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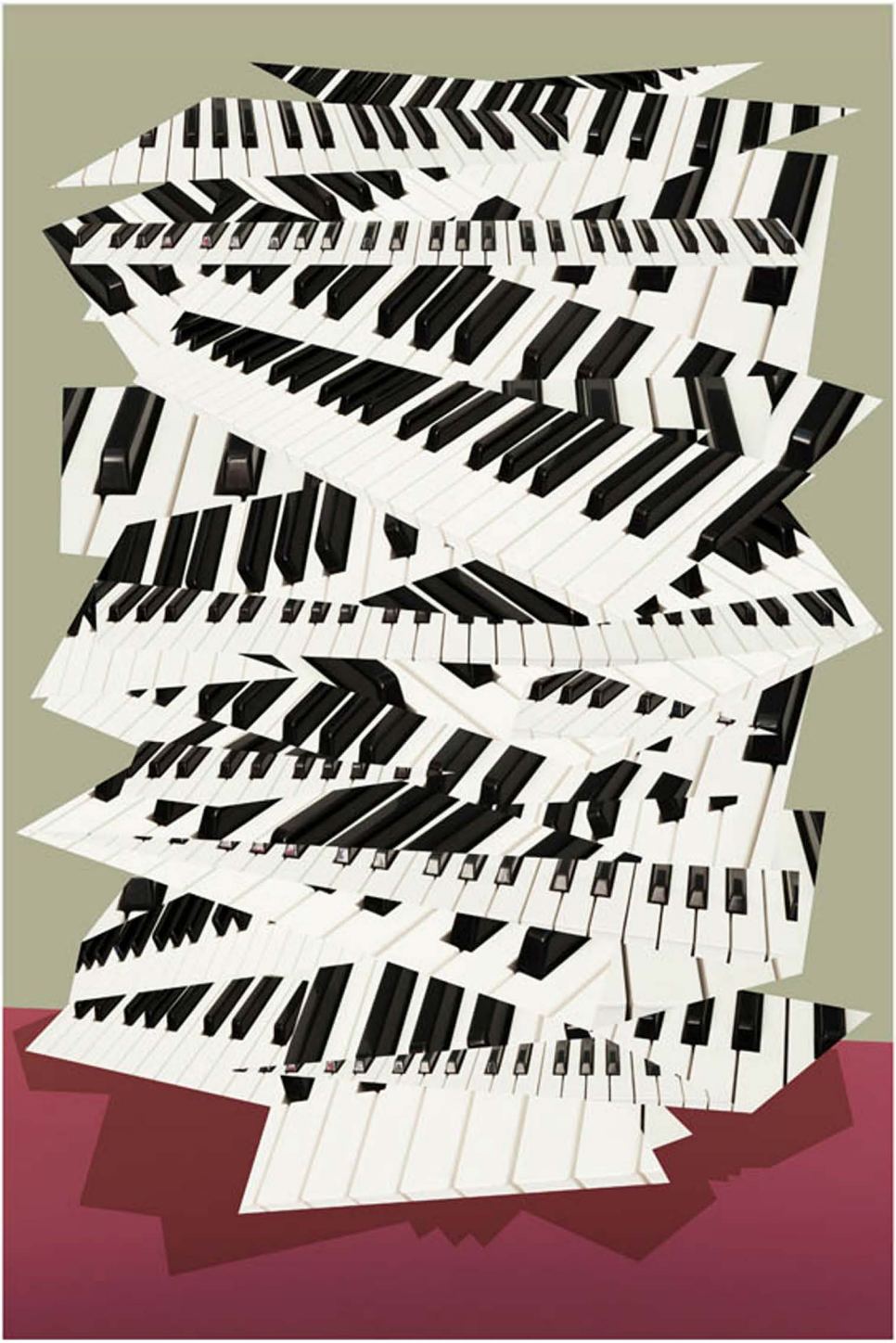

