimuli, and more positive responses to complexity.

9.1.3. Techniques to elicit surprise in jazz and popular music

70 years of musical expectation research has revealed valuable insight about how listeners acquire schemas through statistical learning, the neural correlates of music expectation, how both sensory and cognitive effects contribute to expectation, and how expectation in CP is related to functionality and chord hierarchy. In terms of information that may be of benefit to musicians and music theorists however, little is known. This is due to a disconnect between the music theory and music cognition communities, an inability of these communities to speak the same language, and the belief among scholars that non-CP music theory is not necessary for an understanding of non-CP styles. Musicians, educators, and theorists are therefore unable to use the many findings of music cognition research in practical ways. This thesis thus marks one of the first attempts to explain harmonic expectation in musical terms, for the benefit of musical practitioners. The following practical findings were revealed.

The traditional method of eliciting surprise in CP music is through the deceptive cadence to VIm. The results of both the Explicit and Implicit Experiments in this study have revealed that this cadence is consistently rated by listeners as less surprising than other types of deceptive cadence taken from the jazz and popular music repertoires. The Ecological Experiments confirmed that the traditional CP deceptive cadence does not have a strong surprising effect in real-life musical examples. However, results of the Implicit Experiment revealed that this cadence is strongly preferred by almost all participants, despite its apparent lack of surprise.

Cadences in jazz/popular music may therefore still elicit strong surprise despite differences in hypermeasure, but more striking chords are required. Evidence from the Ecological Experiments demonstrates that MI chords in cadential contexts elicit strong surprise reactions from listeners. Comparison of these chords with the same chords in non-cadential contexts reveal that they are more surprising when following a V chord. In addition, stylistically idiomatic deceptive cadences have been found to elicit surprise; specifically, the V-IIIm, a progression common to jazz, but less common in popular music. This progression elicits surprise in a jazz context, but not in a popular music context. Other deceptive cadences found in the jazz/popular music repertoire, such as cadences to the IVm, ♭VII, ♭III, and ♭VI elicited surprise in listeners. Both surprise reactions to and preferences for these chords were gradated, rather than binary, with ♭VI found to be the most surprising.

Within the context of popular music, factors previously unrelated to expectation were found to elicit surprise in listeners. These consisted of MI chords outside of cadential contexts, particularly the chords of IVm and ♭VIma, secondary dominants, and modulation. Within jazz, techniques found to elicit surprise consisted of quartal harmonies, tritone substitutes, modulation, and SFD chords. Modulations are found to be surprising within jazz, regardless of preparation, and popular music, although evidence within popular music is limited to a single instance.

Overall, the primary means of eliciting surprise in a jazz or popular music context is through chromaticism. The effect of chromaticism as surprising appears to hold regardless of hypermeasure or cadential context, although chromatic cadences generally appear to be more surprising than non-cadential chromatic chords. When considering harmonic expectation and surprise from either a music theory or music cognition perspective, great care must be taken to consider the tonal context of the harmony.

Harmonic structures that do not appear to be surprising are diatonic extensions and slash chords. These were not found to elicit significant surprise from listeners, which further reinforces the fundamental importance of diatonicism and chromaticism in surprise.

9.1.4. Sensory and cognitive styles

Perhaps the most striking finding in this study has been the effect of sensory factors on listeners' surprise levels. This was unexpected. The results of the Implicit Experiment found that pop/rock musicians are influenced by sensory factors in an experimental context, but jazz musicians are not. In addition, sensory factors were a primary contributor to surprise in the ecologically valid popular music context but had a much weaker effect in the jazz context. Taken together, these results suggest that listeners appear to listen to popular music and jazz in different ways.

Given the higher proportion of pop/rock musicians who appear to be influenced by sensory factors in their RTs, and the higher influence of sensory factors on all participants in the popular music experiment, it appears that sensory factors are more important when listening to popular music than when listening to jazz. It may be the case that popular music harmonies are more likely to follow sensory rules, that is, perhaps the harmonies of popular music more firmly align with the rules of psychoacoustic consonance, resulting in overlap. The lack of sensory effects in jazz listening could indicate that this music has deviated further from the rules, and therefore requires a more cognitive style of listening. This theory is supported by the low surprise ratings of jazz musicians in the jazz experiment, suggesting that this cohort were making more accurate predictions than others through learning and knowledge of the style. Jazz musicians across the Implicit Experiment were found to be more appreciative of surprising chords, which further supports this argument.

These results suggest that not only do expectation and surprise function differently within jazz, popular music, and CP, but there may be fundamental physiological and cognitive differences in how we listen to these styles. This finding has applications for further music cognition research outside the realm of harmonic expectation.

9.2. Applications and recommendations

These findings have implications for music theory, music cognition, music education, and our general understanding of music and how it affects us.

9.2.1. Music cognition

In this thesis, further evidence of the importance of expectation and surprise in music listening has been provided. This study adds a qualitative perspective to the quantitative research through participants' own thoughts about expectation, surprise, and its effects on their listening experiences. It also adds quantitative data through the information that even general listeners can categorise gradated ranges of chords in terms of both explicit surprise level and preferences, with uncanny granularity and intersubject correlation. This provides further evidence that prediction and expectation are important to our processing of music.

Evidence is provided to suggest that expectation and surprise are highly contextual and are mediated not only by the stylistic and improvisation expertise of the listener but also by the stimuli style and by tonal and modal contexts. Listeners were both surprised and unsurprised by the same harmonic structures depending on the stylistic context, e.g. secondary dominants were perceived as surprising in a popular music context but relatively unsurprising jazz context. This lends support to Huron's theory of cognitive firewalls and the findings of Vuvan and Hughes (2019) and provides further evidence of stylistic schemas that listeners employ based on context.

In addition, the surprise levels of chords were dependent on their harmonic contexts. As the majority of harmonic contexts in harmonic expectation studies have been limited to major and harmonic minor, these results are novel, and highlight the importance of including a range of tonal contexts in harmonic expectation studies.

These results further emphasise the fact that only limited information can be garnered from experimental results that do not reflect ecological reality. Further, this study provides the first evidence that the influences of sensory and cognitive factors may differ between styles. Thus, this thesis makes the case that tonal contextuality and sensory effects must be a fundamental part of any harmonic expectation experimental methodology going forward.

Experiment results in this study provide some of the first evidence of the effects of stylistic training and improvisation on harmonic expectation. They reinforce the results of studies showing that improvisation affects predictions and the ability to react to surprising information. The results empirically validate the theories of scholars who emphasise the importance of prediction and openness to surprise in improvisation. Expert musicians are by no means a monolith when it comes to music processing, and stylistic expertise and improvisation training should be considered in music cognition.

Throughout this thesis, a disconnect between music theory and music cognition has been described. This thesis has bridged that disconnect through providing tools for further behavioural experiments that are informed by in-depth research into the theory, history, and context of musical elements. These tools consist of a catalogue of harmonic techniques that may be used to study harmonic expectation within both jazz and popular music. An archive of specific musical elements, along with their analysis, in ecologically valid jazz and popular music contexts are provided. These elements have been verified as eliciting explicit surprise. A clear and easily replicable experimental paradigm is also provided.

Further study may be carried out using these materials and paradigm. For example, the Ecological Experiments in this study were carried out on trained musicians only, due to the need to ensure that listeners reacted only to harmonic surprises and ignored, to the best extent they could, rhythmic, melodic, and textural surprise. Further research on general listeners may reveal further insights into whether listeners are surprised by the same techniques as professional musicians, the extent to which they are influenced by sensory factors, and their own perspectives on expectation and surprise within ecologically valid contexts.

In addition, given the significant overlap of jazz and improvising musicians in the cohorts of all four experiments, further research is required to extricate the effects of training in jazz and training in improvisation. Both of these factors appeared to have significant effects, but an experimental paradigm in which these groups may be separated will provide more clarity.

The ecological experiments in this study tested listeners' explicit perceptions, albeit within a timed paradigm. Thus, listeners' results revealed only their conscious determinations of surprise. In terms of the goals of the research, which were to provide a verified account of the techniques that elicit surprise in jazz/popular music, this is sufficient. However, music cognition researchers may have more interest in the implicit expectations of listeners, the differences between implicit and explicit expectations, and differences in the brain responses of listeners in reaction to their explicit and implicit expectations. The experimental stimuli provided could be used within neuroscientific and implicit cognitive paradigms to reveal such information.

The results demonstrated that pop/rock musicians make more use of sensory information in their music processing in comparison to other musicians, and that all musicians utilise sensory information in listening to popular music. Further study may reveal the reasons behind this finding. For example, analysis of popular much may demonstrate whether harmonies in popular music are more aligned with psychoacoustic properties than those of jazz. Further testing of pop/rock musicians in response to other styles of music may also reveal whether this is a feature of music listening common to pop/rock musicians across genres.

9.2.2. Educational tools

The data resulting from these experiments may also inform the creating of machine learning models with which to create tools and resources for use in higher education contexts. For example, given that the experiment data represents a compendium of chords and their perceived surprise levels as verified by a large cohort of musically experienced listeners, a model trained on this dataset may be used to categorise further progressions by expectedness, or to generate new progressions of required expectedness levels. This may have applications within many areas of higher-level music education. For example, many commonly used ear training tools feature harmonic dictation exercises, whereby students practice identifying chord progressions by ear. The algorithms used to construct these chord progressions may benefit from the ability to add an "expectedness" descriptor to chords, allowing the user to generate progressions of varying degrees of surprisingness within an idiomatic context.

The ability to generate and quantify chord progressions by their expectedness may also be of use to students of jazz improvisation. Many jazz students use playalong recordings with which to practice improvisation over chord changes. These often feature progressions taken from typical jazz standards. The inclusion of unexpected but appropriate harmony may be an aid to students whose performance required the ability to respond to unexpected musical events with ease.

9.2.3. Music theory

With regards to music theory, this thesis reinforces the perspectives of scholars who have begun to incorporate cognitive factors such as expectation into their theories. The findings in these experiments give their theories a strong standing and provide evidence for the cognitive and behavioural effects of expectation within jazz/popular music. It bridges the gap between music cognition and music theory by describing the experiment results in the language of jazz and pop/rock musicians, allowing music theorists to incorporate this information into their theories, and musicians to incorporate it into their practice. A categorised range of structures, methods, and chords relating to expectation and surprise are now available to educators and students with empirically verified details on how they may be perceived by listeners.

The research also provides important information on fundamental theoretical aspects of jazz and popular music with respect to narrative, function, tonal language, and structure, and provides evidence which reinforces continuing arguments made by contemporary popular music theorists on the fundamental differences between popular music harmony and CP harmony. The debate on this issue is ongoing, and this study outlines these differences, their historical background, and provides empirical evidence of their effects. Popular music is generally seen as diatonic, but the array of chromaticism and the diversity of perceptual effects elicited in these experiments are further evidence that this style is more worthy of harmonic study than it is traditionally believed to be. This research thus highlights the harmonic diversity within both jazz and popular music, thereby contesting accounts that claim that popular music harmony is simplistic, or that jazz harmony is derivative of CP.

Results of the corpuses analyses indicate that there are areas within jazz theory that may warrant further study, such as the prevalence of non-major/minor tonalities in the repertoire of jazz prior to post-bop. These tonalities include Mixolydian, Mixolydian mixed with major, and major with no 7^{th}. That these tonalities appear to occur with almost the same regularity as major suggests that the tradition conception of non-modal, non-blues jazz tonality as comprised of a binary major/minor framework should be expanded.

In addition, cooperation with the music cognition community may results in further elucidation of harmonic expectation within a broader range of styles. For example, the Ecological Jazz Experiment primarily used stimuli released before 1959. Further study on post-bop styles such as modal jazz and free jazz, and on post-bop harmonic structures such as the rapid tonicisations known as “Coltrane changes” would reveal much information about the progress of jazz harmony in the late 20th century and its effects on listeners. In addition, investigations of 20th century art music such as impressionism, serialism, minimalism could reveal interesting details about how expectation and surprise are perceived in contexts where tonality is ambiguous or absent.

The primary recommendation of this thesis is a call for musical diversity. Within music cognition, music theory, and the practical applications of music, knowledge is best advanced through collaboration, openness, and acknowledgment of diverse perspectives and topics outside of our own areas of expertise. There is much still to be learned about the processes behind music, one of the most important and meaningful elements of collective human experience, and it is only as an ensemble that we can unlock its meanings.

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Appendices

Appendix A. Jazz Corpus

Song	**Standard/Version**	**Feature**
A Nightingale Sang in Berkeley Square	Marian McPartland	bVIIdom7sus
A Nightingale Sang in Berkeley Square	Mimi Fox	V-VI
A Sleepin' Bee	Keith Jarrett	tritone sub, bVII
A Weaver of Dreams	Cannonball Adderley	bVII7sus - III
All Gods Children Got Rhythm	Stan Getz	bVIIdom7
All of Me	Standard	Deceptive Resolution. IVm
All of You	Bill Evans	IVm
Angel Eyes	Sonny Stitt	bVI7
April	Standard	bVI
Armageddon	Standard	Modal interchange
Autumn Nocturne - Chromatic	Lou Donaldson	V-VI
Avalon	Standard	IVm
Barbara	Horace Silver	bVII Sec dom dec res
Bewitched	Standard	V-IV
Black and Blue	Ellington	bVI
Blame It on My Youth	Standard	V-III
Blood Count	Billy Strayhorn	Deceptive Resolution
Blue and Sentimental	Standard	bVI
Blue Daniel	Standard	bVII
Blue Gardenia	Lee Morgan	bVII
Blue Room	Standard	V-VI
Bright Size Life	Metheny	bVI
But Beautiful	Standard	V/III - I
Bye Bye Blues	Standard	bVI following I - HM 2/3 deceptive res.
Cantaloupe Island	Herbie Hancock	bVI
C'est What	Standard	bVI, bVII
Chega De Saudade	Jobim	V-Im
Chelsea Bridge	Ellington	Deceptive res., V chord mod. bIII mod
Cheryl	Standard	bVII, IVm
Come Sunday	Ellington	bVII, I7
Conception	Standard	bVI
Crystal Silence	Chick Corea and Gary Burton	Modal interchange
Daahoud	Clifford Brown	bVI
Darn That Dream	Standard	V - IIIm, V-IVm
Day Dream	Ella Fitzgerald	bVI blues/TTS
Day Dream	Standard	bVI
Day In Day Out	Standard	IVm
Days of Wine and Roses	Standard	bVII, IVm
Dear Lord	Coltrane	V-bVI
Desefinado	Ella	V-bIII mod V-IIIm7b5 IVm6 bIIIdom7 TTS
Detour Ahead	Bill Evans	bVI, bVII, V-Im
Dindi	Standard	V-Im, bVII, IVm
Do You Know the Way to San Jose	Bacharach	Modal interchange
Dolphin Dance	Herbie Hancock	bVII
Don’t Blame Me	Standard	TTS
Dream	Sarah Vaughan	Deceptive resolution of V7/III, IVm
Dreamsville	Standard	Modal interchange
Early Autumn	Ella Fitzgerald	bVII MI, V-III
Early Autumn	Woody Herman	Deceptive Resolution
East of the Sun	Standard	bVII, IVm
Ecclusiastics	Mingus	bVI
El Gaucho	Wayne Shorter	bVI
Elora	Standard	IVm
Everything I Have Is Yours	Standard	bVI
Exactly Like You	Standard	bVII, IVm
Eye of the Beholder	Chick Corea	Deceptive Resolutions
Eye of the Hurricane	Herbie Hancock	bVII, bIII, bVI
Farmer's Trust	Pat Metheny	bVI
Farmer's Trust	Metheny	bVI
Felicia and Bianca	Toots Thielemans	Deceptive resolution of V, IVm, bVII. #IV-7b5

Flamingo	Jimmy Smith	Im, bVI blues, V-III
For All We Know	Standard	bVIma7, V-VI
Forest Flower	Standard	bVII
Four	Standard	tonicization
Four on Six	Wes Montgomery	TTs
Friday Night at the Cadillac Club	Standard	bVII
Gertrude's Bounce	Standard	bVII, IVm
Girl Talk	Standard	Im, IVm, V-III
Gloria's Step	Bill Evans	V-Im
Golden Notebooks	Gerry Mulligan	bVIIma7
Good Morning Heartache	Billie Holiday	TTS
Goodbye Porkpie Hat	Mingus	bVI
Green Mountains	Standard	bVI
Grow Your Own	Standard	bVI, bVII
Half Nelson	Parker	bVII, IVm, LB
Heres That Rainy Day	Stan Getz	Modal interchange
Hold Out Your Hand	Standard	bVI
Horace-Scope	Horace Silver	TTS
I Concentrate on You	Standard	Im
I Live for Your Love	Standard	Deceptive Resolution
I Love You	Standard	Modal interchange
I Mean You	Monk	bVI, bVII
I Remember You	Standard	bVII
I Should Care	Standard	bVII, IVm
I Will Say Goodbye	Standard	Modal interchange
I’m All Smiles	Standard	Dominant chord mods. Deceptive res
I'll Be Around	Marian McPartland	V-bVI
I'll Take Romance	Standard	bIII, bVI
Ill Wind	Standard	bVII
I'm Getting Sentimental Over You	Mingus	V-bVI bIII bVII7 V-III
I'm Glad there Is You	Standard	bVII, IVm
Imagination	Standard	Dominant chord modulations
Infant Eyes	Wayne Shorter	Modal interchange
Interplay	Bill Evans	Modal interchange
It Could Happen to You	Standard	V-III
It's the Talk of the Town	Standard	bVII, IVm
Jersey Bounce	Standard	bVI
Kary's Trance	Lee Konitz	bVI
Katrina Ballerina	Standard	bIII
Killer Joe	Benny Golson	bVII
La Fiesta	Return to Forever. Stan Getz	Modal interchange
Lady Bird	Standard	Subdominant minor
Lady Sings the Blues	Billie Holiday	Dominant chord modulations
Lament	Milt Jackson	Modal Interchange
Like a Lover	Standard	V-IV
Little B’s Poem	Bobby Hutcherson	Modal interchange
Little Girl Blue	Standard	bIII, bVII
Long Ago and Far Away	Oscar Peterson	V-bIII mod
Look to the Sky	Emily Remler	bVII
Love Vibrations	Horace Silver	V-bVII
Love Will Keep Up Together	Sedaka	Deceptive Resolution
Lover	Mary Lou Williams	V-bIII
Lullaby In Rhythm	Benny Goodman	bVII
Lullaby of the Leaves	Standard	bVI
Lush Life	Coltrane	bVII
Meditation	Jobim	IVm following II, V-#IV#11 cad. V-Im cad.
Molten Glass	Joe Farrell	bIII
Monk's Mood	Monk	bVII, IVm
Mood Indigo	Ellington	bVII
Moonlight In Vermont	Ella	bVIIdom7
Nardis	Bill Evans	V-bVI
Never Can Say Goodbye	Standard	Modal interchange
Night and Day	Ella	bIII mod
Nu Som	Mike Stern	bIII, bVII
Old Devil Moon	Standard	Vm in major
Old Folks	Miles	bVII
On Green Dolphin St.	Ellington	Modal interchange
One for My Baby	Standard	bVII
One Note Samba	Jobim	TTS
Our Love Is Here to Stay	Standard	V-bVII
Out of Nowhere	Errol Garner	bVI7, IVm