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Contents

Terms and Abbreviations

aug; +	augmented; augmented triad (in semitones: [048])
C/D	consonance and dissonance
EDO	equal divisions of the octave
dim; o	diminished; diminished triad [036]
dim7; o7	diminished-7th chord [0369]
dominant	$\hat{5}$, V, v
f0	fundamental frequency ("F-zero")
half-dim7; m7♭5; ø7; ø	half-diminished-7th chord [036T]
JND	just-noticeable difference
[L]	eLeven (11) semitones; major-7th interval
M; maj	major
m; min; -	minor; minor triad [037]
M7; maj7; Δ**7;** Δ	major-7th chord [047L]
m7; min7; -7	minor-7th chord [037T]
Mm7; 7	major-minor 7th chord [047T]
MmT	major-minor tonality
mediant	$\hat{3}$, III, iii
predominant	chord that leads to the dominant (subdominant)
subdominant	$\hat{4}$, IV, iv
submediant	$\hat{6}$, VI, vi
subtonic	♭$\hat{7}$, ♭VII, ♭vii
supertonic	$\hat{2}$, II, ii
sus; sus4	suspended; suspended triad [057]
[T]	Ten (10) semitones; minor-7th interval
tonic	$\hat{1}$, I, i

Preface

Like many of my research colleagues in the areas of music cognition and music theory, I have always been fascinated by the structure and emotional power of major-minor tonality (MmT). While this book is not directly about musical emotion, it is certainly motivated by it—as is probably all research on musical structure.

There can be little doubt about the emotional power of tonal music, including simple diatonic chord progressions. Where to begin? There are countless examples. Take the Latvian Song Festival in July 2018 in Riga, which celebrated Latvia's centenary. More than 1,600 choirs, dance ensembles, and music groups took part. As in most music festivals the world over, even today, most of the music was based on simple diatonic chord progressions. The climax of the festival was a performance by all participating choirs—about 11,000 singers—of *Pūt, vējiņi* (Blow, winds), an ancient wedding song that has become a symbol of Latvian national identity. Why do people love this music so much? The lyrics are rather weird, at least for outsiders. The simple tonal structure seems to play an important role, alongside the complex cultural context. Why is music of that kind so powerful?

This book is also motivated by a long-standing lack of academic consensus about seemingly trivial issues. Where do different diatonic scales and modes come from? Why are some chords and chord progressions more common than others? How and why do we perceive most music relative to tonal centers, and what are the defining features of a tonal center? How do these music-structural features contribute to music's emotionality?

Hovering above such questions are issues of nature versus culture. Are the listed aspects of MmT arbitrary? If not, to what extent? In what way might they depend on human biological or psychological universals or general

perceptual principles? Moving to another level, we may ask: Is it politically incorrect to ask these questions? What about the colonial history of MmT?

Those are rather general questions, and there are also more specific ones. Why do most chords in MmT have three or four pitch classes and not some other number? Why are there two main types of trichord (major triad followed by minor triad), and why are major-minor 7th (Mm7) chords so common, despite the dissonant tritone interval between the major 3rd and the minor 7th above the root? Why are chords more often played in root position than in inversion? Why do most scales have seven pitch classes? Why are there two main types of scale in Western music, the other "modes" being less common? Why is the exact tuning of the piano so important to us in practice, although we understand it to be theoretically out of tune, and why do we tolerate much bigger intonational deviations in choral performance? Why are chord progressions with rising 4ths and falling 3rds between successive roots more common than progressions in the opposite direction? Why do rising leading tones tonicize better than falling ones?

In an attempt to answer questions of this kind, this book presents an evidence-based theory of MmT. The theory is founded on empirical psychological research and statistical corpus analyses while also drawing inspiration from the history of music theory and the author's musical practice and intuition. A novel combination of intellectual inputs—mainly from psychology, music theory, and psychoacoustics, but also from music information sciences, music history, and ethnomusicology—gives the theory of MmT a new foundation.