Pensativa	Standard	bVI
Povo	Freddie Hubbard	bVI7
Promenade	Standard	bVI, bVII
Promises Promises	Bacharach	Modal interchange
Pure Imagination	Standard	V-III
Put It Where You Want It	Joe Sample	Deceptive Resolution
Quicksilver	Horace Silver	TTs
Rhythm Changes	Standard	V-IIIm
Rockin' Chair	Standard	bVII
Sad Samba	Standard	V-VI
Save Your Love for Me	Standard	bVI
Sea of Love	Khoury/Batiste	Deceptive Resolution
Search for Peace	Mccoy Tyner	bVI
September In the Rain	Standard	IVm
September Song	Standard	bVI
Shaker Song	Standard	bIII, bVI
Someday My Prince	Bill Evans	V-III
Speak Low	Standard	bVII, IVm
Speak No Evil	Wayne Shorter	TTS
Spring Can Really	Ella	bVIIma7
Stardust	Standard	bVII, IVm
Stockholm Sweetenin'	Quincy Jones	Deceptive Resolution
Struttin With Some Bar-B-Q	Barbara Carroll	V-VI
Summer In Central Park	Standard	bVI
Summer Samba	Les McCann	IV-bVII
Summer Samba	Standard	bVII
Sweet and Lovely	Standard	bVII
Sweet Zurzday	Duke Ellington	bVI7
Temptation	Standard	Modal interchange
Tenderly	Standard	bVII
That Old Feeling	Lew Brown	V-VI
The Best Thing for You Is Me	Standard	bVI
The Dolphin	Standard	bVI, IVm
The Dolphin	Louis Stewart	bVIma7
The Island	Joanne Brackeen	Chromaticism
The Lady Is a Tramp	Basie	bVII, V-III
The Masquerade Is Over	Standard	bVII
The Shepherd	Ellington	Modal interchange
The Song Is You	Cannonball Adderly. Sonny Rollins	bVII. V-III, V-bVI
The Song Is You	Standard	V-IVm. bVII, V-bVI, V-III
The Way We Were	George Cables	Sec doms, bVII, tritones
The Yellow Jacket	Shaun Martin	bVI, pedal point, mods
They All Laughed;	Oscar Peterson. George Shearing. Ella	V-bVII. V-Im. V-bVI
Think on Me	Standard	bIII
This Heart of Mine	Standard	bIII
Three Flowers	Coltrane	bVII
Till there Was You	Standard	bVII, IVm
Tones for Joan's Bones	Chick Corea	Modal interchange
Triste	Standard	IVm, V-Im, bVI
Tune for a Lyric	Bill Evans	Deceptive Resolution
Tune Up	Standard	V-bVI
Up With the Lark	Standard	bIII, bVI
Very Early	Bill Evans	bVII
Waltz for Debby	Bill Evans	V-III
Waltz New	Standard	V-III
Watercolors	Metheny	bIII, bVI, bVII
Wave	Jobim	V-Im, IVm
We'll Be Together Again	Toshiko Akiyoshi	V-VIm, bVI
Wendy	Jim Hall	V-bVI
Wendy	Paul Desmond	V-bVI
What Is This Thing Called Love	Standard	Modal interchange
What's New	Standard	Modal interchange
When Lights Are Low	Willis Delony	V-bVII
Why Can't You Behave No Chart	Oscar Peterson	V-III
Why Did I Choose You	Standard	IVm
Yardbird Suite	Parker/Hank Jones	IVm-bVII, V-III
You Go to My Head	Standard	Modal interchange
You Must Have Been a Beautiful Baby	Standard	Deceptive Resolution
You're My Everything	Freddie Hubbard	V-bVI, V-VI

Appendix B. Popular Music Corpus

Song	Artist	Features
2am	Gavin Turek	I7, Vm7
3005 (Beach Picnic Version)	Childish Gambino	bIIIma7, bVIII
500 Miles	The Proclaimers	V-VIm
A Day In the Life	The Beatles	IV-bVII-VI, I-bVII-I
A Design for Life	Manic Street Preachers	bIIIma
A Glass of Champagne	Sailor	IV-bVII-I
A Hard Day's Night	The Beatles	I-bVII-I
A Kind of Hush	Herman's Hermits	Sec doms
A Little Bit More	Dr Hook	Sec doms, IVm
A Night to Remember	Shalamar	Vm7 II-V, mod
A Season	Zo	bVIIma7, bVIIm7
A Team	Ed Sheeran	V-VIm
A Thing Called Love	Johnny Cash	I-bVII-IV, sec dom
Africa	Toto	VI-bVII-II, mod
Ain't No Mountain High Enough	Diana Ross	mod up a ma2nd
Ain't No Sunshine	Michael Jackson	Mod prep
Alison	Elvis Costello	VI-bVII-V
Alive and Kicking	Simple Minds	bVII
All By Myself	Celine Dion	IVm, mod
All By Myself	Eric Carmen	IVm, Vm, IIm7b5, sec dom
All I Have to Do Is Dream	The Everly Brothers	Sec doms
All My Loving	The Beatles	bVII
All Night	Marika Hackman	IVm, bVII, bIII, mod
Alone Again Naturally	Gilbert O'Sullivan	Sec doms, Vm, mod
America	Simon and Garfunkel	bVII, mod
Amie	Pure Prairie League	bVII, bVI
And I Love Her	The Beatles	unprep mod, sec dom
Angel Eyes	Wet Wet Wet	Mod, bVII, VIma7
Annie Waits	Ben Folds	Sec doms, V/V, V-VI
Annie's Song	John Denver	V-VIm
Another Nail In My Heart	Squeeze	Mods, Vm?, V-VI
Arthur's theme	Christopher Cross	Mod prep, sec domweak
Ashes to Ashes	David Bowie	Ext doms, V-VI
Atlantic Avenue	Average White Band	V-VI, mod, Vm, sec doms
Avalon	Roxy Music	bVII, bVII, sec dom
B4	Ginger Root	bII
Baby I Love You	The Ramones	IVm
Baby Love	The Supremes	Modulation
Baby, Now That I've Found You	The Foundations	Mod, Vm
Baby, Now That I've Found You	Alison Krauss	Mod, Vm, IVm
Back In the High Life Again	Steve Winwood	bIII-bVI
Back on the Chain Gang	Pretenders	Modulation
Baggy Trousers	Madness	bIII
Band on the Run	Wings	IVm
Believe It Or Not	Joe Scarbury	Modulation prep and unprep, bIII, bVII
Ben	Michael Jackson	Im
Best of My Love	The Emotions	Sec dom
Billy, Don't Be a Hero	Paper Lace	Mod, IVm
Bin Guy	Brett Domino	Mod unprep, bVIIpassing
Bittersweet Symphony	The Verve	Vm, bVII
Blame It on the Sun	Stevie Wonder	IVm, Ima7#11
Blue Jeans	Blur	bVII, bVI
Born to Run	Bruce Springsteen	Mod
Boys	Charlie XCX	V-VI not decep
Breakaway	Gallagher and Lyle	V-VIm, mod, sec doms
Bridge to Your Heart	Wax	bVI, bVII, mod
Brown Sugar	The Rolling Stones	bIII, bVI, bVII
Build Me Up Buttercup	The Foundations	Sec doms, IVm
Business Casual	Vulfpeck	Mod unprep, sec dom
But It's Alright	Huey Lewis	Modunprep
California Soul	Marlena Shaw	bIII, bVImin?, sec dom, rev pic 3rd
Can't Get By Without You	The Real Thing	bVII, modunprep
Capturism	Fox Capture Plan	bV minor key
Carrie	Cliff Richard	bII minor
Cat's In the Cradle	Harry Chapin	bIII?
Chain Reaction	Diana Ross	Mods, bVII, sec doms
Champage Supernova	Oasis	bVII

Change the World	Eric Clapton	bIII, sec dom weak
Cherish	Madonna	V-VI
Come Sail Away	Styx	V-VI, bVI, mod
Coming Back Around	Cory Wong	bII minor key
Copacobana	Barry Manilow	Sec doms
Cracklin' Rose	Neil Diamond	Mod
Crazy	Patsy Cline	Sec doms
Crazy Little Thing Called Love	Queen	bVII, bVI ****mods
Creeping Away	Swamp Dogg	bIII, bVII, sec dom
Crime of the Century	Supertramp	V/V
Crocodile Rock	Elton John	Sec Doms
Crucify	Tori Amos	mod up a 4,– weak rev Pic 3rd
Cruising	Smokey Robinson	bVII
Daniel	Elton John	Sec doms, bVI, V-VIm
Days	The Kinks	Mod, bVII
Desperado	The Eagles	Sec doms, IVm
Diamond In the Bell Jar	Mama's Gun	bVII
Distant Sun	Crowded House	Sec doms
Do You Realise	Flaming Lips	Sec doms, mod
Do You Wanna Party	Nile Rodgers	Mods
Don't Delete the Kisses	Wolf Alice	Sec dom?
Don't Go	Hothouse Flowers	bVI, mods
Don't It Make My Brown Eyes Blue	Crystal Gayle	Sec doms
Don't Let It Rain on My Parade	The Icicle Works	bVII, bVI
Don't Look Back In Anger	Oasis	Sec doms, IVm
Don't Think Twice, It's Alright	Bob Dylan	Sec doms
Dream a Little Dream	The Mamas and the Papas	bVI, IVm
Dream Lover	Bobby Darin	Mod, sec dom
Ecstasy	Rusted Root	Rev Pic 3rd min
Eight Days a Week	The Beatles	Sec dom
Electric Connect	Milo Clare	bIII, bII, bVIm7, IVm7, bV, Vm7
Eventually	Tame Impala	Nothing useful
Everlasting Love	The Love Affair	bVI
Every Breath You Take	The Police	bIII, sec dom, V-VIm
Every Day	Buddy Holly	Ext doms
Every Time You Go Away	Paul Young	V-VIm, sec dom
Everything	Michael Buble	Sec doms, IVm, mod
Everything I Own	Bread	IVm, bVII
Everything You Know Is Wrong	Weird Al Yankovic	V-bIII cadence
Evolution Orange	Earth, Wind, and Fire	Pic 3rd, ext dom, mods
Eye In the Sky	The Alan Parsons Project	IVm
Fear the Future	St Vincent	bVI, bVII
Feeling Stronger Every Day	Chicago	bIII, bVII, ext doms, mods
Fields of Gold	Eva Cassidy	V-VI
Fifty Ways to Leave Your Lover	Paul Simon	bVII passing, bIII
Fire and Rain	James Taylor	Vm7, bVII
Follow You, Follow Me	Genesis	Sec doms, V-IIIdom
Foreign Room	Sure Sure	bVII, bIII
Forever In Blue Jeans	Neil Diamond	bVII
Forever Young	Bob Dylan	V-VIm
Free Coffee	Ben Folds	bVI, bVII
Friday I'm In Love	The Cure	V-VI
Friends	Eric Johnson	Isusb9
Funky Fanfare	Keith Mansfield	bIII, bVI, bVII, mod
Gentle Thoughts	Herbie Hancock	Mod, pedal point
Get Back	The Beatles	bVII
Get It On	T-Rex	bIII
Giraffe Centre	Alarmist	bII, bV minor key
Girls	The Moments	Mod, bIII
Girls Talk	Dave Edmunds	Mod, b7
Give Me Love	George Harrison	IVm, bVII
Give Me the Night	George Benson	Mod
Give You Up	Bantum	#Vidim in minor key
God Gave Rock and Roll to You	Kiss	bIII, bVI, bVII, mod
Good Riddance Time of Your Life	Green Day	V-VIm
Goodbye Yellow Brick Road	Elton John	bVII, mod up a min3rd, V/VI, bVI
Goodnight Saigon	Billy Joel	bVII
Got to Be Real	Cheryl Lynn	Mod
Got to Go My Own Way	Caroline Rose	Modunprep
Gravity	John Mayer	bIII, bVI
Guitar Man	Bread	Sec doms, V-VI

Half the World Away	Oasis	Sec doms, IVm
Hallelujah	Leonard Cohen	V-VI, sec doms
Handbags and Gladrags	The Stereophonics	bVII, V-VI
Handle With Care	The Travelling Wilburys	Sec dom
Happy Birthday	Stevie Wonder	bVII, bVI, mod up a min 2nd
Happy Together	The Turtles	Vm, Pic 3rd, bIII
Have Some Love	Childish Gambino	Mod, pedal point
He Ain't Heavy, He's My Brother	The Hollies	b7, V-VI, Vm, sec doms
Heart to Heart	Kenny Loggins	bIII, Vm7, bVII
Heaven	Bryan Adams	bVII, V-VI
Hello	Lionel Richie	bVII, bII, sec dom, Pic 3rd
Help	The Beatles	bVII
Hey	Nilufer Yanya	bII minor, IVma
Hey Jude	The Beatles	bVII, sec dom
Hey there Delilah	Plain White T's	V-VI
Higher Love	Kygo, Whitney Houston	V/V
Home Movies	Radical Face	bIII
Homeword Bound	Simon and Garfunkel	Chromatic bVII
Honesty	Billy Joel	VIIm7, sec dom
Human	The Killers	Sec dom
I Can Dream About You	Dan Harmon	Mod
I Can See Clearly Now	Johnny Nash	bVII, mod
I Can't Stop Loving You	Leo Sayer	bVII
I Choose You	Sara Bareilles	IVm
I Don't Want to Put a Hold on You	Berni Flint	V-III, Idim7
I Feel Love	Donna Summer	bIII
I Know the End	Phoebe Bridgers	Pic 3rd
I Only Want to Be With You	Dusty Springfield	bVI
I Should Be So Lucky	Kylie Minogue	Mod, IVm, Vm, bVII
I Should Have Known Better	The Beatles	Sec dom
I Wanna Be the Only One	Eternal	Mods
I Want You	Cheap Trick	Sec dom, IVdom7, b7
I Will	The Beatles	V-bVI, V-VI, sec doms
I Won't Last a Day Without You	Diana Ross	V-VI, bVII, mods
I Won't Let the Sun Go Down on Me	Nik Kershaw	Mod, bII in minor, bVII
If I Could Turn Back Time	Cher	mod up a m3
If We Loved	A Taste of Honey	bVIaug, IVm, bVII, bVI, II, VII cycle of 5ths
If You Know You Know	Pusha T	bVII, bV
I'll Be Your Baby Tonight	Bob Dylan	Sec dom
I'm a Rover	Ye Vagabonds	V-VIm
I'm So Happy I Can't Stop Crying	Sting	Mod, bVI, bVII, Vm
I'm So Tired	The Beatles	IVm, V/III
Imagine	John Lennon	Sec dom
In My Life	The Beatles	IVm, bVII, sec doms
In Your Eyes	Anjumile	V-VI, bVII
Is She Really Going Out With Him	Joe Jackson	bVII
It's Different for Girls	Joe Jackson	bVII
It's Money That I Love	Randy Newman	bVII blues
It's Only Natural	Crowded House	bVII, sec dom
It's Still Rock and Roll to Me	Billy Joel	bVII, sec doms, b3, b6
I've Got a Feeling	The Beatles	bVII
Je Vous Aime	Donny Hathaway	bVI, sec doms, I7, IV7, VIIdomblues approach
Jeans On	David Dundas	Sec doms deceptive
Jumping Jack Flash	The Rolling Stones	bIII, bVII blues
Jupiter	Earth, Wind, and Fire	Mods, bVIIm7minor key
Just the Way You Are	Billy Joel	IVm, bVI, bVII, sec doms
Kid	Aaron Parks	#III minor key
Killing Me Softly	Roberta Flack	bVII, V-VI
King Kunta	Kendrick Lamar	Unprep mod
Kingston Boogie	Young Gun Silver Fox	Mods, bVII, sec doms
Lavender	Badbadnotgood	bII minor
Lax	Vulfpeck	Mod, #IVm7b5, sec doms
Lay Lady Lay	Bob Dylan	bVII
Lea	Toto	bVII
Let It Be	The Beatles	V-VI, bVII passing
Lets Wait Awhile	Janet Jackson	Mod, bVII, Vm7rel II, #IVm7b5
Life	Fox Capture Plan	Mods
Listen to the Music	The Doobie Brothers	Sec dom, bVII
Listen to what the Man Said	Wings	Sec dom
Living Thing	ELO	bVI, IVm
Lola	The Kinks	bVI, bVII, sec dom

Long Hot Summer	The Style Council	Mods, bIII, bVII
Longer	Dan Fogelberg	bIII
Lorens Dance	Idris Muhammad	bII minor and major keys, mod
Love and Peace	Larry Marshall	bIII
Love Bites	Def Leppard	1.20/2.13 - Mods up/down a 2nd
Love Growns Where My Rosemary Goes	Edison Lighthouse	Mod prepared
Love Is In the Air	John Paul Young	V-VI, IVm
Love Is the Drug	Roxy Music	Rev Pic 3rd
Love on Top	Beyonce	#IVm7b5, bVI
Love Really Hurts	Billy Ocean	Mod
Love Train	The O Jays	bIII
Love's Been Good to Me	Frank Sinatra	IVm
Lucille	Kenny Rogers	Mod
Lucy	Yenkee	Mods, bVI, bVII, sec doms
Lultimo	Ennio Morricone	bVII, bVI, VIIm7
Luminol Trial	Ryan Adams	bIII-bVII-bVI, Mod -3
Lying Eyes	the Eagles	Sec dom
Magic	Pilot	bVII, IVm
Man In the Moon	Yellowjackets	Mods, bIII, bVI, bVII
Mandy	Barry Manilow	bVII
Mango	Michelle	IVm7, bVII
Marian	Nouvelle Vague	bII minor key, Vsusb9?
Michelle	The Beatles	IVm7, bVII, line cliché, rev Pic 3rd
Midnight Train to Georgia	Gladys Knight and the Pips	V-VI
Missing You	Chris De Burgh	IVm, sec doms
Monday Monday	The Mamas and the Papas	unprep mod2, bVII
Money for Nothing	Dire Straits	Nothing useful
Moonlighting	Leo Sayer	Mod
Motorcycle Emptiness	Manic Street Preachers	bIII, bVI, bVII
Mr Blue Sky	Elo	bVII, bIII, bVI, sec doms
Mr Bojangles	the Nitty Gritty Dirt Band	V-Vi
Mr Sunshine	Lydian Collective	bVI, bVII, bIII?
Music	D-Train	bII minor key
My Girl	The Temptations	Mod
My Kind of Lady	Supertramp	Mod, sec dom
My Kinda Life	Cliff Richard	bVI, bVII, weird II chord?
My Life	Billy Joel	Mod, V-VI, sec doms
Naa Er Druene Paa Sitt Beste	Lindstrøm	b7
Need Your Love So Bad	Fleetwood Mac	bVI blues, sec dom
Needles and Pins	Jackie Deshannon	sec doms ext doms?
Never Let Her Slip Away	Andrew Gold	sec doms, bVII, IVm
New Kid In Town	the Eagles	Mod, sec doms
New York State of Mind	Billy Joel	Mod, sec doms, bVII, bVI, bIII, bII, V-VI
Nights In White Satin	The Moody Blues	bII in minor
No Frontiers	Mary Black	sec doms
No Shame	5 Seconds of Summer	b6
Nobody Knows You	Eric Clapton	sec doms
Norweigan Wood	the Beatles	bVII, Pic 3rd
Not Another Word	Anjumile	V-VI
Nothin' You Can Do	Airplay	Mods, sec doms, bIII
Nothing Rhymed	Gilbert O'Sullivan	bVII, IVm, sec doms
Nothing's Impossible	Caroline Rose	bVII, sec dom
Nowhere Man	The Beatles	IVm
Nu Som	Mike Stern	bVI, bVII, sec doms, mod
Ob La Di Ob La Da	the Beatles	V-VI
Oh, Pretty Woman	Roy Orbison	Mod prepared
Okinawa	Sure Sure	Rev Pic 3rd min, bVII, #3m minor key
Old Man	Neil Young	bIII, bVII, Vm7
Oliver's Army	Elvis Costello	Sec doms, mod unprep
On the Bright Side of the Road	Van Morrison	IVm, sec doms
Only the Good Die Young	Billy Joel	V-VI, sec doms
Out In the Middle	The Duckworth Lewis Method	Vm7, bIII, bVI, mods, pedal point
Overkill	Men at Work	b7 chromatic
Owner of a Lonely Heart	Yes	Rev Pic 3rd, b6, mod
Oyibo	Hypnotic Brass Ensemble	Rev Pic 3rd
Past the Point of Rescue	Mary Black	V-VI, sec dom
Pearl's a Singer	Elkie Brooks	Sec doms
People Get Ready	Aretha Franklin	Mod
Please Please Me	The Beatles	bIII
PS I Love You	The Beatles	V/III, bVI
Real Gone Kid	Deacon Blue	bVII, sec dom