The book belongs to the academic discipline known as systematic musicology. The word "systematic" implies a combination of empirical observation, clear argumentation, and interdisciplinarity. As an academic label, systematic musicology dates to the late nineteenth century in Germany and Austria, although the discipline itself, one might argue, has ancient roots. Guido Adler (1885) divided musicology into two parts: historic and systematic. Under the heading of systematic musicology, he included music theory, music aesthetics, music education, and comparative musicology (non-Western music). He also listed parent disciplines: acoustics, mathematics, physiology, psychology, (philosophy of) logic, linguistics, education, and aesthetics. During the twentieth century, three of Adler's subdisciplines of systematic musicology became independent (music theory, music education, and comparative

musicology, the latter transformed into ethnomusicology); they are no longer regarded as subdisciplines of systematic musicology.

Today's systematic musicologists tend to identify with (music) acoustics, neuroscience, psychology, sociology, computer science, and/or philosophy; with the exception of sociology, all these disciplines are relevant for the present book. In international English-speaking research, the term "music cognition" now seems equivalent to systematic musicology. Whichever term is used, the discipline is defined in practice by its leading peer-reviewed academic journals: *Music Perception*, *Psychology of Music*, *Musicae Scientiae*, *Music & Science*, *Jahrbuch Musikpsychologie* and *Journal of New Music Research*. The discipline is also defined by pan-national societies such as the European Society for the Cognitive Sciences of Music and the (North American) Society for Music Perception and Cognition.

My attempts to understand musical structure began in childhood. I diligently learned the piano while also singing in various choirs, including the chapel choir of Melbourne Grammar School. That school and I did not agree on everything, but singing in their chapel choir did teach me the foundations of MmT, for which I am grateful and without which my research in the area is unlikely to have happened. My musical explorations continued in the late 1970s as a student of music (piano) and science (physics) at the University of Melbourne and in the early 1980s as a doctoral candidate at the University of New England (Armidale, New South Wales). For decades, I performed regularly as a solo pianist, piano accompanist, or pop pianist, and sang in choirs. Today, I am writing and performing a cappella arrangements.

Some of my music-theoretical explorations led to dead ends. As a student, my background in physics inspired me to experiment with mathematical modeling in the style of pseudo-physical quasi-universal music theory, which for millennia has been an armchair pastime of the musically curious. But I came to understand a serious problem with that approach. There is something especially human about music that the quasi-universal discipline of physics cannot capture. That may seem obvious, but it is not so easy to incorporate that insight into a comprehensive theory of tonal music.

Around 1980, I remember attending a lecture-recital by Melbourne pianist Ronald Farren-Price in which he asked an interesting question. What should we put inside a time capsule as a relic of human civilization to allow future intelligent visitors from another galaxy to get some idea of who we were?

His answer: the notated scores of the thirty-two piano sonatas of Ludwig van Beethoven. The idea sounded convincing at the time, and the audience nodded in agreement. I only later realized how wrong it was. I love the music of Beethoven—no doubt about that. But it is a product of a specific cultural context whose track record has had its ups and downs to say the least. We can hardly sweep the biggest European white-male errors under the carpet. Those errors include the crusades, the Napoleonic wars, the slave trade, the scramble for Africa, two world wars, and the global climate and biodiversity crisis. Whereas Beethoven himself is surely innocent, at the same time, the idea that one white man's music is humanity's greatest achievement is surely sexist and racist, and it continues the familiar narrative according to which Western "man" is the pinnacle of creation or evolution and "his" culture is the pinnacle of culture (Ewell 2020).

While the focus of this book—like that of related books such as David Huron (2001, 2016), Carol Krumhansl (1990), and Fred Lerdahl and Ray Jackendoff (1983)—is on Western classical music, aspects of the theory may also shed light on the structure of diverse Westernized non-Western and/or nonclassical Western musics, especially if they use a twelve-tone chromatic scale. But the theory cannot claim to be cross-culturally valid, and when making intercultural comparisons, we need to avoid the implicit arrogance of some Western music-theoretical traditions. The focus on MmT in this and comparable books is not intended as a value judgment, nor is it intended to either include or exclude relevant non-European or non-Western styles. Intercultural issues are addressed in chapter 23.