Rebellion	Arcade Fire	Rev Pic 3rd
Reminiscing	Little River Band	bVII, bVI, sec dom, mod
Rikki Don't Lose That Number	Steely Dan	bVII, Vm7, bIII, sec doms
Roar	Miriam-Teack Lee	bVII
Roll With It	Steve Winwood	bVI, bIII
Running on Faith	Eric Clapton	bVII
Same Old Lang Syne	Dan Fogelberg	IVm, V-bVII, sec dom, V-VI
Satin Soul	The Love Unlimited Orchestra	Pic 3rd, mod
Seasons In the Sun	Terry Jacks	Mods
See Saw	Aretha Franklin	Sec doms
She Makes My Day	Robert Palmer	IVm, bVI, sec doms
Sherry	Frankie Valli	bIII
She's Electric	Oasis	bVI, bVII
She's Got a Way	Billy Joel	bVI, bVII, mod
She's Leaving Home	The Beatles	bVII passing, Vm7
Shine on You Crazy Diamond	Pink Floyd	VII min key
Short People	Randy Newman	bVI passing, V-IV
Show You the Way to Go	The Jacksons	Mod, bVI, bVII
Silver Lady	David Soul	Unprep mod
Sit Down and Cry	Aretha Franklin	bVI, bVII
Sky High	Jigsaw	IVm, bVI, mods
Slightly Drunk	Squeeze	IVm, bVI, bVII, sec doms
Snowbound	Donald Fagan	Mods, bVII
So Bad	Young Gun Silver Fox	bVII, mod
Somebody to Love	Queen	IVm, sec doms
Something	The Beatles	bIII, mod
Something for the Weekend	Divine Comedy	Vm, bVII, sec dom, mod
Something Inside So Strong	Labi Siffre	V-VI, bVII, unprep mod
Sometimes It Snows in April	Prince	b5m7, sec doms
Soon It Will Be Fire	Hypnotic Brass Ensemble	V-VI, IVma7#11 Change
Sorrow	David Bowie	bVII
Space Oddity	David Bowie	IVm, bVII, sec doms
St. Elmo's Fire	John Parr	Mod IVm, bVI
Starman	David Bowie	bIII, IVm, sec doms, V-IV
Still Crazy After All these Years	Paul Simon	V/IV, IVm, V-VI, V-IVm, bVII, mod up 2nd
Strawberry Letter 23	Shuggie Otis	bII, bVI, Vm7, #4m7b5, IIIm7b5, mods
Streams of Time	Myles Sanko	Mod, bVI, bVII, bII minor key
Street Life	the Crusaders	Mod
Stuck In a Moment You Can't Get Out of	U2	V-VI, bVII, sec doms
Stuck In the Middle	Stealer's Wheel	bVII
Summer Soft	Stevie Wonder	Mods, bVII, bVI, bIII, #IVm7b5, IVm7, bVII, sec
doms		
Summer Sun	Koop	bIII chr, mods, b7 4/4
Sweet Little Mystery	Wet Wet Wet	Mod, b7
Tainted Love	Soft Cell	Pic 3rd
Take It to Heart	Michael McDonald	V-VI, bIII, bVII
Takin' It Back	Toto	bII, bV
Tell Me Trial	Conor Albert	bIImb6
Tempted	Squeeze	Im?, IVm, mod, bVII passing, bVI? sec doms
Thank You Master	Donny Hathaway	bVII, VIIm7, Idom7, IVdom7
That's Entertainment	the Jam	bVII
That's Life	Frank Sinatra	bIII, bVI, bII, sec doms, mod
The Air That I Breathe	the Hollies	IVm, Vm, sec dom
The Band Wore Blue Shirts	Joe Jackson	bVII, bII, bIII
The Best Mistakes	Divine Comedy	bVI, bVII, Vm
The Best of My Love	The Eagles	IVm
The Christmas Song	Nat King Cole	bVI, sec doms, tritone subs
The Lazy Song	Bruno Mars	Sec dom, V-VI
The Living Years	Mike and the Mechanics	bVII
The One Who Loves You	Divine Comedy	Mods
The Painter	Chris De Burgh	bVI, bVII
The Riddle	Nick Kershaw	bII #VI, #III minor key, mods
The Things We Do for Love	10cc	Sec doms, IVm, mod prep?
The Weight	Aretha Franklin	Mod
Then Came You	Dionne Warwick	bVII, mod up a 2nd
There Must Be An Angel	Eurythmics	bIII, bVI, mods, sec doms
Thinking Out Loud	Ed Sheeran	V-VI
This Place Hotel	The Jacksons	#VIm7
Through the Barricades	Spandau Ballet	bVII, IVm
Tie a Yellow Ribbon Round the Ole Oak Tree	Dawn and Tony Orlando	Vm, sec doms
Tiger Feet	Mud	bVII

Till Death	Japanese Breakfast	Mod, bIII
Till there Was You	The Beatles	IVm, bVI
Timber Lake Road	Tommy Emmanuel	bVII, bVII, bVI
Time After Time	Cyndi Lauper	V-VI non-cadence, V-III
Tiny Dancer	Elton John	Mod
To Be with You	Mr Big	Mods, bIII, bVII, V-VI
To Love Somebody	The Bee Gees	bVII
Total Eclipse of the Heart	Bonnie Tyler	bVII, Mods, sec doms
Trail of Tears	Fattburger	Mod
Tropicana	Ratatat	bVI
Trouble	Coldplay	bVII, mods? maybe dorian mode?
Two Out of Three ain't Bad	Meatloaf	bVII, V-III
Use Somebody	Kings of Leon	Mod unprep
Veronica	Elvis Costello	IVm, bVII, line cliché
Video Killed the Radio Star	the Buggles	V-VI non-cadence
Vincent	Don Mclean	V-VI, IVm, bVII passing
Wait	Earth, Wind, and Fire	Mods, bVII, bIII
Wait for the Sun	Special Others	IIm7b5/b5
Walk on By	D-Train	Mods
Walking on Broken Glass	Annie Lennox	bVII
We Don't Talk Anymore	Cliff Richard	Mods, bVII
We Have All the Time	Milton Hamilton	Vima minor key, mods, bVII, bVI, bIII, bII, subs
We've Got Tonight	Bob Seger	bIII, b6, pedal point
Weather With You	Crowded House	Mid, sec dom
What a Wonderful World	Louis Armstrong	b6, sec doms, TTS
What Makes Me Think About You	Nicholas Godin	IVm, bVI, bVII
What's Going On	Marvin Gaye	IVm7???
Wheels Within Wheels	Rory Gallagher	5m6/b3 passing
When We Dance	Sting	Mods, bVII, I#11
While My Guitar Gently Weeps	the Beatles	Pic 3rd
Whip Appeal	Babyface	bVII, IVm
Whiskey In the Jar	Thin Lizzy	b7 passing riff
Who Are You	The Who	b7, b6, pedal point
Who Can It Be Now	Men at Work	bVII
Wichita Lineman	Glen Campbell	Mods, sec dom mod, bVI, bVII
Wish You Were Here	Incubus	bVII
With a Little Luck	Wings	b7, mod, V-VI
Woman	John Lennon	Mod
Wouldn't It Be Good	Nik Kershaw	Mods, b2
Year of the Cat	Al Stewart	Sec doms, bVII, VIma7
You and I	Stevie Wonder	Sec dom mod, sec doms, bVI, mod
You Are the Sunshine of My Life	Stevie Wonder	Pic 3rd, mod sec doms
You May Be Right	Billy Joel	bVII
You to Me Are Everything	The Real Thing	Mod
Your Love	The Outfield	Modunprep
Your Song	Elton John	Sec dom
You're the Best Thing	The Style Council	Mod unprep
You've Got to Hide Your Love Away	The Beatles	bVII
You've Got Your Troubles	The Fortunes	bVII, IVm, sec doms
You've Lost That Loving Feeling	The Righteous Brothers	bVII

Appendix C. Song catalogue (ordered by song title)

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Mendes, S. (1967). Wave [Song]. On Equinox. A&M Records.
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Campbell, G. (1968). Wichita Lineman [Song]. On Wichita Lineman. Capitol Records.
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Appendix D. Supplementary Material – Experiment 1

Explicit Experiment Questionnaire

Questionnaire Variation 1

Before beginning the experiment, please complete this short questionnaire:

1) Which of the following best describes you?

- ◯ Professional Musician/Music Teacher
- ◯ Full-time Music Student
- ◯ Amateur Musician/Part-time Music Student
- ◯ Non-musician

If participant answers "Professional Musician/Music Teacher", questionnaire continues as follows:

4) What style of music do you primarily play/teach? Please select *one style* only.

- ◯ Jazz
- ◯ Classical
- ◯ Pop/Rock
- ◯ Traditional Irish
- ◯ Folk
- ◯ Gospel/Blues
- ◯ Electronic/Electro-acoustic
- ◯ Contemporary Classical
- ◯ Other (please specify one style only)

5) For how many years have you been performing/teaching music professionally?

- ◯ < 5
- ◯ 6-10
- ◯ 11-20
- ◯ 21-30
- ◯ 31-40
- ◯ > 40

To what extent does your performance or teaching involve musical improvisation?

- ◯ Musical improvisation is an integral part of my regular performance/teaching
- ◯ I sometimes use musical improvisation as part of my performance/teaching
- ◯ I rarely use musical improvisation as part of my performance or teaching
- ◯ My performance/teaching does not involve musical improvisation

Have you ever formally studied improvisation with a teacher?

- ◯ Yes - I've had several lessons/workshops on improvisation
- ◯ Yes - I've had the occasional lesson/workshop on improvisation
- ◯ No - but I've studied improvisation on my own
- ◯ No

Thank you for completing the questionnaire.

Click Next to go to the Experiment

Next

Questionnaire Variation 3

Before beginning the experiment, please complete this short questionnaire:

1) Which of the following best describes you?

- ◯ Professional Musician/Music Teacher
- ◯ Full-time Music Student
- ◯ Amateur Musician/Part-time Music Student
- ◯ Non-musician

If participant answers "Amateur Musician/Part-time Music Student", questionnaire continues as follows:

4) What style of music do you primarily play?
Please select *one style* only.

- ◯ Jazz
- ◯ Classical
- ◯ Pop/Rock
- ◯ Traditional Irish
- ◯ Folk
- ◯ Gospel/Blues
- ◯ Electronic/Electro-acoustic
- ◯ Other (please specify one style only)

5) For how many years have you been playing/studying music?

- ◯ < 5
- ◯ 6-10
- ◯ 11-20
- ◯ 21-30
- ◯ 31-40
- ◯ > 40

To what extent does your performance or practice involve musical improvisation?

- ◯ Improvisation is an integral part of my regular practice/performance
- ◯ I sometimes improvise as part of my practice/performance
- ◯ I rarely improvise as part of my practice/performance
- ◯ My practice/performance does not involve improvisation

Have you ever formally studied improvisation with a teacher?

- ◯ Yes - I've had several lessons/workshops on improvisation
- ◯ Yes - I've had the occasional lesson/workshop on improvisation
- ◯ No - but I've studied improvisation on my own
- ◯ No

Thank you for completing the questionnaire.

Click Next to go to the Experiment

Next

Questionnaire Variation 4

Before beginning the experiment, please complete this short questionnaire:

1) Which of the following best describes you?

- Professional Musician/Music Teacher
- Full-time Music Student
- Amateur Musician/Part-time Music Student
- Non-musician

If participant answers "Non-musician", questionnaire ends:

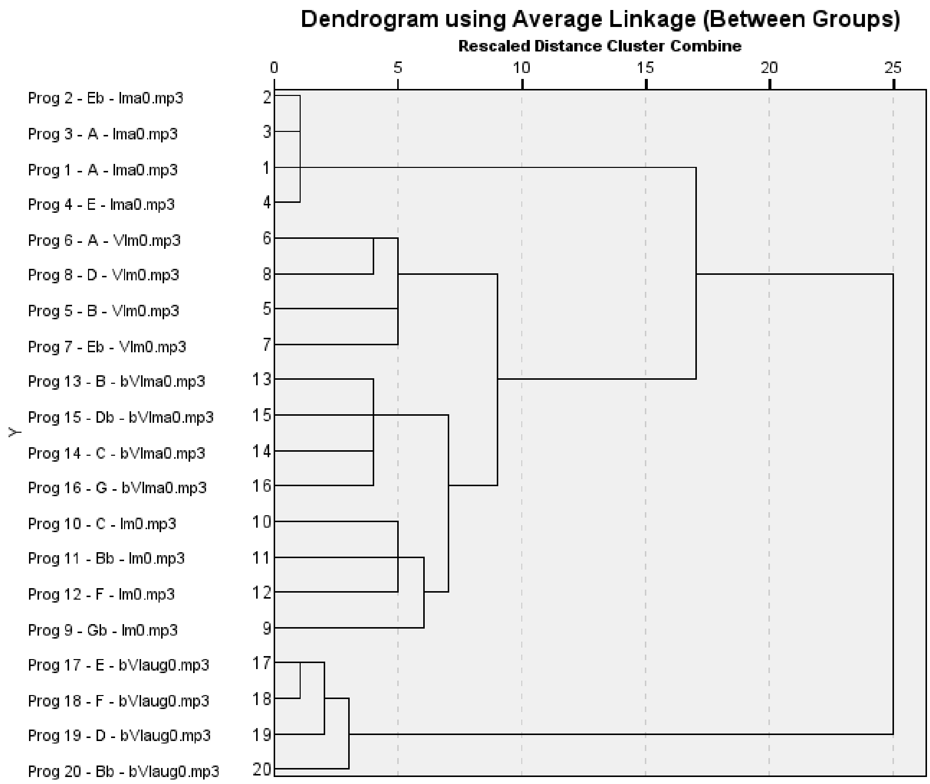
Thank you for completing the questionnaire.