If one day some intelligent aliens visit our planet, they will presumably have no idea what Beethoven's piano sonatas were for or what they were about. Music is inseparably linked to human biology and society and to the human environment. While Beethoven's most famous music may today be recognizable for people all over the planet, regardless of cultural background, that same music would surely mean nothing to visitors from another galaxy, even if they somehow managed to decode the relationship between notation and sound (something that most humans cannot do).

For those aliens would have no access to human subjectivity. They would have little idea how humans experience the world, let alone music. A color-blind philosopher could understand "red" better than those aliens could understand "music." We humans hardly understand our own subjectivity: the mind-body problem is not solved and may never be solved, although

we have been wondering about it for millennia and although lately there have been big developments in neuroscience and philosophy (see chapter 4). Given our persistent failure to answer our biggest questions, those hypothetical aliens would have even less idea of what our music is about than we do. Nicholas Cook (1990) made a similar point, imagining "Martian musicologists of ten thousand years hence . . . attempting to reconstruct an authentic performance of Chopin's E minor Prelude" (122).

That being the case, it should be clear that physics alone can never fully explain the structure of any music, regardless of its cultural origin. Psychology and psychoacoustics are also necessary, but they too are insufficient; the culture specificity of Western music must be central to any explanation. In late-nineteenth-century colonialist Europe, German musicologist Hugo Riemann, in his *Natur der Harmonik* (1882), may not have fully grasped the cultural aspect of the problem, but he did understand its inherent interdisciplinary:

> Scientific investigation in the domain of music concerns itself, primarily, with ascertaining the laws which govern *sounding bodies*, and is thus a department of *physics*; i.e., the science of acoustics. Then pursuing tones still further, and inquiring into the effects they produce on the human ear, and the mode in which those effects are produced, it becomes a special department of *physiology*. Finally, concerning itself with tone-perceptions, with the *mental effects* of these acoustic and physiological phenomena, and with the mental connections and relations of the sensations produced by sound, it enters the domain of *psychology*. Out of the results of scientific investigation in all three fields of physics, physiology and psychology, we get the elements of an exact theory of the nature of harmony. (As cited in Mickelsen 1977, 45; italics in original)

Formulations of that kind are too positivist for modern tastes (especially the use of the word "exact" in the last line), and tacitly assume that Western society and culture are inherently superior. The following quote from US composer Norman Cazden (1954) comes closer to the truth on both accounts: "Few manuals of recent times enter into fundamental questions of music theory, and often one must deduce the implied axioms. Of theories deserving the name, we may distinguish three main types: those claiming to be founded on the laws of Nature, those claiming the priority of the arbitrary instinct of the composer, and those which rely on the observed practice of the art of music. We may term these the natural, the subjective and the empirical theories, and suggest that none of them fully satisfy our requirements" (288).

But again, this description is incomplete. First, there is still a Western cultural bias in Cazden's thinking. Second, he failed to notice a fourth type of

music theory—one based on psychological listening experiments—that can be combined with the other three (physics, composition, and performance).

The omission was hardly surprising. In 1954, the academic discipline of music psychology barely existed, the German tradition having suffered terribly in the war. Things got started again in the 1960s with the international cognitive turn in psychology and linguistics (Pléh 2019). In 1973, the British journal *Psychology of Music* was founded. Between 1973 and 1985, Juan Roederer, an Italian-Austrian-Argentinian physicist at the University of Alaska Fairbanks, organized a series of international workshops on the "Physical and Neuropsychological Foundations of Music" at the Carinthian Music Festivals in Ossiach, Austria. Several key authors cited in this book took part in those workshops, including Jamshed Bharucha, Albert Bregman, David Butler, Robert Crowder, Lola Cuddy, Irène Deliège, Diana Deutsch, Adrian Houtsma, Carol Krumhansl, Fred Lerdahl, Stephen McAdams, Rudolf Rasch, Johan Sundberg, Ernst Terhardt, Joos Vos, and Dixon Ward. I had the good fortune to present my research at two of those meetings (1983 and 1985). In 1983, the *Deutsche Gesellschaft für Musikpsychologie* was founded by Klaus-Ernst Behne, Günter Kleinen, and Helga de la Motte-Haber; in the same year, Diana Deutsch founded the journal *Music Perception* in the USA (Spiller 1995). The first International Conference on Music Perception and Cognition was held in Japan in 1989. These developments were made possible by growth in the discipline of (cognitive) psychology in the late twentieth century, enabling research in music psychology to expand internationally, especially in North America.