Click Next to go to the Experiment

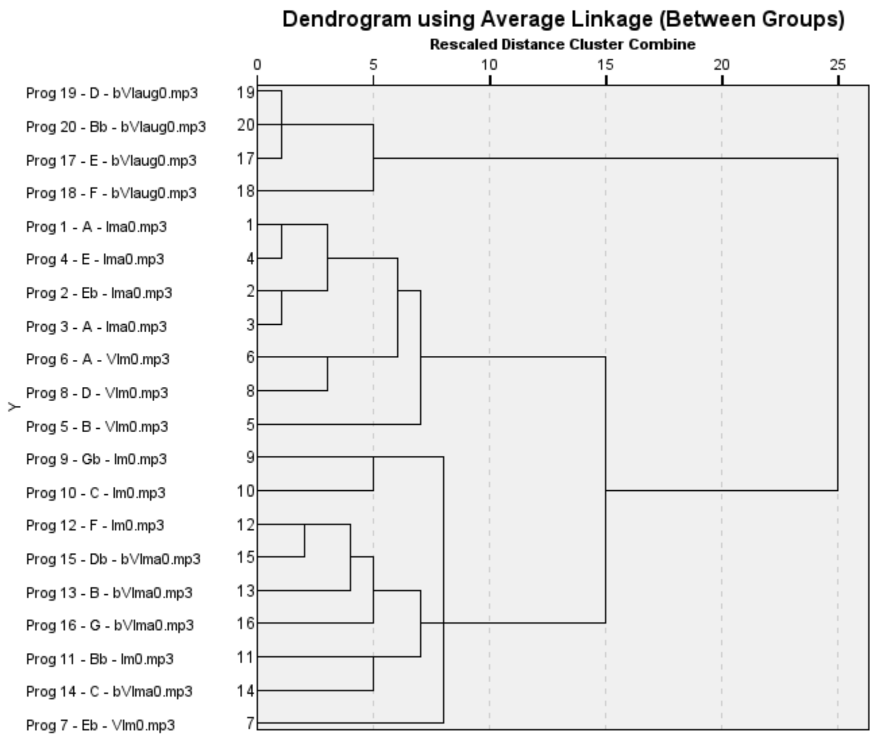
Next

Implicit Experiment Dendrograms

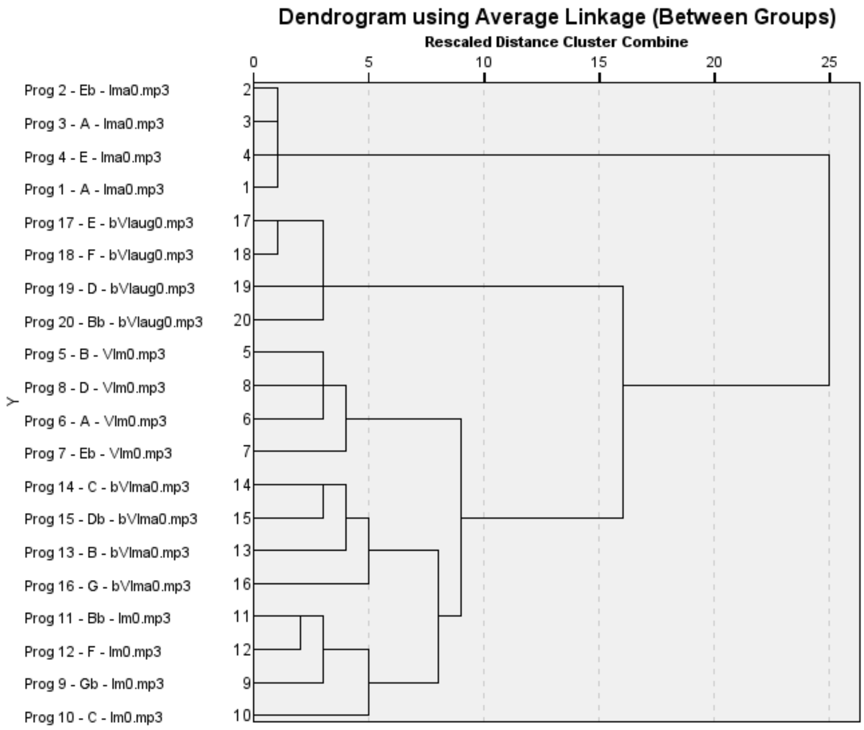
All Participants



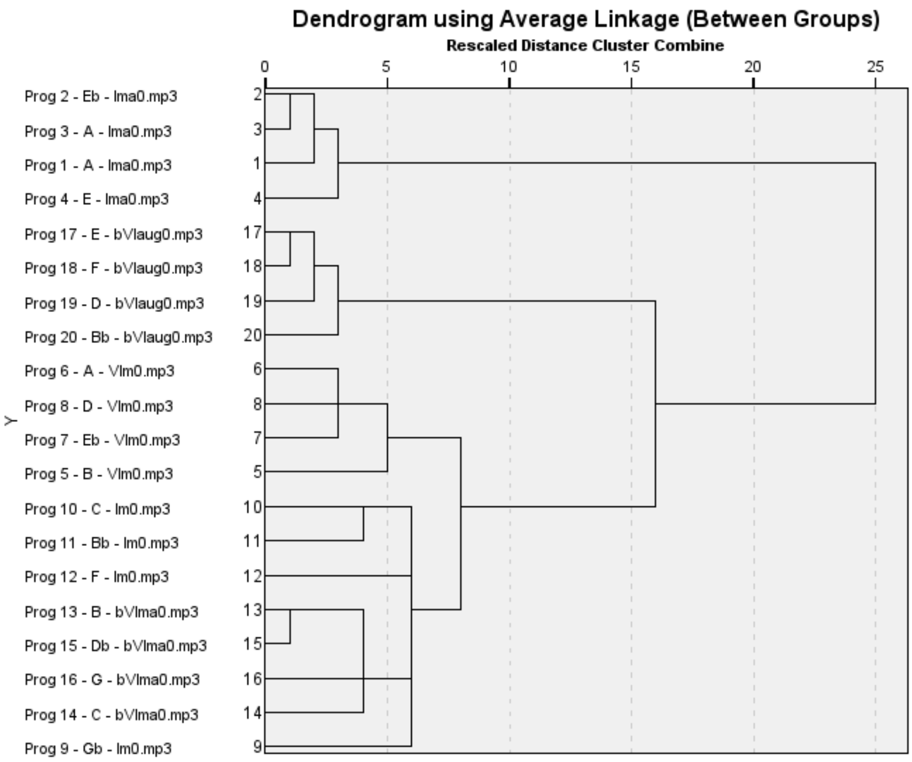
General Listeners



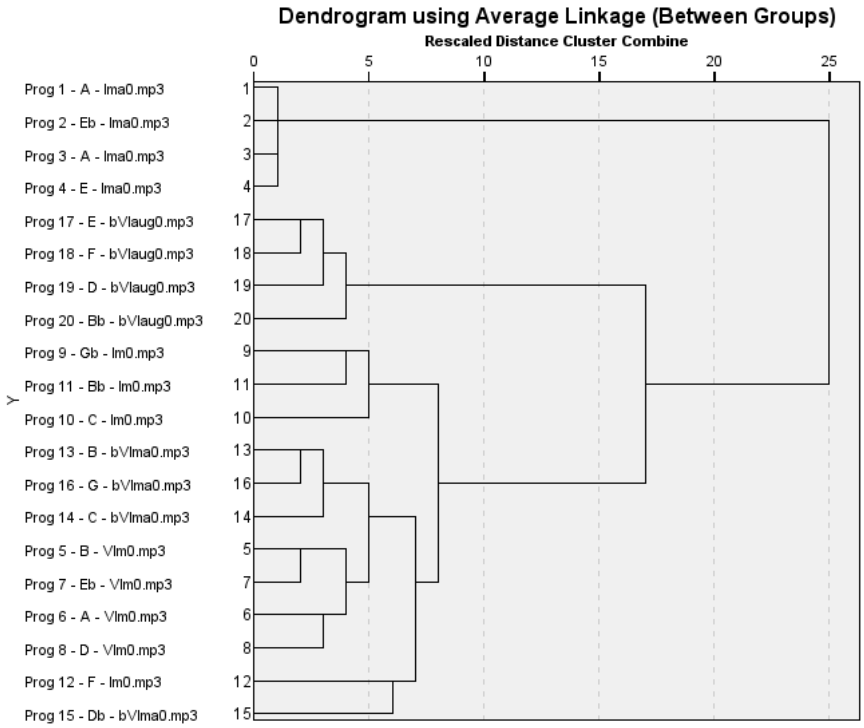
Jazz Musicians



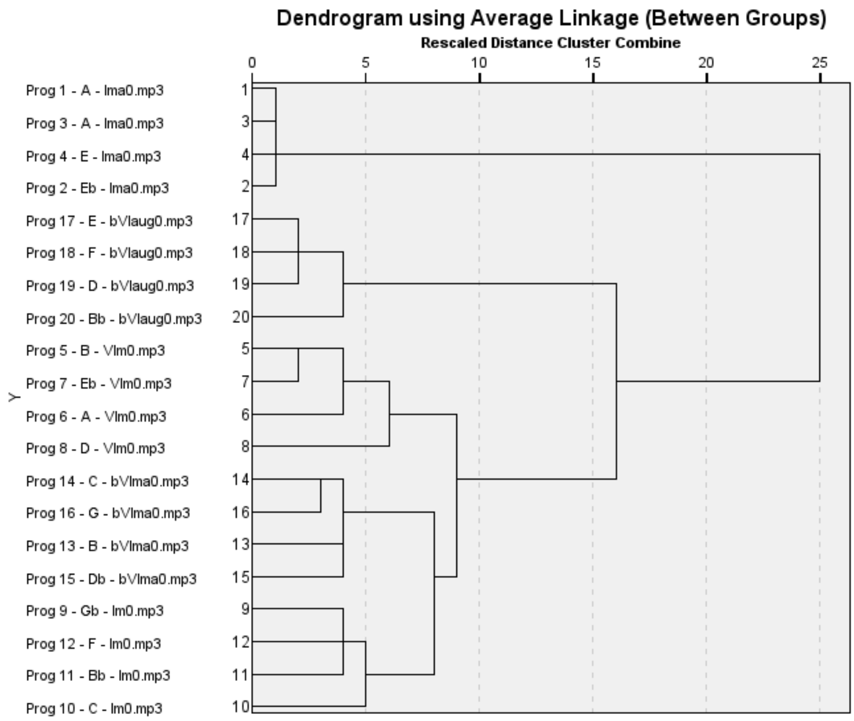
Classical Musicians



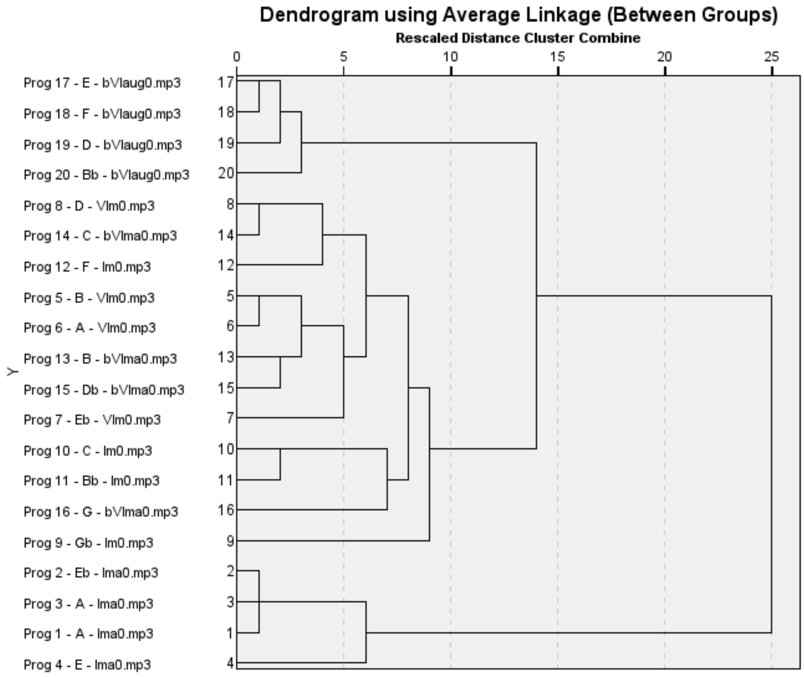
Pop/Rock Musicians



Improvising Musicians



Non-improvising Musicians



Appendix E. Supplementary Material – Experiment 2

Implicit Experiment Questionnaire

Musical Experience Questionnaire

1) What is your age?

☐ less than 18 ☐ 18 – 25 ☐ 26 - 35 ☐ 36 – 45

☐ 46 – 55 ☐ 56 – 65 ☐ over 65 ☐ prefer not to say

2) What is your gender?

☐ female ☐ male ☐ other ☐ prefer not to say

3) Are you left- or right-handed?

☐ left-handed ☐ right-handed ☐ ambidextrous ☐ prefer not to say

4) Have you ever had any difficulties with your hearing, e.g. tinnitus, hearing loss in one or both ears, hyperacusis etc.?

☐ No hearing difficulties ☐ Some hearing difficulties

Please specifiy:

____

5) Do you play any musical instruments (including the voice)?

☐ yes, I play multiple instruments ☐ yes, I play one instrument

☐ no, I don't play any musical instruments

6) If yes, how long have you been playing your primary instrument?

☐ less than 1 year ☐ 1 – 2 years ☐ 3 – 5 years

☐ 6 – 10 years ☐ 11 – 20 years ☐ over 20 years

7) How would you rate your musical proficiency?

☐ Professional ☐ Advanced ☐ Intermediate

☐ Beginner ☐ I do not play music

8) What style of music do you primarily play?

☐ Jazz ☐ Classical ☐ Pop/Rock ☐ Blues

☐ Traditional ☐ Other *Please specifiy:* _________________ ☐ I do not play music

9) Have you taken any formal musical training? Tick all that apply.

☐ yes, I studied music at university ☐ yes, I have taken private music lessons

☐ yes, I studied music at school ☐ no, I have not taken any musical training

10) If yes, for how many years did you study music?

☐ less than 1 year ☐ 1 – 2 years ☐ 3 – 5 years

☐ 6 – 10 years ☐ over 10 years

11) How well do you understand music theory?

☐ I understand it very well ☐ I understand most of it

☐ I understand some of it ☐ I do not understand any music theory

12) How often do you listen to music?

☐ Multiple times a day ☐ Once or twice a day ☐ Once every few days

☐ Once a week ☐ less than once a week

13) How important would you rate music listening in your life?

☐ Extremely important ☐ Very important ☐ Fairly important

☐ Not very important ☐ Not important at all

14) When you hear music in your daily life, how distracting do you find it in general?

☐ I usually find it quite distracting, and struggle to focus my attention elsewhere

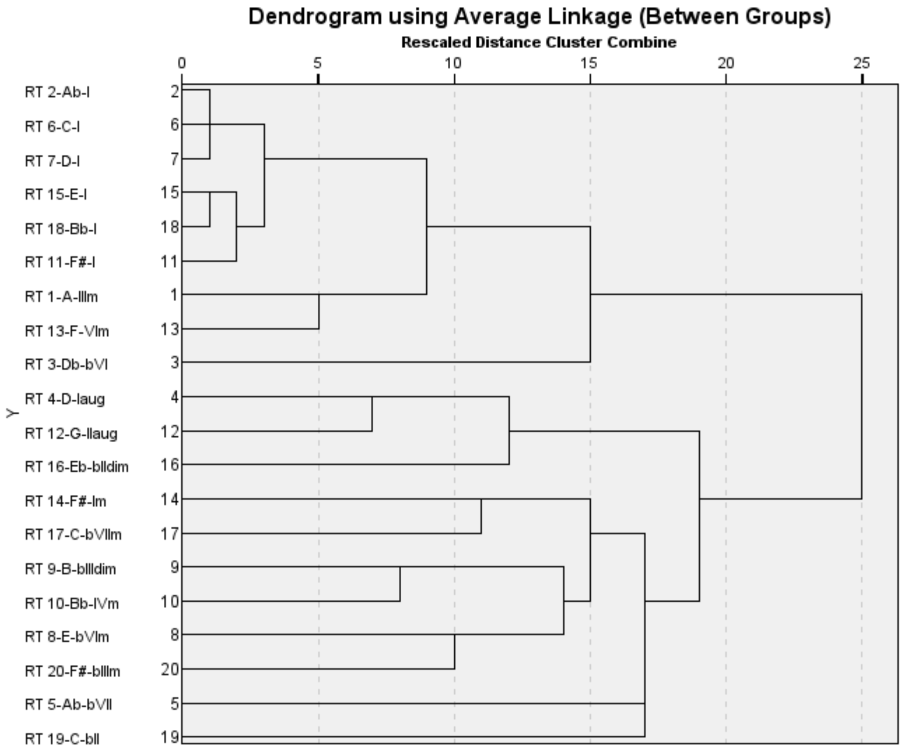
☐ I find it occasionally distracts my attention

☐ I usually notice it but it does not distract my attention

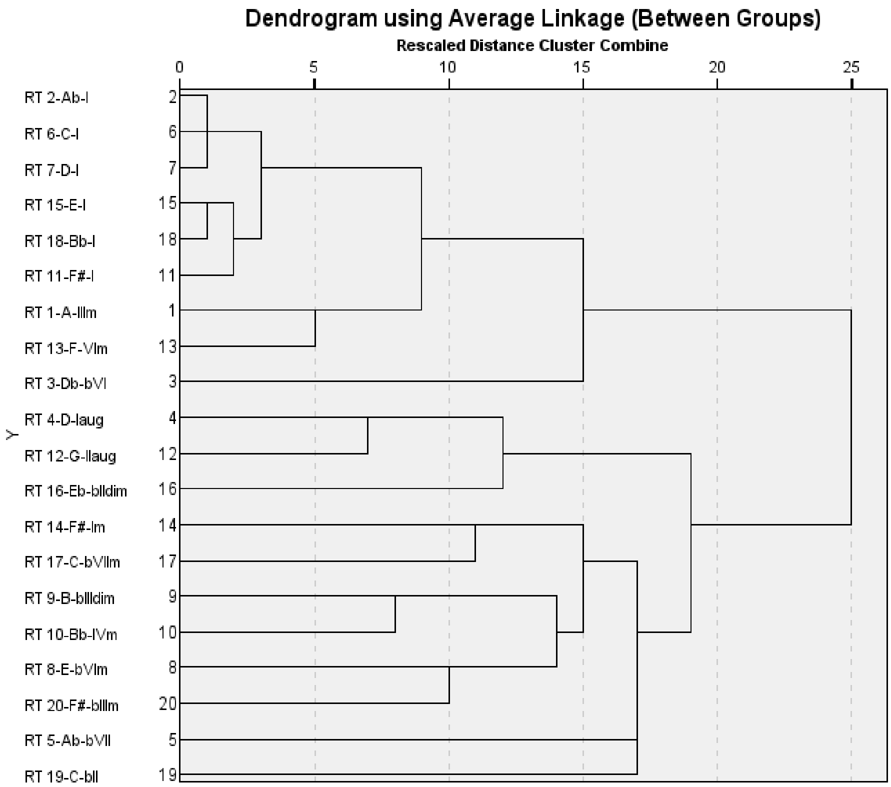
☐ I do not usually notice background music

Implicit Experiment Dendrograms

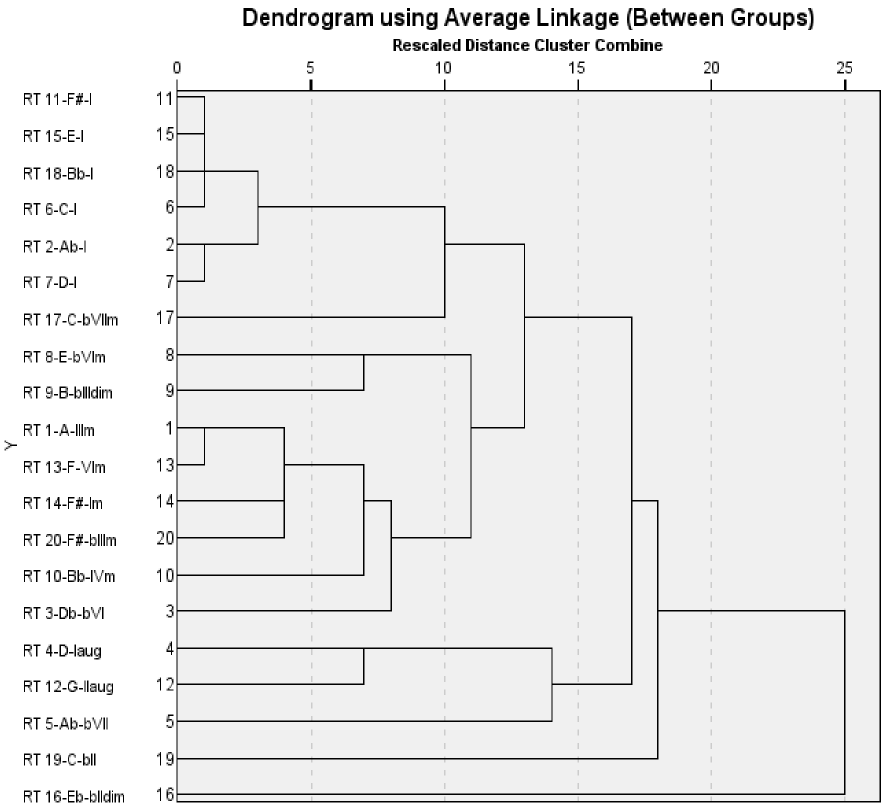
All Participants – Liking Ratings



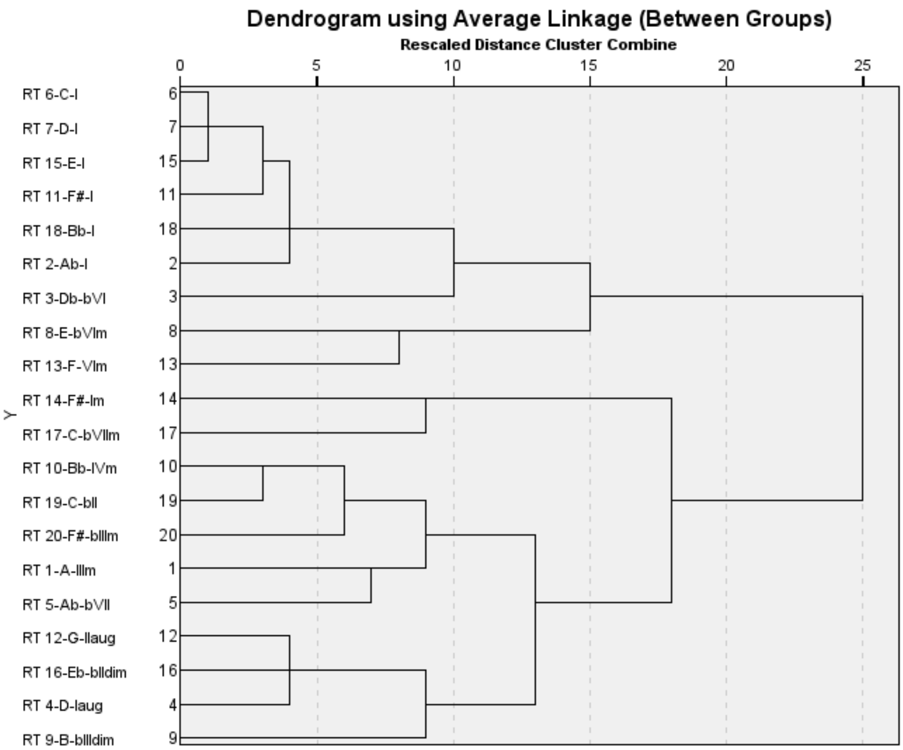
General Listeners – Liking Ratings



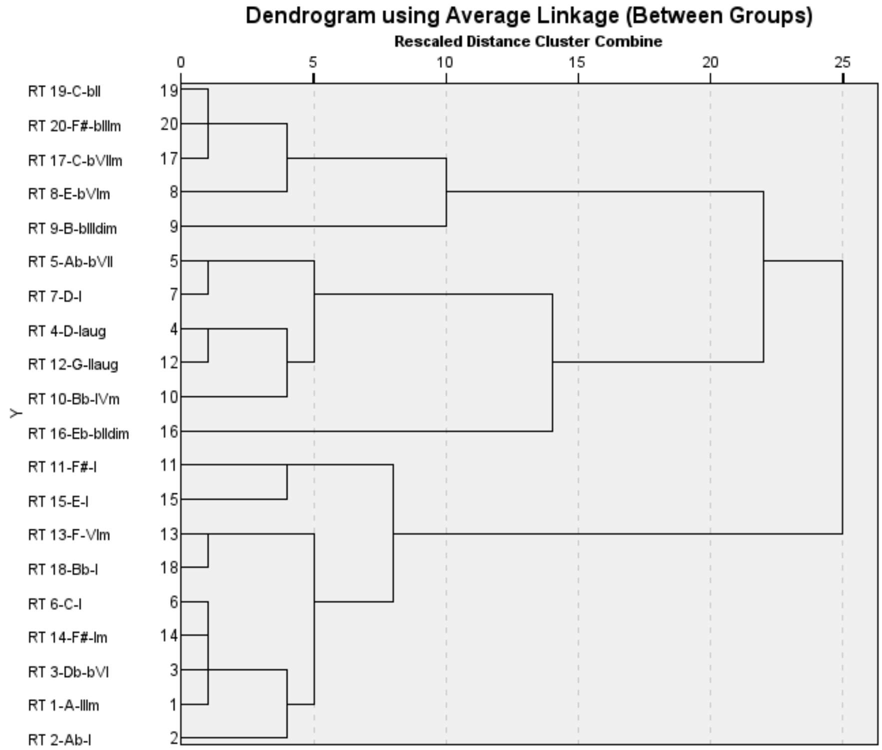
Jazz Musicians – Liking Ratings



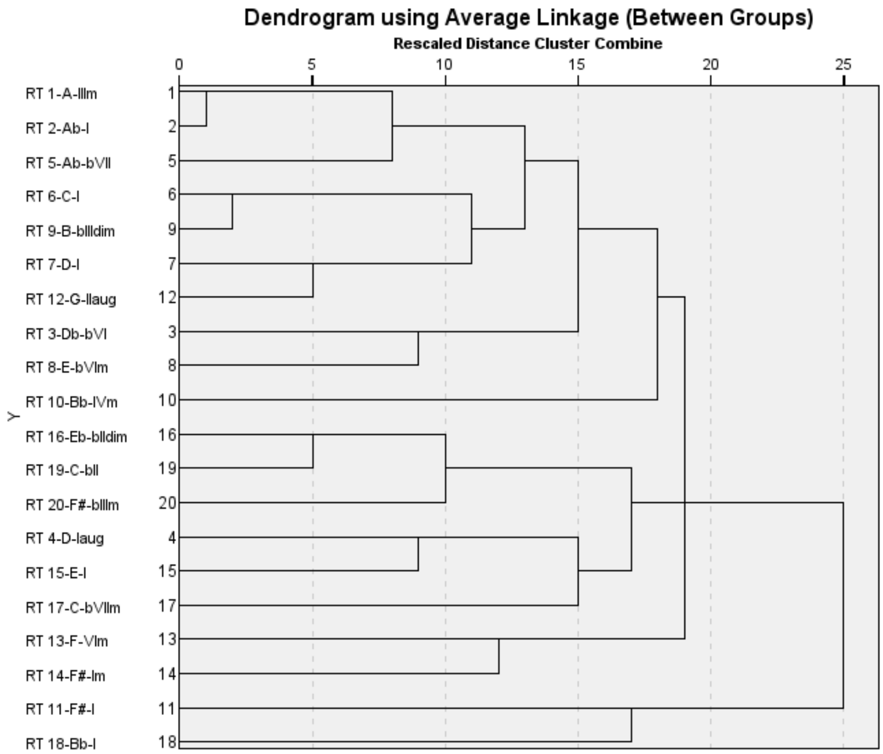
Pop/Rock Musicians – Liking Ratings



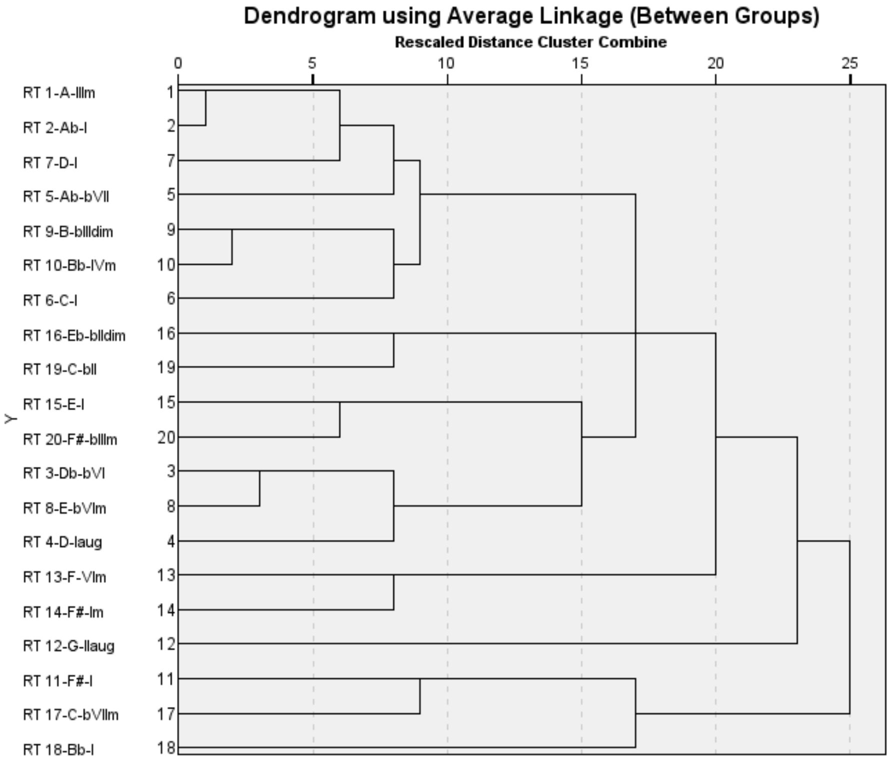
Other Musicians – Liking Ratings



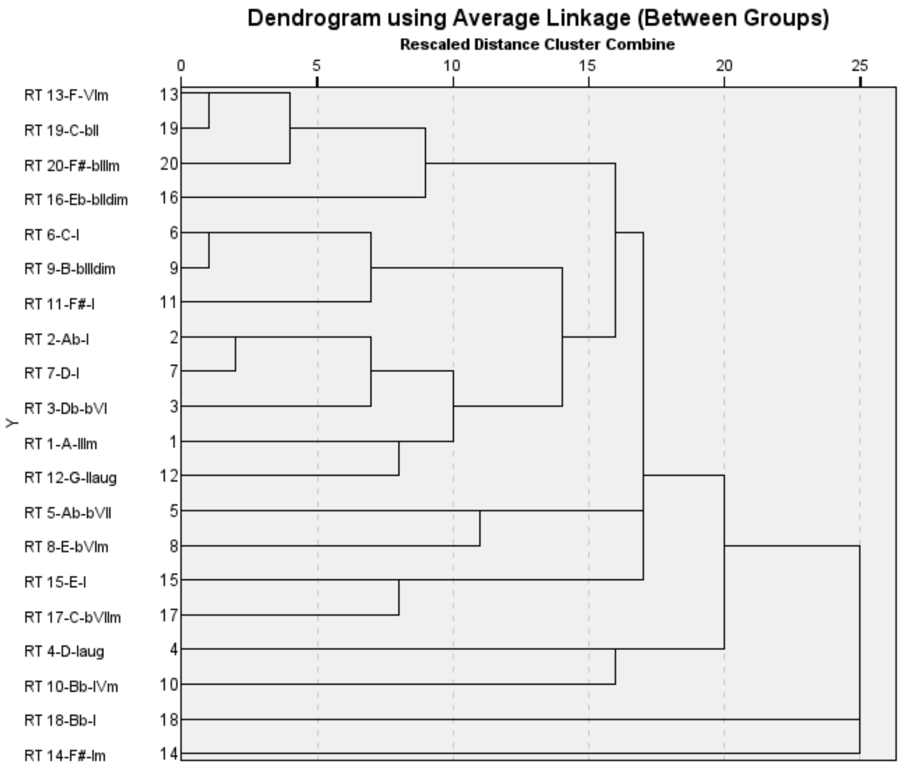
All Participants – Reaction Time



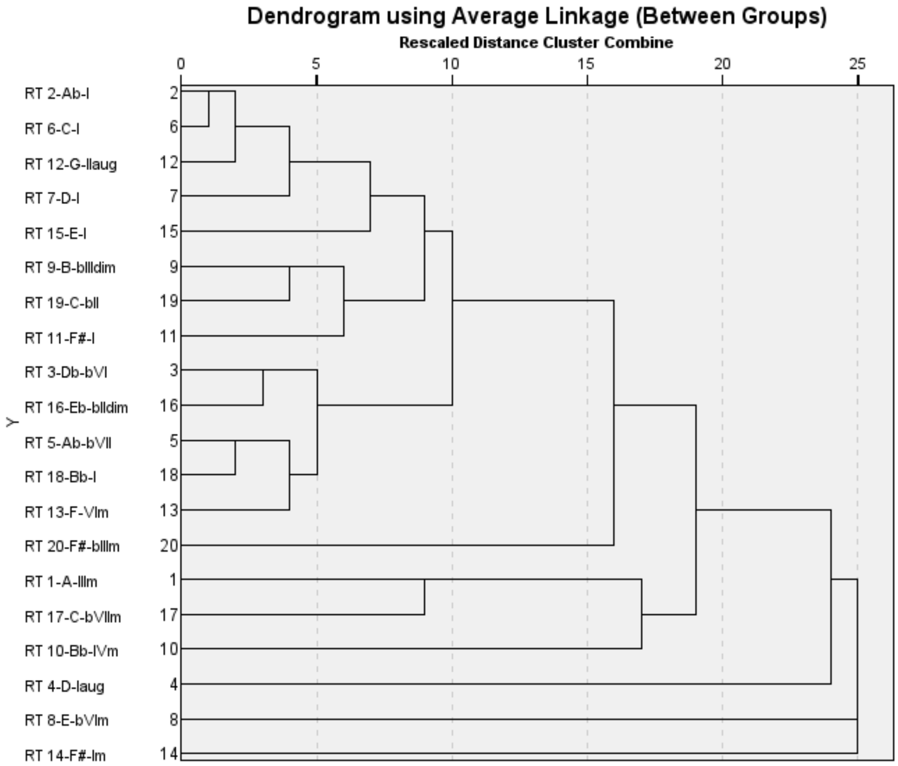
General Listeners - Reaction Time



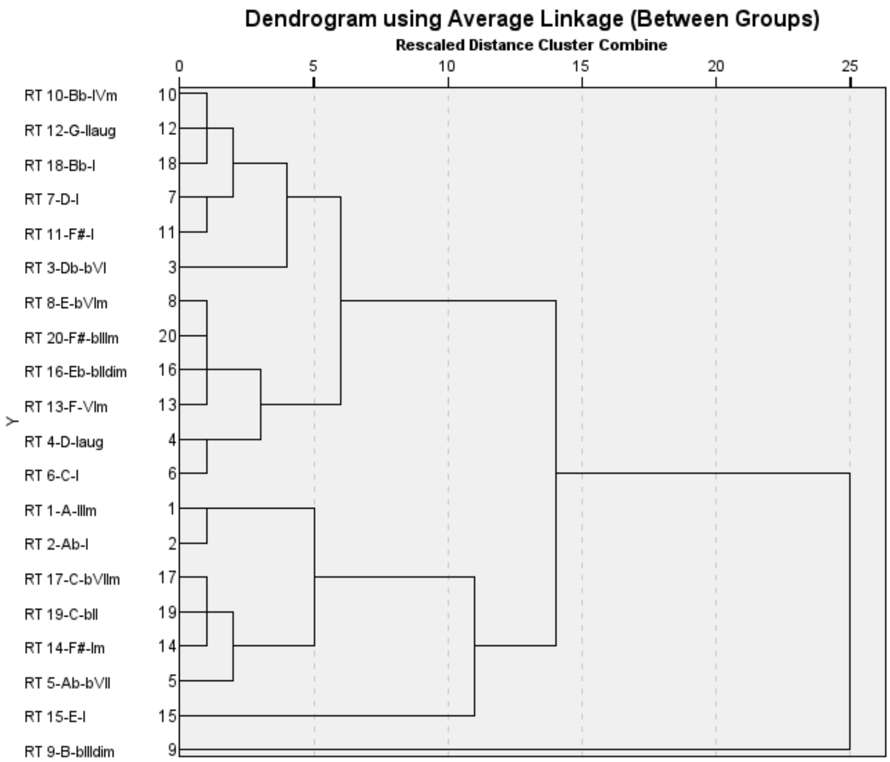
Jazz Musicians - Reaction Time



Pop/Rock Musicians - Reaction Time



Other Musicians - Reaction Time



Appendix F. Supplementary Material – Experiment 3

Ecological Pop Experiment Questionnaire

Section 1: Questionnaire

1) Which of the following best describes you?

○ Professional Musician
○ Full-time Music Teacher
○ Full-time Music Student (3rd year or above)
○ None of the above (Selecting this option will end the experiment after the current page)

2) What is your age?

○ < 20
○ 21-30
○ 31-40
○ 41-50
○ 51-60
○ > 60
○ Prefer not to say

3) What is your gender?

○ Female
○ Male
○ Prefer not to say

Next

Section 1: Questionnaire (page 2)

4) What style of music do you primarily play/teach? *Please note that only jazz, classical, pop, and rock musicians are required for this study*

○ Jazz
○ Classical
○ Pop/Rock
○ Other genre (Selecting this option will end the experiment after the current page)

5) For how many years have you been playing music?

Please Select...

6) Does your performance/teaching involve a significant amount of improvisation?

○ Yes
○ No

Next

Musical Stimuli: Timestamps and Chords

Audio files may be downloaded at the following link: https://github.com/adamsls/adamsl_exp_3_audio

Manic Street Preachers		Pure Prairie League		Ben Folds		Marlena Shaw		Smokey Robinson		Elton John	
A design for life		Amie		Annie Waits		California Soul		Cruising		Daniel	
0	1	0	1	0	1	0	3ma	0	1	0	1
5400	2m7 (add 13	1310	b7	1320	5	1360	1	2550	2	2250	2m7
10770	5	2000	4	1550	4	3580	6add11	5390	1	5910	5
16290	b3ma7	2680	1	1810	1	6430	5sus	5360	2	9610	3dom7
19020	2m7b5	4030	b7	3780	6	8990	2dom/3	11050	1	11200	6
		4750	4	5740	5	10290	4	13850	4	13260	4
		5370	1	7720	2ma	11570	1m	16680	b7	14850	5
		6640	b7	11650	4ma7	14000	6 min key	17720	5	16910	6
		7500	4	13610	5	16660	1	19540	1	20530	4
		8050	1	15600	6	17960	2 bass				
		11000	4	17570	2ma						
		13560	b3	19510	4						
		16380	4								
		19130	b3								
		22210	5								

Mama's Gun		Bread		Weird Al Yankovic		St Vincent		Keith Mansfield		Kenny Loggins	
Diamond in the bell jar		Everything I own		Everything you know is wrong		Fear the future		Funky fanfare		Heart to heart	
0	5	0	1	0	6	0	1	0	1	0	2
300	1	4800	3/5	650	6m7/b7	1620	1/5	590	b7	2830	5sus
3020	4	6430	6	1390	2ma/3	3470	4	850	1	5790	1
4920	5sus	8020	1/5	2130	2ma	5020	b7	7700	4	8760	6
6470	1	9640	4	1880	5	6930	1	8360	1	10210	b7add9
9080	4	11220	4m6 (mel)	3620	5dom7/b7	8460	4	10160	4	11640	1
11080	5sus	12820	5sus	4360	3m	10200	1	10790	1	14600	6
12200	b7dom7	14460	5	5090	5/5	11900	4	13320	b6	16050	5
18830	2	16080	1	5880	1	13620	b6	14580	b7	17660	4
		17680	3/5	7350	4	17060	b7	15840	1	20380	5sus
		19260	6	8100	5			17290	4		
				8820	1			18370	1		
				10340	7m7b5						
				11060	3dom7						
				11810	6						
				12570	1/5						
				13320	2dom7/3						
				14060	2dom7						
				14770	4						
				15720	5						
				16290	b3						
				17210	4						
				17970	1						

Radical Face		Kylie Minogue		The Beatles		Diana Ross		Pusha T	
Home movies		I should be so lucky		I will		I won't last a day without you		If you know you know	
0	1	0	5	0	1dom7/5	0	2	0	1
7780	4	1210	1	920	4	720	5	6570	b7
16850	6	3270	4	1970	5	1350	1ma7	9630	b5
26110	4		5	3370	6	2930	1dom7	15950	1
35170	6	5370	3	3960	#5aug	4640	4	19060	b7
39830	1/3	6410	6	4530	1dom7/5	6290	2		
44300	b3add9	7430	2	5730	4	7060	5		
48720	4	8470	5	6730	5	7990	1ma7		
	1	9470	1	7970	6	9610	1dom7		
		11050	1(mod)	8610	#5aug	11260	4		
		13610	6 (mod)	9170	1dom7/5	12890	1/3		
		15680	b7	10330	2	14550	2		
		17760	5	11490	5	15980	5		
				12670	b6	17880	3		
				17230	1	19130	b7ma7		