As a result of these developments, we now understand more about MmT (music based on major and minor triads and scales) than we ever did before. But the same can be said of many other topics, and not enough has been done to bring together and unify the leading approaches to MmT in humanities and sciences, which is an aim of this book.

The second half of the twentieth century saw interesting new approaches. The best-known development in North American music theory was the organic, reductive approach to music analysis of Austrian music theorist Heinrich Schenker, made popular by US music theorists, including Allen Forte (Forte and Gilbert 1982). It plays an important role in this book, as does Forte's version of pitch-class set theory (Forte 1973), although it was originally intended for the analysis of post-tonal music. Parallel international developments in music psychology included Ernst Terhardt's (1974a) psychoacoustic

theory of pitch perception and Carol Krumhansl's (1990) cognitive-structural approach to MmT. At first glance, these theories may seem incompatible; one of the goals of this book is to contradict that first impression.

When I started to think about the possible acoustical and psychological origins of MmT in the early 1980s, I was unaware of the richness of the epistemological environment that I was naively entering. For me at the time, there were merely interesting questions and answers, which I was seeing more or less in isolation. I only gradually discovered how much each cited author and paper had been influenced by academic traditions in different geographical locations and historical periods.

Terhardt's theory of pitch perception, which I learned about during a visit to the Technical University of Munich as a guest researcher and doctoral student in 1982–1983, overlaps in many ways with that of Brian Moore (1989). In their self-perception, however, these two scientists belonged to entirely different schools—one German, the other British; one engineering and cybernetic, the other psychological with a neurocognitive focus. Both nevertheless relied on empirical methods and modeling, and both developed models in which pitch depends on a combination of place of excitation the basilar membrane, timing information in the auditory signal, and the recognition of familiar patterns. Their approaches differed in many details, but those differences are not so important for the musical questions addressed in this book. For the purpose of building a music theory based on the psychoacoustics of pitch perception, one could equally refer to one or the other. I will focus on Terhardt's approach for the following reasons:

- Its general algorithmic formulation makes it convenient to apply to both everyday sound (including speech and music) and music-theoretical questions.
- The theory assumes an important role for the spontaneous learning of pitch patterns, consistent with both neuroscience (Hebbian learning in neural networks) and musicology (in particular, ethnomusicology).
- The theory clarifies the distinction between spectral and virtual pitch, which has interesting implications for both psychoacoustics and music theory.

This book focuses on simultaneous relationships among musical pitches, also called vertical aspects of musical scores. The vertical can hardly be separated from interacting horizontal aspects, and hence from counterpoint and

voice leading, and underlying psychoacoustical and psychological principles. The leading source on the latter is Huron (2001, 2016), whose contribution relies on original computer-based analyses of databases of musical scores. Huron and I met after he reviewed Parncutt (1989)—a revision of my doctoral dissertation at the University of New England (Armidale, NSW, Australia) that presented a musically oriented interpretation of Terhardt's pitch theory. We collaborated during the 1990s, interpreting Terhardt's contribution in the context of North American music psychology and music theory.