Ye Vagabonds		Donny Hathaway		Alabama Shakes		Nora en Pure		Larry Marshall		Caroline Rose	
I'm a rover		Je vous aime		Joe		Life on Hold		Love and peace		Nothing's impossible	
0	1	0	1	0	1	0	4m7	0	1	0	2
1830	4	2430	6m7	4110	5	1840	4m	3110	4	3010	1
3370	1/3	5090	2m7/b7	8110	1	4000	1m	5830	1	4560	5
5170	5	7650	1/5	12340	2(root)	5980	b7	8630	4	6030	2
6910	1	10350	5sus	12930	3 (root)	7970	b6	11420	1	9060	1
8470	4	12960	1/5	13520	4	11880	4m	14210	b3	10600	5
10140	1	15600	5sus	15420	1	13930	b3	16960	2	12100	4ma7
11280	5	18180	6	17360	5	15830	4m	19730	1	15160	1
11850	1	19490	2	19270	1	18420	b6			16620	5
15230	4	20790	6			18960	b7			18200	4ma7
16990	1/3	22090	2			19850	1m				1
18780	5	24340	6								5
20660	6m7	24690	2								
22390	4	25890	6								
24230	1	27160	1270								
		27420	260								
		31110	3690								

Sure Sure		The Beatles		Janelle Monae		Arcade Fire		Halestorm		Paul Simon	
Okinawa		PS I love you		Queen		Rebellion (Lies)		Skulls		Still crazy after all these years	
0	2m7	0	1	0	1m	0	1	0	1m	0	1
320	1	3520	2	2070	1m7	1710	4	950	b6	3240	1dom7
1420	2m7	5320	1	6550	b3ma7	3580	1	2360	4m	4800	4
2440	1	7070	5	11080	4m7	5440	4	3700	b6	6380	4m6
3590	2m7	8860	6	15600	b6ma7	7310	1	5080	4m	8050	1
4710	b7ma7	10650	5	17920	5dom7b9	9190	4	6490	1ma	9850	7m
6930	2m7	12420	b6	20170	1m7	11040	1m	8080	b3	11250	3ma
7880	4ma7	15540	b7			12950	6 (min key)	9330	b6	12310	3ma/3
8930	1	15990	1			14810	3 (min key)	10760	4m	12870	6
10020	2m7					16690	7 (min key)	12120	1ma	13950	b6aug
11180	1							13700	b3	14550	5m7
12270	2m7							14860	b6	16080	1
17560	1m							16430	4m	17630	4sus
19770	#3m							17650	1m	19300	#4dim
								18430	b3	20840	1/5
								19070	1m	22610	5
								19770	b3	24330	6
										25860	#4dim
										27530	1/5
										29170	5
										30800	4m
											5sus
											1

Spandau Ballet		Tommy Emmanuel		Slant 6		Nicholas Godin		Stevie Wonder	
Through the barricades		Timber lake road		What kind of monster are you		What makes me think about you		You and I	
0	4	0	1	0	6	0	5 bass	0	2dom7
1210	5	1000	b7	550	5	320	1	2160	5
2880	1	1980	1	600	6	3170	4ma7	6000	1
3720	5/3	2940	4/3	1370	2	5980	1	9680	5m7
4430	6	3320	b7	1700	1	8870	4ma7	11700	1dom7
7760	4	3940	1	1900	4	11710	1	13570	4
9410	2	4860	b7	3110	1	14510	4m6	17430	4m7
12680	5	5710	4	4220	6	17360	1	21180	1
14330	b7	6620	b3	5350	5	18760	5/3		
17580	4	7570	1	5570	6				
20910	1/3	8640	b7	6130	2				
		9630	1	6470	1				
		10630	4/3	7060	4				
		11340	b7	8040	1				
		11590	1	9190	6				
		12510	b7	10390	5				
		13370	4	10650	6				
		14300	b3	11160	2				
		15250	1	11480	1				
		17300	6	11940	4				
		19210	b6	12930	1				
		21140	5	14230	2				
				15430	3				
				16680	5				
				19340	5				
				19340	1				

Number of occurrences of chords in stimuli

Chord	No. of occurrences	Chord	No. of occurrences
1	87	3dom7	2
4	46	4/3rd	2
5	34	4add9	2
6	22	4m7	2
2m7	19	5/3rd	2
b7	19	5m7	2
6m7	15	7m7b5	2
4ma7	14	b6dom7	2
3	10	#6m	1
5sus	10	2 bass	1
1/5th	8	2dom7	1
2	7	2m13	1
1dom7	6	2m7b5	1
1ma7	6	3dom7/3rd	1
b3	6	3ma7	1
1/3rd	5	3sus	1
b6	4	4m	1
7	3	4sus	1
1m	3	5/5th	1
4m6	3	5dom7alt	1
b7ma7	3	6add11	1
#4dim	2	6add6	1
1dom7/5th	2	6ma7	1
1m7	2	b3add9	1
1ma	2	b3ma7	1
2dom7/3rd	2	b5	1
2m7b5/b5th	2	b7add9	1
2ma	2	b7dom7sus	1
3/5th	2	Mod 1	1

Number of votes per chord

Song	Chord	Votes	Song	Chord	Votes
What makes me think	4m6	43	Everything I own	1	2
Home Movies	b3add9	40	Everything I own	1	2
Through the barricades	b7	39	Love and peace	1	2
PS I love you	b6	38	Love and peace	1	2
Diamond in the bell jar	b7dom7sus	38	What kind of monster	4	2
I will	b6dom7	38	Everything I own	3/5th	2
Still crazy	4m	36	California Soul	6add11	2
Timberlake road	b6	34	Funky Fanfare	1	2
A Design for life	b3ma7	33	If you know you know	1	2
I should be so lucky	Mod 1	31	PS I love you	2	2
California Soul	1m	30	Amie	4	2
Love and peace	b3	30	Skulls	4	2
Fear the future	b6	29	Nothing is impossible	5	2
Amie	5	25	PS I love you	5	2
Funky Fanfare	b6	24	PS I love you	5	2
Okinawa	1m	24	Diamond in the bell jar	4ma7	2
Rebellion	1m	24	Fear the future	b7	2

Everything I own	4m6	23		A Design for life	1	2
You and I	4m7	22		Cruising	1	2
Okinawa	#6m	22		I should be so lucky	1	2
Annie Waits	2ma	22		I should be so lucky	3	2
Amie	b3	21		Everything you know	4	2
Je vous aime	b7ma7	21		I should be so lucky	5	2
I wont last a day	b7ma7	21		Everything you know	7	2
Rebellion	6	20		Everything you know	1/5th	2
If you know you know	b5	19		Still Crazy	1dom7	2
Daniel	3dom7	19		Cruising	2m7	2
Home Movies	6m7	19		What makes me think	4ma7	2
You and I	5m7	18		What makes me think	5/3rd	2
Home Movies	1/3rd	18		Everything you know	5/5th	2
Fear the future	b7	17		Je vous aime	6m7	2
Joe	4	16		Je vous aime	6m7	2
I wont last a day	3	16		Through the barricades	1	2
Everything you know	4	15		Through the barricades	4	2
Still crazy	6	15		Timberlake road	4	2
A Design for life	2m7b5	15		Timberlake road	4	2
Still Crazy	4m6	15		I will	5	2
Timberlake road	6	15		Okinawa	2m7	2
Queen	5dom7alt	15		I will	2m7b5/b5th	2
Nothing is impossible	4ma7	14		Timberlake road	4/3rd	2
Funky Fanfare	b7	14		Im a rover	4ma7	2
Everything you know	1	14		Okinawa	4ma7	2
Cruising	5	14		I will	6m7	2
Still Crazy	#4dim	14		Timberlake road	b3	2
Heart to heart	b7add9	13		Timberlake road	b7	2
Je vous aime	6	13		Rebellion	3	2
Still Crazy	3sus	13		Rebellion	4	2
Still Crazy	5m7	13		California Soul	1	1
Timberlake road	1	13		Love and peace	1	1
Still Crazy	#4dim	12		What kind of monster	1	1
Still Crazy	7m7b5	12		What kind of monster	1	1
Queen	3ma7	12		What kind of monster	1	1
You and I	1ma7	11		What kind of monster	2	1
California Soul	2dom7/3rd	11		Love and peace	4	1
Diamond in the bell jar	2m7	11		Love and peace	4	1
Je vous aime	5	11		What kind of monster	4	1
Everything you know	3dom7	11		Everything I own	6	1
Everything you know	b3	11		What kind of monster	6	1
Cruising	b7	11		Everything I own	1/5th	1
Home Movies	4ma7	11		Amie	1	1
Annie Waits	2ma	11		Funky Fanfare	1	1
Love and peace	2	10		If you know you know	1	1
Daniel	6	10		Nothing is impossible	1	1
Still Crazy	5sus	10		Nothing is impossible	1	1
I should be so lucky	b7	10		Skulls	3	1
Annie Waits	6	10		Amie	4	1
What kind of monster	3	9		Life on hold	6	1

California Soul	4	9		Skulls	6	1
Life on hold	4	9		Life on hold	7	1
Heart to heart	1	8		Diamond in the bell jar	1ma7	1
California Soul	6add6	8		Diamond in the bell jar	4ma7	1
PS I love you	1	8		A Design for life	1	1
Skulls	1ma	8		Still Crazy	1	1
Everything you know	6	8		Still Crazy	1	1
Still Crazy	4sus	8		What makes me think	1	1
Timberlake road	1	8		What makes me think	1	1
Timberlake road	5	8		Everything you know	3	1
I will	1dom7/5th	8		Everything you know	4	1
What kind of monster	2	7		Everything you know	5	1
Life on hold	1	7		Still Crazy	5	1
PS I love you	6	7		Still Crazy	5	1
Skulls	1ma	7		Still Crazy	1dom7	1
Amie	b3	7		Everything you know	2dom7	1
A Design for life	2m13	7		Je vous aime	2m7	1
Je vous aime	2m7	7		Je vous aime	2m7	1
I should be so lucky	6m7	7		Je vous aime	5sus	1
Through the barricades	4	7		Je vous aime	5sus	1
I will	1dom7/5th	7		I should be so lucky	6m7	1
Queen	1m7	7		Im a rover	1	1
Queen	4m7	7		Timberlake road	1	1
Home Movies	6m7	7		Timberlake road	1	1
Rebellion	7	7		I will	4	1
Joe	1	7		Im a rover	4	1
I wont last a day	1dom7	7		Im a rover	1/3rd	1
What kind of monster	2	6		Okinawa	2m7	1
You and I	4	6		Okinawa	2m7	1
California Soul	1dom7	6		I will	6m7	1
Everything I own	5sus	6		Through the barricades	6m7	1
Nothing is impossible	4ma7	6		Timberlake road	b7	1
If you know you know	b7	6		Timberlake road	b7	1
A Design for life	5	6		Okinawa	b7ma7	1
Daniel	6	6		Annie Waits	1	1
I will	1	6		Annie Waits	5	1
Annie Waits	4ma7	6		Annie Waits	5	1
Joe	5	6		Joe	1	1
I wont last a day	5sus	6		What makes me think	4ma7	0
Heart to heart	1	5		California Soul	5sus	0
You and I	1	5		Heart to heart	4	0
Everything I own	4	5		Love and peace	1	0
Fear the future	1	5		What kind of monster	1	0
Life on hold	4	5		What kind of monster	1	0
Skulls	4	5		What kind of monster	1	0
If you know you know	b7	5		You and I	1	0
What makes me think	1	5		What kind of monster	2	0
Je vous aime	1/5th	5		What kind of monster	4	0
Im a rover	5	5		What kind of monster	5	0
Home Movies	4add9	5		What kind of monster	5	0

Im a rover	6m7	5		What kind of monster	6	0
Queen	6ma7	5		What kind of monster	6	0
Timberlake road	b3	5		What kind of monster	6	0
Joe	1	5		Amie	1	0
California Soul	5sus	4		Fear the future	1	0
Heart to heart	5sus	4		Fear the future	1	0
Heart to heart	6m7	4		Funky Fanfare	1	0
Everything I own	5	4		Nothing is impossible	1	0
What kind of monster	5	4		PS I love you	1	0
Everything I own	6	4		PS I love you	1	0
You and I	1dom7	4		Skulls	1	0
Everything I own	3/5th	4		Skulls	1	0
Funky Fanfare	1	4		Amie	4	0
Life on hold	3	4		Amie	4	0
Skulls	3	4		Amie	4	0
Skulls	3	4		Fear the future	4	0
Skulls	4	4		Funky Fanfare	4	0
Cruising	4	4		Funky Fanfare	4	0
Daniel	4	4		Funky Fanfare	4	0
Daniel	4	4		Skulls	4	0
Still Crazy	1/5th	4		Life on hold	6	0
Everything you know	2dom7/3rd	4		Skulls	6	0
Daniel	2m7	4		Fear the future	1/5th	0
Still Crazy	3dom7/3rd	4		Diamond in the bell jar	1ma7	0
Still Crazy	6m7	4		Diamond in the bell jar	5sus	0
Im a rover	1	4		Diamond in the bell jar	5sus	0
Okinawa	1	4		Amie	b7	0
I will	2m7	4		Amie	b7	0
Through the barricades	2m7	4		Amie	b7	0
Home Movies	4add9	4		PS I love you	b7	0
Okinawa	b7	4		Cruising	1	0
Annie Waits	4	4		Daniel	1	0
I wont last a day	1/3rd	4		I should be so lucky	1	0
I wont last a day	1dom7	4		Je vous aime	1	0
I wont last a day	2m7	4		Still Crazy	1	0
Heart to heart	6m7	3		What makes me think	1	0
California Soul	2 bass	3		I should be so lucky	4	0
Amie	1	3		Everything you know	5	0
Funky Fanfare	1	3		I should be so lucky	5	0
Life on hold	1	3		I should be so lucky	5	0
Nothing is impossible	2	3		Still Crazy	1/5th	0
Skulls	3	3		Cruising	1ma7	0
Fear the future	4	3		Je vous aime	2m7	0
Fear the future	4	3		Je vous aime	6m7	0
Nothing is impossible	5	3		Je vous aime	6m7	0
Nothing is impossible	5	3		Still Crazy	b6dom7	0
Skulls	6	3		Home Movies	1	0
Skulls	6	3		Im a rover	1	0
Life on hold	7	3		Im a rover	1	0
What makes me think	4ma7	3		Okinawa	1	0

Cruising	1	3		Okinawa	1	0
Everything you know	1	3		Okinawa	1	0
Everything you know	1	3		Queen	1	0
Still Crazy	4	3		Timberlake road	1	0
Daniel	5	3		Timberlake road	1	0
Daniel	5	3		I will	5	0
Je vous aime	1/5th	3		Im a rover	5	0
Cruising	2m7	3		Im a rover	1/3rd	0
I should be so lucky	2m7	3		Through the barricades	1/3rd	0
Je vous aime	2m7	3		Okinawa	2m7	0
Home Movies	1	3		Timberlake road	4/3rd	0
Im a rover	1	3		Through the barricades	5/3rd	0
Im a rover	5	3		Timberlake road	b7	0
Through the barricades	5	3		Timberlake road	b7	0
Queen	1m7	3		Timberlake road	b7	0
Okinawa	2m7	3		Rebellion	1	0
I will	2m7b5/b5th	3		Rebellion	1	0
Im a rover	4ma7	3		Rebellion	1	0
Im a rover	4ma7	3		Annie Waits	4	0
Rebellion	4	3		Rebellion	4	0
Annie Waits	6	3		Annie Waits	5	0
I wont last a day	1ma7	3		Joe	1	0
I wont last a day	2m7	3		Joe	5	0
I wont last a day	4ma7	3		I wont last a day	1ma7	0
I wont last a day	4ma7	3		I wont last a day	5sus	0
Heart to heart	1/5th	2				

Appendix G. Supplementary Material – Experiment 4

Ecological Jazz Experiment Questionnaire

Section 1: Questionnaire

1) Which of the following best describes you?

- ◯ Professional Musician
- ◯ Full-time Music Teacher
- ◯ Full-time Music Student (3rd year or above)
- ◯ None of the above (Selecting this option will end the experiment after the current page)

2) What is your age?

- ◯ < 20
- ◯ 21-30
- ◯ 31-40
- ◯ 41-50
- ◯ 51-60
- ◯ > 60
- ◯ Prefer not to say

3) What is your gender?

- ◯ Female
- ◯ Male
- ◯ Prefer not to say

Next

Section 1: Questionnaire (page 2)

4) What style of music do you primarily play/teach? *Please note that only jazz, classical, pop, and rock musicians are required for this study*

- ◯ Jazz
- ◯ Classical
- ◯ Pop/Rock
- ◯ Other genre (Selecting this option will end the experiment after the current page)

5) For how many years have you been playing music?

Please Select...

6) Does your performance/teaching involve a significant amount of improvisation?

- ◯ Yes
- ◯ No

Next

Musical Stimuli: Timestamps and Chords

Audio files may be downloaded at the following link: https://github.com/adamsls/adamsl_exp_4_audio-

A nightingale sang in Berkeley Square		A sleepin' bee		Bewitched		Blue Gardenia		Bye bye blues	
Cedar Walton		Keith Jarrett		Oscar Peterson		Lee Morgan		Sonny Stitt	
0	1	0	1	0	1	0	6dom7	0	1
1450	6	1490	4/5	2581	#1dim	1527	2	2752	b3m7
3160	3	1970	1	3585	2	3590	5	3920	b6dom7
4850	#1m7	2790	4/5	6322	#2dim	5615	1	4949	1
5810	#4dom7	3100	b7dom7b	7295	3	7572	#4m7	7343	3m7
6750	4	3630	1	9185	3dom7	8570	7dom7	8469	6dom7
8550	3dom7alt	4330	#4dom7	11056	4ma7b7	9738	b7ma7	9675	2
10280	6	5230	4dom7	12918	b7dom7	11678	3	13089	5
12140	4m7	6070	b7dom7alt	14838	3	12730	6dom7	14124	3
13020	b7	6730	1	16937	b3dim7	13919	2	15279	b3dim7
14200	1/5	7630	4	18629	2	14971	5	16368	2
16700	4/2	8420	3	20496	5	15898	1	17584	5
17410	1/5	9200	6dom7alt	21402	b5dom7	16933	3	18216	1
19290	3dom7alt	9910	2	22270	4	17507	6dom7	21129	3dom7
20130	b7dom	10720	#5dom7	25971	3m7b5	18091	2	25830	End
21200	1/5	11630	5dom7	27904	6dom7alt	20101	5		
21930	#5dim7	12480	2m11/4	28550	End	20600	End		
22800	6dom7alt	13250	3dom7alt						
24620	2m9	14850	6dom7						
26410	5dom7alt	16820	2						
28300	1sus	18000	5dom7sus						
29550	End	18800	5dom7alt						
		19580	1dom7						
		21370	4dom7						
		22000	b7dom7						
		22860	line						
		24530	5dom7sus						
		26140	1						
		27040	4/5						
		27670	1						
		28870	4/5						
		29390	1						
		30220	#4dom7						
		31090	4dom7						
		31850	b7dom7alt						
		32610	1						
		33490	4						
		34290	3						
		35080	6dom7alt						
		35790	2						
		36720	#5dom7						
		37590	5dom7						
		38220	5dom7/b7						
		39090	3dom7						
		40890	6dom7						
		42350	#2m7						
		44060	2						
		45210	5						
		45540	1						
		46500	4						
		47310	3						
		48000	6dom7alt						
		48840	2						
		49660	5dom7alt						
		50410	3						
		51230	6dom7						
		52070	2						
		53850	5dom7alt						

Dear Lord		Flamingo		For all we know		Girl Talk		Half Nelson	
Kenny Garrett		Jimmy smith		Billie Holiday		Kenny Burrell		Charlie Parker	
0	1	0	1	0	5	1202	1	0	1
4686	4	2182	6	2033	1	2937	#4dom7	3123	4m7
19645	Phantom 1	4152	2	5396	6dom7sus	4631	4	4326	b7dom7
24672	3	6076	5	9194	2	6322	2	5644	1
29628	4	8082	1m	12878	5	7126	5	8035	7m7
34762	2	11775	4dom7	16470	6	7699	3		mod - 3
37220	3	15640	b6dom7	18264	1/5.	9713	6dom7	9288	2
39721	4	19388	2	20109	#4m7b5	11413	2	10570	1
42306	5	21366	5	21793	2dom7	12253	3		mod + 3
45745	b6	23197	3	22750	End	13081	4	13184	6
47000	End	25152	6			13939	5	14359	2dom7
		27096	2			14775	1m	15609	2
		28530	End			16590	4m7	16888	5
						18205	2m7b5	18130	3
						20180	End	18769	b3dom7
								19386	b6ma7
								20025	b2ma7
								20836	1
								23060	End

I concentrate on you		I'll be around		Ill Wind		It could happen to you		Long ago and far away	
Dianne Reeves		Marian McPartland		Lee Morgan		Miles Davis		Oscar Peterson	
0	5dom7alt	0	1	0	5dom7alt	0	2	0	5
1868	1	713	6	1567	1	1993	5	4691	1
6105	4dom7#11	1546	2	3290	6dom7alt	3308	1	5824	6
10086	1m	2064	5(implied)	4990	2	5322	#1dim7	6859	2
12454	b7m7	3724	3	6609	5	5827	2	7990	5
14570	6m7b5	4317	6	8776	1	7124	#2dim7	9052	3
18736	b6m6	5433	2	10692	6	8807	1	10084	6
22872	7dim7	7081	4m11	12567	7m7	9566	4	11125	2
23370	End	8698	b3m11	14460	3dom7alt	10857	3m7b5	12149	5
		9179	b2m11	16420	6	12195	6dom7	13168	1
		9854	5m11	18367	3dom7alt	13360	2	14344	#1
		10530	b6sus12?	20309	4m7	15094	5	15423	2
			mod+4	22166	b7dom7	16079	1	16511	#2
		12490	4madd9	23955	1	16606	b7 bass	17600	3
		12969	5dom7sus	25826	6dom7alt	17276	3	18638	6
		13532	5dom7b9	27070	End	17872	6dom7	19720	2
		14233	5dom13			18627	2	20759	5
		16804	1			19938	5		mod +m3
		17828	4			21154	3	21827	1
		18813	3			22684	6dom7	22892	6
		19766	6			24093	2	23954	2
		20724	4			24800	End	24918	5
		21664	3					26101	1
		22643	2					26900	End
		23622	5dom7alt						
		24690	1						
		25624	6						
		26618	2						
		27553	5						
		28569	1						
		29549	b6ma7						
		30572	b2ma7						
		31562	5dom7sus						
		33360	End						

Look to the sky		Lover		Old folks (Miles)		Old folks		Our love is here to stay	
Emily Remler		Mary Lou Williams		Miles Davis		Vi Redd		Ella Fitzgerald	
0	2	0	b6	0	7	0	3	4347	2
2058	5dom7alt	1246	5	2602	3dom7	3319	6dom7	7375	5sus
3649	1	2478	1	4998	6	5878	2	10328	1
7062	1m7	3978	#4	6114	b6dom7	8325	5	11843	5
8907	4dom7	4784	7dom7	7300	5m7	9500	5/b7	13334	1
10583	1	5534	4m7	8375	1dom7	10658	3m7b5	16268	2
12325	4ma7	6302	b7dom7	9543	4	12980	6dom7	19298	5
13994	3	7070	3	11925	b7dom7sus	15589	2	22253	b7
15699	6dom7	7828	6dom7	14175	3m7b5	19180	5	25217	6
17816	2	8628	#2m7	16568	6dom7	20411	1	16092	5
20687	4m7	9394	#5dom7	18972	2	24870	End	28340	End
22391	b7dom7	10141	2	21226	5				
	mod +m3	10893	5	22426	5dom7/b7				
24266	1	11689	1	23696	3				
26028	b7ma7	12385	6	26012	6				
27924	6ma7	12913	#4m7	28463	5sus?				
28800	End	13925	7dom7	33147	5				
			mod+m5	36120	End				
		14734	1						
		15609	6						
		16433	2						
		17345	5						
		18349	1						
		19059	6						
		19729	2						
		20469	5dom7alt						
			mod+m3						
		21467	1						
		22219	6dom7alt						
		23065	2						
		23660	End						

Out of nowhere		Pensativa		September in the rain		Spring can really hang you up		That old feeling	
Benny Carter		Bill Evans		Roy Hargrove		Ella Fitzgerald		Chet Baker	
0	5	0	5	0	5	0	2	0	5
2607	1	1684	1	3857	1	2284	5	374	1
7709	b6	3322	b2dom7#1	4874	4dom7	3931	3	3427	5m7/4
12785	1	5004	1	5819	3	5855	6dom7alt	5135	1dom7
17867	3	6528	b2dom7#1	6665	6	7204	2	6724	2
19056	6dom7	8277	1	7826	2	8798	6dom7	9714	4m7
22615	2	9903	6dom7	11579	4m6	10498	2	11313	5dom7alt
25230	3	11442	b6ma	13665	5dom7alt	12715	5	12923	6
26333	6dom7	13131	6dom7	15674	1	15134	1	14523	7
27902	2		mod -3	16616	6	17437	b7ma7	15180	3dom7
30411	4minMa7	14842	4ma7#11	17623	2	19725	1	16034	3m7b5
32998	3	16459	3	18615	5	21945	b7ma7	16877	6dom7
34040	b3dim7	17378	6	19607	1	24258	1	18260	End
35554	2	18015	2	20642	4dom7	25270	End		
36973	5	18923	5	21480	End				
38071	1	19756	1						
38570	End		mod +3						
		21400	2						
		23047	b6dm7						
		23831	b2dom7						
		24598	1						
		26353	5m7						
		27212	1dom7						
			mod -m5						
		28024	1						
		31670	End						

The song is you		The way we were		There will never be another you		They all laughed		This heart of mine	
Art Blakey		George Cables		Shirley Scott		Sarah Vaughan		Fred Hersch	
0	5	2256	3	0	b7dom	0	2	1318	1
1419	1	4952	4	1316	1	1730	5	3848	2
3821	2	7784	3	2781	6	3307	1	5668	5
4987	5	10365	4	4086	2	5894	2	6350	3dom13
6191	1	13204	3	8332	5	6730	5	8366	6dom7alt
8639	2	14594	6	9694	1	7698	3	8809	2
9753	5	15996	2dom7	12494	7	8951	6dom7	10618	5
11028	3	17321	5	13952	3dom7	9738	2dom7	11287	3
12050	6dom7	18659	b7sus	15344	6	12189	3	12516	b3
13397	2	24022	6	18171	5m7	12890	6	13734	b6
14582	5	29540	End	19556	1dom7	13804	2	15137	2
15752	1			21090	4	14948	5	15573	5
16339	1/3			22320	End	15922	b6	16345	3
16934	4					17985	5	18037	6
17506	5					20172	3	18691	2
18099	1					21169	6	19828	5
	mod +3					22183	2	21196	1dim7
19190	2					22750	End	21832	1
19796	5							23747	2
20465	1							25606	5
22889	2							26353	3
24941	5							27190	End
25265	1								
27475	#4m7								
28660	7dom7								
29853	3								
30975	line cliché								
34488	6dom7								
36850	2								
37976	5								
	mod-3								
39109	1								
42240	End								

Three flowers		Till there was you		Up with the lark		Wave		You're my everything	
McCoy Tyner		Sonny Rollins		Eddie Gomez		A. C. Jobim		Freddie Hubbard	
0	1	1551	1	1230	1	0	1m	1000	6
1148	b7ma7	4383	#1dim	2439	5	5892	1	2320	b6m7
2276	1	7102	2	3596	1	7556	b6dim7	2680	5m7
3235	b7ma7	9833	4m	4708	5	9261	5m7	3500	1dom7
4258	1	12477	1	5821	3	10895	1dom7	4360	#4m7
5307	b7ma7	13883	b3	6965	6	12583	4	5190	4dom7
6318	1	15229	2	8058	2dom7	14003	4m7	5830	3
7319	b7ma7	16534	5	10287	2	15856	3dom9	6290	b3dom7#1
8368	1	17844	3	11417	5	17318	6dom7	7570	2
9385	b7ma7	19233	b3	12530	2	19011	2dom7	10840	5
10377	#4m7	20538	b6	13644	5	20882	b6dom7	12300	dom7alt/b
11366	7dom7	21941	b2	14753	1	22685	5dom7	14180	3
	mod +3	23276	1	15734	b3	22445	1m	16500	b3m7
12397	1	26500	End	16959	b6	26030	End	16740	
13481	b7dom7			18009	5dom7alt			19090	7
14460	1			19110	1			19740	3dom7
15509	b7dom7			20224	5			20780	6
	mod -m3			21326	1			22360	2
16512	1			22435	5m7			23980	2dom7#9
17554	b7dom7				mod +3			25480	5
18600	1			23542	2			27380	6
	mod -m2			24669	5			28940	#4dom7alt
19622	2			25781	1			30580	4
20301	5			27881	2			32150	3
20696	1			28967	5			33020	6dom7alt
21716	b7dom7			29914	1			33960	2
22749	1				mod-m2			37360	7
23757	b7dom7			32207	2			38990	3dom7
24766	1			33275	5			40640	6
25826	b7dom7			34351	1			41490	b6dom7
26837	#4m7			35590	End			42250	5m7
27830	7dom7							43190	b5dom7
	mod +3							43940	4
28860	1							45690	b7dom7
29926	b7dom7							47270	3
30907	1							48160	b3m7
32098	b7dom7							49030	2
	mod -3							49720	5
32959	1							50660	b6
34200	End							52700	End

Number of occurrences of chords in stimuli

Chord	No. of occurrences	Chord	No. of occurrences
1	77	b6dom13	2
2	57	b6ma9	2
5	48	b7dom9	2
6dom7alt	30	b7ma7#11	2
3	26	Mod 2m11	2
6	26	#4m7b5	1
5dom7alt	26	#5dim7	1
b7dom7	20	1dim7	1
3dom7alt	16	1m6	1
2dom7	13	1sus	1
4	12	2dom7alt	1
4dom7	10	2dom7sus	1
6dom7	9	2m11 (Quartal)	1
Mod 1	9	2m13	1
5dom7sus	8	3 line cliché	1
#4m7	7	3dom7	1
1ma9	7	3m13	1
2m9	7	3m13b5	1
3m7b5	7	3m6	1
5m7	7	4/2nd	1
b6dom7	7	4add9	1
1/5th	6	4m	1
2m11	5	4m11 (Quartal)	1
b3dim7	5	4ma13	1
b5dom7alt	5	4ma6/9	1
7	4	4ma7b7	1
1/3rd	4	5add9	1
1dom7	4	5m11 (Quartal)	1
1dom7alt	4	5m7/4th	1
1ma6/9	4	5sus	1
3dom13sus	4	6/5th	1
4m7	4	6dom13sus	1
4ma9	4	6m11	1
6dom7sus	4	6m7b5	1
7dom7	4	6m9	1
b6ma7	4	7dim7	1
Mod 2	4	b2	1
#2dim7	3	b2dom7	1
2dom13sus	3	b2m11 (Quartal)	1
3m9	3	b2m7	1
4/5th	3	b2ma7#11	1
4dom7alt	3	b3dom7	1
4m6	3	b3dom7alt	1
b2ma7	3	b3dom9	1
b3m7	3	b3m11 (Quartal)	1
b7dom7alt	3	b3m9	1
#1dim	2	b3ma7	1
#1dim7	2	b6	1
1add9	2	b6dim7	1
1m	2	b6dom7alt	1
1m7	2	b6m11 (Quartal)	1
1sus2	2	b6m6	1
3m11	2	b6m7	1
4ma7#11	2	b6ma7/5th	1
4miMa9	2	b6sus2	1
5dom13	2	b7	1
5dom7/b7th	2	b7 bass	1

5dom7alt/b7th	2	b7dom7sus	1
5dom9	2	b7m6	1
6m6	2	b7ma7	1
7dom7alt	2	b7sus	1
7m7	2	II line cliche	1
b2dom7alt	2	Mod 1m	1
b3	2	Mod 3	1
b3dom7sus	2	Mod 4madd9	1
b5dom7	2	Mod 6	1

Number of votes per chord

Song	Chord	Votes	Song	Chord	Votes
The way we were	b7sus	30	A sleepin bee	6dom7alt	2
Flamingo	1m6	23	Bewitched	6dom7alt	2
Ill be around	4m11 (So what)	19	Ill Wind	6dom7alt	2
This heart of mine	3dom13sus	19	This heart of mine	6dom7alt	2
Flamingo	b6dom7	19	A sleepin bee	6dom7sus	2
Pensativa	Mod 1	19	A nightingale sang	b2m7	2
Dear Lord	b6sus2	18	A nightingale sang	b5dom7	2
Out of nowhere	b6dom7	18	A sleepin bee	b6dom7	2
Dear Lord	4ma7#11	17	Ill Wind	b7dom7	2
Bye bye blues	3dom7	17	A sleepin bee	b7dom9	2
Girl Talk	Mod 1m	17	Our love is here to stay	1	2
Ill be around	b6m11 (So What)	15	Spring can really	1	2
Our love is here to stay	b7dom7	15	Flamingo	2	2
The song is you	Mod 1	14	There will never be another you	2	2
Ill Wind	7m7	14	They all laughed	2	2
Long ago and far away	6dom7alt	13	Blue Gardenia	3	2
Ill be around	b2m11 (So What)	13	Girl Talk	3	2
Dear Lord	3	13	They all laughed	3	2
The way we were	4	13	Flamingo	5	2
A sleepin bee	b3m7	13	There will never be another you	5	2
Pensativa	6m6	13	They all laughed	5	2
They all laughed	b6ma7	13	Till there was you	5	2
The song is you	1	12	Our love is here to stay	6	2
September in the rain	4m6	12	There will never be another you	7	2
Long ago and far away	Mod 1	12	Half Nelson	4m7	2
Bewitched	3m7b5	12	Blue Gardenia	5dom7alt	2
Old folks (Miles)	5dom7sus	12	Pensativa	5m7	2
Half Nelson	1	12	Our love is here to stay	5sus	2
Out of nowhere	1	12	That old feeling	6dom7	2
Look to the sky	b2ma7	12	Blue Gardenia	6dom7alt	2
Ill be around	5dom13	11	Pensativa	b2dom7	2
For all we know	6	11	Till there was you	b3	2
A sleepin bee	3dom7alt	11	Half Nelson	b7dom7	2
A nightingale sang	b7	11	It could happen to you	1	2
Youre my everything	2	11	Three flowers	1	2
Up with the lark	5	10	Three flowers	1	2
Wave	3dom13sus	10	Three flowers	1	2
Ill be around	5dom7alt	10	Three flowers	1	2
September in the rain	5dom7alt	10	Three flowers	1	2
I concentrate on you	b6m6	10	It could happen to you	2	2
Bewitched	4ma13	10	It could happen to you	2	2
This heart of mine	b6ma9	10	Youre my everything	2	2
Pensativa	Mod 2	10	Youre my everything	2	2
Youre my everything	b6dom13	10	Youre my everything	2	2
Look to the sky	b7dom7	10	Youre my everything	5	2
Lover	6dom7alt	10	Youre my everything	6	2
I concentrate on you	6m7b5	9	Youre my everything	7	2
Ill be around	b2ma7	9	It could happen to you	#2dim7	2
The way we were	6	9	Youre my everything	1dom7alt	2
A nightingale sang	4miMa9	9	Youre my everything	3dom7alt	2
A nightingale sang	b7dom7	9	It could happen to you	3m7b5	2
There will never be another you	4	9	Out of nowhere	3m7b5	2

Till there was you	b6	9		Youre my everything	4dom7alt	2
Pensativa	b6ma9	9		Out of nowhere	b3dim7	2
Look to the sky	3	9		Youre my everything	b3dom7alt	2
Lover	Mod 1	8		Lover	Mod 1	1
Wave	1m	8		Up with the lark	2m11	1
Long ago and far away	5dom7alt	8		Lover	6dom7alt	1
I concentrate on you	b7m6	8		They all laughed	6dom7	1
Up with the lark	Mod 2m11	8		September in the rain	4dom7	1
Ill Wind	3dom7alt	8		Long ago and far away	1	1
Old folks (Miles)	3dom7alt	8		Long ago and far away	1	1
A sleepin bee	5dom7sus	8		Lover	1	1
A sleepin bee	5dom9	8		September in the rain	1	1
Old folks (Miles)	6dom7alt	8		September in the rain	1	1
Spring can really	2dom13sus	8		The song is you	1	1
Half Nelson	Mod 2	8		Up with the lark	1	1
Youre my everything	5	8		Up with the lark	1	1
Look to the sky	b3ma7	8		Long ago and far away	2	1
Three flowers	Mod 1	8		Long ago and far away	2	1
Old folks (Vi)	1	7		Wave	4	1
Up with the lark	6	7		Long ago and far away	5	1
The song is you	3 line cliché	7		Lover	5	1
Lover	3m9	7		The song is you	5	1
I concentrate on you	4dom7alt	7		The song is you	5	1
Lover	5dom7alt	7		The song is you	5	1
Up with the lark	b3dom7sus	7		Up with the lark	5	1
Ill be around	b6ma7	7		Ill be around	6	1
Up with the lark	Mod 2m11	7		Long ago and far away	6	1
A sleepin bee	2	7		Lover	6	1
Dear Lord	3	7		Long ago and far away	#1dim7	1
Old folks (Miles)	5	7		Lover	#4m7	1
A nightingale sang	1sus	7		The song is you	1/3rd	1
A sleepin bee	4ma6/9	7		September in the rain	2dom7	1
Till there was you	1	7		Old folks (Vi)	2m9	1
Girl Talk	4	7		Ill be around	3m11	1
That old feeling	4m7	7		September in the rain	3m13	1
Flamingo	6dom7alt	7		The song is you	3m7b5	1
Youre my everything	6	7		Ill be around	4ma9	1
Look to the sky	1m7	7		Ill be around	5dom13	1
Out of nowhere	4m6	7		Up with the lark	5m7	1
Up with the lark	5	6		Wave	5m7	1
The song is you	#4m7	6		Ill be around	6m11	1
The song is you	5dom7alt	6		A sleepin bee	1	1
Old folks (Vi)	6dom7alt	6		Ill Wind	1	1
Wave	b6dom7	6		Old folks (Miles)	2	1
This heart of mine	1	6		Old folks (Miles)	5	1
The way we were	2dom7	6		The way we were	5	1
A nightingale sang	2m9	6		This heart of mine	5	1
This heart of mine	3dom13sus	6		Ill Wind	6	1
Ill Wind	4dom7	6		Bewitched	#2dim7	1
Bewitched	4ma7b7	6		Bewitched	1/3rd	1
This heart of mine	b6ma7/5th	6		For all we know	1/5th	1
Bewitched	b7dom7alt	6		A sleepin bee	1ma6/9	1
Bye bye blues	1	6		A sleepin bee	1sus2	1
Girl Talk	2	6		This heart of mine	2dom13sus	1
They all laughed	5dom7alt	6		This heart of mine	3dom13sus	1
There will never be another you	5m7	6		A sleepin bee	3dom7alt	1
Half Nelson	7m7	6		A sleepin bee	4/5th	1
Till there was you	b2	6		A sleepin bee	4dom7	1
Blue Gardenia	b7ma7	6		A sleepin bee	5dom7/b7th	1
Spring can really	b7ma7#11	6		A sleepin bee	5dom7alt	1
It could happen to you	3m7b5	6		This heart of mine	5dom7sus	1
It could happen to you	6dom7	6		Old folks (Miles)	5m7	1
Three flowers	7dom7	6		A sleepin bee	6dom7alt	1
Three flowers	b7dom7	6		A sleepin bee	6dom7alt	1
Three flowers	Mod 1	6		Ill Wind	6dom7alt	1
Three flowers	Mod 2	6		Ill Wind	6dom7alt	1
The song is you	2	5		For all we know	6dom7sus	1
Ill be around	1add9	5		Old folks (Miles)	6m6	1
I concentrate on you	1m7	5		This heart of mine	b3dim7	1