This book is intended for researchers and graduate students in two main areas: music cognition and music theory. It may be too advanced for undergraduate or high school teaching, but I hope that some undergraduate teachers will become acquainted with its main ideas and adapt their teaching accordingly. Some readers (mainly in the humanities) will be disappointed by the paucity of musical examples, while others (mainly in the sciences) will have expected more empirical data. But the book is not intended as an introduction to relevant tonal repertoires or empirical methods. I am assuming that my readers are already acquainted with diverse tonal styles, on the one hand, and the foundations of psychological methodology, on the other. In particular, I am assuming that my readers can hear the pitch patterns that are discussed in the text—in the music that they listen to, perform, arrange, or compose themselves. Those who cannot do that will have difficulty evaluating the book's approach and claims.

The book may be received differently in North America and Europe due to persistent differences in the epistemology and pedagogy of music theory that emerged across the Atlantic in the late twentieth century. Post-secondary music students in North America may be better acquainted than their European colleagues with the details of theory that I am taking for granted in this book: Rameau, Riemann, Schenker, and Forte. They may also have better-trained ears and have received more detailed practical training in, for example, counterpoint in the style of Palestrina or harmonization in the style of J. S. Bach. Their Western European colleagues may be accustomed to a freer style of teaching and learning and may be more scholarly than their North American colleagues: better at constructing an original coherent argument and independently finding and evaluating literature.

These are clichés, of course, and the exceptions may be more common than I realize. The book may nevertheless be better received in North America if advanced music students there better understand its music-theoretical

foundations: harmonic functions, Schenkerian analysis, and pitch-class set theory. But when it comes to critically evaluating the ideas that I am presenting and weighing different arguments up against each other, European students and colleagues may have the edge.

My main target readers will read a page or chapter here and there, depending on their interest or curiosity. Not many will read the book from start to finish, although that is also a possible strategy. With that in mind, I have aimed for a clear hierarchical structure on the contents page and consistent assignment of material within that structure. Given the complex web of connections within the material (that never stopped growing as I wrote), similar topics are sometimes addressed in different places. In those cases, the index will come in handy.

I should mention in closing that this book was written under a threatening cloud. The global climate and biodiversity crisis is steadily intensifying, along with a complex series of other, related global crises. This process is life-threatening for billions of people, and it also threatens to undermine academic research in all disciplines. This is not the place for a detailed explanation, but perhaps I should say this: Most readers of this book will have a high income and a high educational level relative to the average person in the world today—as I do. Many of us don't seem to have noticed how privileged we are, nor has it clicked with us that with privilege comes responsibility. If we care about young people and the future of humanity, it is up to us to send governments and corporations the right messages with the right level of urgency. It is also up to us to reduce our environmental footprints unilaterally, both individually and collectively. If we can't do that, one might reasonably ask why anyone else should; and if others don't do that, there is little point in writing books of this kind. I write these words knowing that most colleagues will ignore them, pretending not to understand. Thankfully, others will not, and some of us might have enough influence to make the necessary changes and avoid the worst.

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The book's content also depends on countless interactions with other academic colleagues over many years. I could hardly do justice to all of them, so allow me to present an alphabetical list that is bound to be incomplete:

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I Interdisciplinary Introduction

1 Definitions

To avoid misunderstandings in an interdisciplinary approach, it helps to define some central terms, or at least to clarify their intended meanings. The definitions and explanations that I will propose are generally tentative and depend on cultural and historic context, which includes musical diversity (both globally and within Western or Westernized culture) and contrasting approaches in humanities and sciences. Music *is notoriously difficult to define because its origins and ultimate functions are shrouded in mystery.* Musicology *can be defined as the study of music,* psychology *as the study of human behavior and experience, and* music theory *as the study of musical structure.* Tonality *is about hearing music relative to a given reference pitch or pitch pattern (the "tonic"), and major-minor tonality* (MmT) *is tonality based on major and minor chords and scales. Musical* prolongation *happens when a musical sound or pattern is extended in time (e.g., by elaboration or decoration) such that a passage of music is heard relative to that original sound or pattern; prolongation may be the ultimate foundation of tonality, including MmT.* Salience *is the degree to which a musical event in the musical surface grabs our attention, whereas* stability *is how well the event is anchored in the musical structure.* Consonance *is how well (simultaneous or successive) tones are perceived to go together; dissonance is the opposite.* Psychohistory *is any combination of psychology and history, including the history of perception, the effect of psychological processes on history, and the effect of historical processes on psychology.*

Music

The average person devotes enormous amounts of time, energy, and money to music. Nonmusicians choose the music that they listen to, contribute actively as audience members, and discuss (often passionately) the music and the musicians. Musicians spend hours per day practicing, composing,

performing, and recording. Music contributes to the construction of psychosocial (cultural, political) identities, particularly during adolescence. It provides stimulation, entertainment, and solace from infancy to old age.

The importance of music for most people justifies continuing research to try to understand how it works. After centuries of speculation, we still have remarkably little idea where music comes from or why all known human societies devote so much time and energy to it—at least not within today's dominant Darwinist evolutionary paradigm. The large and thriving literature on the origin of music (e.g., Honing 2018) can better explain *how* music works than *why* it is like it is (or how it originated). The task of explaining music's origin, function, emotion, and structure—while at the same time considering its cultural diversity—is further complicated by epistemological differences between researchers in humanities and sciences, as well as within humanities (e.g., ethnomusicology versus historical musicology) and within sciences (e.g., psychology versus physics). The continuing lack of agreement about musical origins means that the discipline of musicology lacks a stable foundation.

Because there is no clear objective criterion for the difference between music and nonmusic, definitions of music are often circular: we tend to define music in terms of music. We could for example say that music is a pattern of sound and movement that is perceived as music, as opposed to patterns of sound and music that are perceived as language or something else. Definitional circularity may be appropriate given that people in every musical culture have a good intuitive idea of what kinds of sound are perceived as music—at least for them. But circularity may prevent us from understanding music's origin and ultimate function.

In Western culture, music usually comprises artistic sound patterns that are based on relatively consonant chord progressions, played from tones taken from an almost equally spaced twelve-tone chromatic scale and dominated by tones from a diatonic scale (a subset of the chromatic). Whether that is a good or a bad thing is not the point: this book is inspired by the discipline of music cognition, in which the so-called average person is often the focus of attention. The focus is not usually on musical elites who perform and appreciate diverse post-tonal styles—although their experience is certainly relevant and sometimes crucial for understanding what MmT is and how it works.

The focus of this book is on music that is based on, or can somehow be reduced to, chord progressions (or harmonic progressions)—in particular, sequences of diatonic major and minor triads. In the key of C major or

A (natural) minor, diatonic triads are the chords C major, D minor, E minor, F major, G major, A minor, and B diminished. I will assume that Western listeners usually perceive progressions of such chords, or chords based on them, to be consonant—even if they are unsure what consonance means and may never use that word themselves. For the average person, the music may simply sound good (or like music), with the musical tones and chords going together in a musical way.

In classical harmony theory, a chord progression can be defined by three things: the root of each chord (the pitch, often ambiguous, relative to which the chord is often perceived and notated), the type of each chord (the intervals relative to the root, e.g., minor triad, diminished 7th; see chapter 3), and the inversion of each chord (which chord tone is in the bass). The voicing (which chord tones are in which voice, including the spacing and doubling of the voices) and the voice leading from one chord to the next are also important but are not necessarily implied when we say "chord progression," and they are not the focus of this book. If MmT can be reduced to harmonic progressions, as defined, we may ask a simple question: Why are some progressions more common than others? Much of the material in this book is intended as a foundation for answering this deceptively simple question.

In a global perspective, "music" is much more than MmT. In fact, one can argue that there is nothing particularly special about MmT. For many decades, the academic discipline of ethnomusicology (or comparative musicology) has been documenting the diversity of the world's musics. That diversity is one reason why scholars and scientists with different backgrounds have different ideas about the nature and origins of music; another reason involves underlying philosophical assumptions (see chapter 4). Given the importance of music for almost all humans, the apparent regularity (but also diversity) of its structure, the range of available explanations its function and existence, and the long history of trying to answer such fundamental musical questions, it is hardly an exaggeration to say that understanding music is one of humanity's great intellectual challenges.