Lover	2m11	5		This heart of mine	b3dim7	1
Up with the lark	5dom7alt	5		A sleepin bee	b5dom7alt	1
Lover	6dom7	5		Bewitched	b5dom7alt	1
Lover	b3m7	5		A sleepin bee	b7dom9	1
Dear Lord	1	5		Blue Gardenia	1	1
Dear Lord	2	5		Bye bye blues	1	1
For all we know	2	5		Bye bye blues	1	1
A nightingale sang	1/5th	5		Girl Talk	1	1
This heart of mine	1dim7	5		Half Nelson	1	1
This heart of mine	2m13	5		Our love is here to stay	1	1
A nightingale sang	3dom7alt	5		That old feeling	1	1
A sleepin bee	3dom7alt	5		There will never be another you	1	1
Ill Wind	3dom7alt	5		Till there was you	1	1
Old folks (Miles)	3m6	5		Till there was you	1	1
A nightingale sang	4/2nd	5		Bye bye blues	2	1
Dear Lord	4ma7#11	5		Bye bye blues	2	1
A nightingale sang	4ma9	5		Girl Talk	2	1
This heart of mine	5dom7sus	5		Half Nelson	2	1
Half Nelson	1	5		Spring can really	2	1
There will never be another you	1	5		Blue Gardenia	3	1
Blue Gardenia	#4m7	5		Girl Talk	3	1
That old feeling	5m7/4th	5		They all laughed	3	1
Spring can really	6dom7alt	5		Till there was you	3	1
Pensativa	b2ma7#11	5		Girl Talk	4	1
Girl Talk	b5dom7	5		Girl Talk	4	1
Pensativa	b6dom7	5		Girl Talk	5	1
Three flowers	#4m7	5		Spring can really	5	1
Look to the sky	1ma9	5		Pensativa	6	1
Look to the sky	4m7	5		That old feeling	6	1
It could happen to you	6dom7alt	5		There will never be another you	6	1
Out of nowhere	6dom7alt	5		They all laughed	6	1
Three flowers	b7dom7	5		Pensativa	1ma9	1
Three flowers	b7dom7	5		There will never be another you	2dom7	1
Three flowers	b7dom7	5		Our love is here to stay	2m9	1
Three flowers	Mod 1	5		There will never be another you	3dom7alt	1
Long ago and far away	1	4		That old feeling	3m7b5	1
Up with the lark	1	4		Bye bye blues	3m9	1
The song is you	2	4		Flamingo	4dom7	1
The song is you	3	4		Our love is here to stay	5dom7alt	1
Long ago and far away	#2dim7	4		Spring can really	5dom7alt	1
Wave	1dom7alt	4		They all laughed	6dom7	1
Ill be around	1ma9	4		Girl Talk	6dom7alt	1
Ill be around	2m11	4		Pensativa	6dom7alt	1
Old folks (Vi)	3m13b5	4		Spring can really	6dom7alt	1
Lover	4m7	4		Pensativa	b2dom7alt	1
Ill be around	4ma9	4		Half Nelson	b2ma7	1
Ill be around	5dom7alt	4		Bye bye blues	b3dim7	1
Ill be around	5m11 (So What)	4		Half Nelson	b6ma7	1
The song is you	7dom7alt	4		Half Nelson	Mod 6	1
Ill be around	b3m11 (So What)	4		Half Nelson	1	1
Lover	b7dom7	4		Look to the sky	1	1
Lover	Mod 1	4		Look to the sky	1	1
The way we were	4	4		Three flowers	1	1
For all we know	#4m7b5	4		Three flowers	1	1
A nightingale sang	1/5th	4		Three flowers	1	1
A nightingale sang	1/5th	4		Flamingo	2	1
A sleepin bee	1ma6/9	4		Out of nowhere	3	1
For all we know	2dom7	4		Youre my everything	5	1
Ill Wind	2dom7	4		It could happen to you	6	1
For all we know	5dom7alt	4		Youre my everything	3dom7alt	1
A sleepin bee	6dom7	4		Youre my everything	3m9	1
A nightingale sang	6dom7alt	4		It could happen to you	4dom7	1
A sleepin bee	b3dom9	4		Youre my everything	5m7	1
Old folks (Miles)	b7dom7sus	4		Youre my everything	5m7	1
A sleepin bee	II line	4		Youre my everything	6dom7alt	1
Spring can really	1	4		Youre my everything	6m9	1
Our love is here to stay	2	4		Youre my everything	b3dom7sus	1
Till there was you	2	4		Youre my everything	b6dom7	1
Pensativa	5	4		Three flowers	b7dom7	1

That old feeling	1dom7	4		Three flowers	b7dom7	1
They all laughed	2dom7	4		Three flowers	b7dom7	1
That old feeling	5dom7alt	4		Three flowers	b7dom7	1
Blue Gardenia	7dom7	4		Up with the lark	3m11	0
Bye bye blues	b3m9	4		A sleepin bee	6dom7sus	0
Bye bye blues	b6dom13	4		September in the rain	4dom7	0
Pensativa	Mod 3	4		Timberlake road	b7	0
Out of nowhere	1	4		They all laughed	6dom7	0
Out of nowhere	2	4		Up with the lark	2m11	0
Three flowers	5	4		Up with the lark	b6ma7	0
Three flowers	#4m7	4		Up with the lark	3dom7sus	0
Youre my everything	#4m7	4		Lover	1	0
Youre my everything	3dom7alt	4		The song is you	1	0
Look to the sky	4dom7	4		The song is you	1	0
Youre my everything	5dom7alt/b7th	4		Up with the lark	1	0
Out of nowhere	6dom7	4		Up with the lark	1	0
Three flowers	b7dom7	4		Long ago and far away	2	0
Lover	6dom7alt	3		Lover	2	0
The song is you	1	3		Old folks (Vi)	2	0
Up with the lark	1	3		The song is you	2	0
Lover	2	3		The song is you	2	0
Long ago and far away	3	3		The song is you	2	0
Lover	#4m7	3		Ill be around	3	0
Up with the lark	2m11	3		The song is you	4	0
Up with the lark	2m9	3		Long ago and far away	5	0
Wave	4m6	3		Long ago and far away	5	0
Long ago and far away	5dom7alt	3		Old folks (Vi)	5	0
Lover	5dom7alt	3		The song is you	5	0
September in the rain	5dom7alt	3		The song is you	5	0
Ill be around	5dom7sus	3		Up with the lark	5	0
Ill be around	5dom7sus	3		Wave	5	0
The song is you	6dom7alt	3		Ill be around	6	0
Wave	6dom7sus	3		Long ago and far away	6	0
Lover	7dom7	3		The song is you	6	0
Wave	b6dim7	3		Up with the lark	1/5th	0
The way we were	3	3		Up with the lark	1/5th	0
A sleepin bee	4	3		Ill be around	1add9	0
A nightingale sang	#5dim7	3		September in the rain	1ma9	0
A sleepin bee	1dom7	3		Ill be around	2m11	0
A sleepin bee	1sus2	3		Ill be around	2m11 (So What)	0
This heart of mine	2dom13sus	3		Ill be around	2m9	0
Bewitched	3dom7alt	3		Long ago and far away	2m9	0
Old folks (Miles)	4ma9	3		Old folks (Vi)	5dom7alt	0
A nightingale sang	5dom7alt	3		Long ago and far away	6/5th	0
A sleepin bee	5dom7alt	3		A sleepin bee	6dom7sus	0
Dear Lord	5dom7sus	3		Lover	7dom7alt	0
This heart of mine	6dom13sus	3		Ill be around	Mod 4madd9	0
For all we know	6dom7alt	3		A sleepin bee	1	0
Old folks (Miles)	6dom7alt	3		Bewitched	1	0
Bewitched	b3dim7	3		Ill Wind	1	0
A sleepin bee	b6dom7alt	3		It could happen to you	1	0
Pensativa	1	3		A sleepin bee	2	0
Pensativa	1	3		Bewitched	2	0
They all laughed	1	3		Bewitched	2	0
Blue Gardenia	2	3		A sleepin bee	3	0
That old feeling	2	3		A sleepin bee	4	0
They all laughed	2	3		A sleepin bee	5	0
Till there was you	2	3		For all we know	5	0
Bye bye blues	3	3		This heart of mine	5	0
Flamingo	3	3		This heart of mine	5	0
Till there was you	#1dim	3		A nightingale sang	6	0
There will never be another you	1dom7alt	3		A nightingale sang	6	0
Pensativa	1ma9	3		Old folks (Miles)	6	0
That old feeling	3dom7alt	3		A sleepin bee	1ma6/9	0
Till there was you	4m	3		A sleepin bee	1ma6/9	0
Bye bye blues	6dom7	3		This heart of mine	1ma9	0
Blue Gardenia	6dom7alt	3		A sleepin bee	2dom7	0
Pensativa	b2dom7alt	3		A sleepin bee	2dom7	0

Till there was you	b3	3		A sleepin bee	3dom7alt	0
Half Nelson	b3dom7	3		A sleepin bee	4/5th	0
Spring can really	b7ma7#11	3		A sleepin bee	4/5th	0
Three flowers	1	3		A sleepin bee	4dom7	0
It could happen to you	2	3		A sleepin bee	5dom7alt	0
It could happen to you	2	3		Ill Wind	5dom7alt	0
Look to the sky	2	3		Old folks (Miles)	5dom7alt/b7th	0
Out of nowhere	2	3		A sleepin bee	5dom7sus	0
Out of nowhere	3	3		Bewitched	5dom9	0
Youre my everything	3	3		A sleepin bee	b5dom7alt	0
Youre my everything	2dom7alt	3		A sleepin bee	b7dom7	0
Youre my everything	4dom7alt	3		A sleepin bee	b7dom7alt	0
Look to the sky	6dom7	3		Blue Gardenia	1	0
Three flowers	7dom7	3		Spring can really	1	0
Youre my everything	b5dom7alt	3		Blue Gardenia	2	0
Youre my everything	b7dom7alt	3		Flamingo	2	0
Three flowers	Mod 1	3		Girl Talk	2	0
I concentrate on you	1	2		Pensativa	2	0
Lover	1	2		They all laughed	2	0
The song is you	1	2		Half Nelson	3	0
Up with the lark	1	2		Blue Gardenia	5	0
Up with the lark	1	2		Bye bye blues	5	0
Wave	1	2		Bye bye blues	5	0
Wave	1	2		Girl Talk	5	0
Lover	2	2		Half Nelson	5	0
September in the rain	2	2		Our love is here to stay	5	0
Ill be around	3	2		Our love is here to stay	5	0
Ill be around	5	2		They all laughed	5	0
The song is you	5	2		They all laughed	5	0
Up with the lark	5	2		There will never be another you	6	0
Long ago and far away	6	2		That old feeling	7	0
Long ago and far away	2dom7	2		Spring can really	1/3rd	0
Up with the lark	2dom7	2		Pensativa	1dom7	0
Wave	2dom7	2		Pensativa	1ma9	0
Up with the lark	2dom7sus	2		Half Nelson	2dom7	0
September in the rain	4dom7	2		They all laughed	3dom7alt	0
Up with the lark	5add9	2		Blue Gardenia	5dom7alt	0
Old folks (Vi)	5dom7/b7th	2		Flamingo	5dom7alt	0
September in the rain	6dom7alt	2		Flamingo	1	0
September in the rain	6dom7alt	2		It could happen to you	1	0
I concentrate on you	7dim7	2		Out of nowhere	1	0
Lover	b6dom7	2		Three flowers	1	0
The song is you	Mod 2	2		Out of nowhere	2	0
Dear Lord	1	2		Youre my everything	2	0
For all we know	1	2		Youre my everything	3	0
This heart of mine	2	2		Look to the sky	4	0
This heart of mine	2	2		It could happen to you	5	0
This heart of mine	2	2		Out of nowhere	5	0
A nightingale sang	3	2		Flamingo	6	0
The way we were	3	2		Youre my everything	6	0
This heart of mine	3	2		Youre my everything	7	0
Dear Lord	4	2		It could happen to you	#1dim7	0
The way we were	6	2		It could happen to you	3m7b5	0
Bewitched	#1dim	2		Youre my everything	4add9	0
Bewitched	1/3rd	2		It could happen to you	5dom7alt	0
Ill Wind	1dom7	2		Youre my everything	b3m7	0
Old folks (Miles)	1dom7alt	2		Youre my everything	b5dom7alt	0
A sleepin bee	2dom7	2		Youre my everything	b6m7	0
A sleepin bee	2m9	2		It could happen to you	b7 bass	0
A sleepin bee	3dom7alt	2		Three flowers	b7dom7	0
A sleepin bee	4dom7	2		Three flowers	b7dom7	0
A sleepin bee	4dom7	2		Three flowers	b7dom7	0
A nightingale sang	4miMa9	2		Three flowers	b7dom7	0
A sleepin bee	5dom7alt	2				

Appendix H. Ethical Approval Documentation

Ollscoil Chathair Bhaile Átha Cliath
Dublin City University

DCU

Ms. Linda Adams
School of Theology, Philosophy, and Music

Dr. Patricia Flynn
School of Theology, Philosophy, and Music

25th November 2020

REC Reference:	**DCUREC/2020/228**
Proposal Title:	**An Investigation of Harmonic Expectation in Trained and Untrained Listeners**
Applicant(s):	**Ms. Linda Adams & Dr. Patricia Flynn**

Dear Colleagues,

This research proposal qualifies under our Notification Procedure, as a low risk social research project. Therefore, the DCU Research Ethics Committee approves this project.

Materials used to recruit participants should state that ethical approval for this project has been obtained from the Dublin City University Research Ethics Committee.

Should substantial modifications to the research protocol be required at a later stage, a further amendment submission should be made to the REC.

Yours sincerely,

Geraldine Scanlon

Dr Geraldine Scanlon
Chairperson
DCU Research Ethics Committee

DCU
Research & Innovation

Taighde & Nuálaíocht Tacaíocht
Ollscoil Chathair Bhaile Átha Cliath,
Baile Átha Cliath, Éire

Research & Innovation Support
Dublin City University,
Dublin 9, Ireland

T +353 1 700 8000
F +353 1 700 8002
E research@dcu.ie
www.dcu.ie

Research Ethics Committee
Technological University Dublin,
Grangegorman, Dublin 7

18/07/2024

Dear Linda

In relation to your project entitled '*Investigating listeners' expectation levels for diatonic and non-diatonic harmonic cadences*', our reference REC-18-131, which would have been submitted to the REC of the Dublin Institute of Technology, I can confirm approval of this study.

I hope that this suffices for your requirements in DCU.

Yours sincerely,

Steve Meaney, PhD
Chair - Research Ethics Committee, Technological University Dublin

Seoladh Cláraithe / Registered Address
OT Baile Átha Cliath - Teach na Páirce Ghráinseach Ghormáin
191 An Cuarbhóthar Thuaidh, D07 EWV4, Éire
TU Dublin - Park House Grangegorman
191 North Circular Road, D07 EWV4, Ireland

OT Baile Átha Cliath
Teach na Páirce Ghráinseach Ghormáin
191 An Cuarbhóthar Thuaidh
D07 EWV4, Éire

TU Dublin
Park House Grangegorman
191 North Circular Road
D07 EWV4, Ireland

+353 1 402 3000
tudublin.ie

Faculty of Humanities & Social Sciences
DUBLIN CITY UNIVERSITY

16 June 2022

CONFIRMATION OF RESEARCH ETHICS APPROVAL FOR A PROJECT

Application Reference:	**DCU-FHSS-2022-035**
Project Title:	**Ecological Validity in the Study of Harmonic Expectation**
Project contact(s):	linda.adams4@mail.dcu.ie

Let this letter certify that the proposed project identified above has been reviewed by the *Humanities & Social Sciences Faculty Research Ethics Committee* (F-REC) and has been approved as a low-risk project. The application was found to comply with university requirements and best practices for research ethics, and with GDPR guidelines and requirements where personal data is processed in the project.

A copy of the application, including appended documents related to participant consent, is archived under the reference above. Queries about this project's approval may be directed to the F-REC Chair.

Sincerely,

Dr Dónal Mulligan
donal.mulligan@dcu.ie

Chair, Faculty Research Ethics Committee
Faculty of Humanities & Social Sciences
Dublin City University

Dámh na nDaonnachtaí agus na nEolaíochtaí Sóisialta
Ollscoil Chathair Bhaile Átha Cliath

Faculty of Humanities & Social Sciences
DUBLIN CITY UNIVERSITY

13 February 2023

CONFIRMATION OF RESEARCH ETHICS APPROVAL FOR A PROJECT

Application Reference:	**DCU-FHSS-2022-035**
Project Title:	**Ecological Validity in the Study of Harmonic Expectation**
Project contact(s):	linda.adams4@mail.dcu.ie

This project was originally approved on 16 June 2022, and was re-approved based on notification and review of amendments to the research on 13 February 2023.

Let this letter certify that the proposed project identified above has been reviewed by the *Humanities & Social Sciences Faculty Research Ethics Committee* (F-REC) and has been approved as a low-risk project. The application was found to comply with university requirements and best practices for research ethics, and with GDPR guidelines and requirements where personal data is processed in the project.

A copy of the application, including appended documents related to participant consent, is archived under the reference above. Queries about this project's approval may be directed to the F-REC Chair.

Sincerely,

Dr Dónal Mulligan
donal.mulligan@dcu.ie

Chair, Faculty Research Ethics Committee
Faculty of Humanities & Social Sciences
Dublin City University

Dámh na nDaonnachtaí agus na nEolaíochtaí Sóisialta
Ollscoil Chathair Bhaile Átha Cliath