Academic Disciplines

This book derives its material from a series of academic disciplines, including musicology, psychology, and music theory. What characterizes those disciplines, and how do they differ?

Musicology, understood to include ethnomusicology, addresses all phenomena called "music" (from either a cultural-insider "emic" or outsider "etic" perspective) in all its cultural and historical contexts. It includes all academic disciplines that successfully investigate musical phenomena and answer interesting musical questions ("all types of scholarship in music are, and properly ought to be, part of musicology"; Nettl 1999, 289). Some musicologists limit this broad vision in arbitrary ways or promote hierarchical structures in which some subdisciplines are central and others are auxiliary. Don Randel (1986) noted that "The great majority of scholars who describe themselves as musicologists (as distinct from ethnomusicologists) are students of Western art music" (520), implying a hierarchical structure within musicology in which Western art music is at the top and other forms of musicology (including systematic musicology, the psychology of music, the study of popular music and jazz, and so on) are subsidiary. But when one considers the entirety of published academic research on music and its interdisciplinary readership, musicology seems more like a collection of equally important and partly interacting subdisciplines (Parncutt 2007).

Psychology is the study of human behavior and experience. Perception (seen as an aspect of psychology) is a process of picking up information about the environment—usually while interacting with it—and taking advantage of previously acquired perceptual knowledge (perceptual memory). Cognitive psychology, in that view, is about how humans behave and what they experience when picking up and processing information from the environment. In the case of music, cognitive psychology involves behavioral and experiential aspects of complex interactions among musicians, listeners, social environments, and physical environments. What we know about the psychology of music is based mainly on experiments in which variables are independently varied and quantitative data collected. On that basis, possible causalities are investigated. Experiments often focus on specific responses to specific stimuli or situations. That approach differs markedly from the more qualitative and all-encompassing approach of musicology in the humanities.

Just as cognition is an important aspect of psychology, music cognition is an important aspect of music psychology. Cognition involves a long list of psychological and linguistic skills that are relevant for music, including perception, attention, thought, skill, knowledge, learning, memory, evaluation, reasoning, computation, problem solving, decision making, and the production and comprehension of language. The discipline of cognitive psychology

and its subdiscipline, music cognition, tend to assume the existence of cognitive (or mental) structures (or representations) that correspond to an external reality and enable the organism to interact with that reality. Such cognitive representations, while possessing considerable explanatory power, can also be questioned; the interaction of the organism and its environment can instead be regarded as an emergent property of a complex system (e.g., Sterck and Begeer 2010).

According to English-language Wikipedia (checked on September 22, 2021), music theory is "the study of the practices and possibilities of music." That definition is at once too general and too vague. German-language Wikipedia, consulted on the same day, explained that music theory is both a subdiscipline of musicology and an independent artistic and academic discipline that involves harmony, counterpoint, form, and music analysis—which is closer to the definition assumed here. One could argue that music theory is a subdiscipline of musicology; it is music research that addresses musical structure, focusing on pitch (harmony), time (rhythm, form), and combinations of the two (melody, counterpoint). But in practice, music theory and musicology are often separate, with musicologists mainly studying music history.

Music theory has a long, dynamic history that dates to ancient times. As such, it represents an important chapter in the history of ideas. The Western music theory of recent centuries usually takes conventional music notation as its starting point. The focus tends to be on musical structure (melody, rhythm, harmony, phrasing, form, and so on) as represented in musical scores and their analysis (music analysis). At the same time, music theorists are keenly aware of the limitations of scores ("Notation conserves music . . . but it conceals as much as it reveals"; Cook 1998, 55), and ask broader questions about the context in which music is performed, composed, improvised, and received.

This book belongs to a long tradition of music theory, but it also departs from that tradition by juxtaposing contrasting perspectives on musical structure from different academic disciplines. Musical structure may be considered from the perspective of music notation, but that is not the only possibility. Music also has corresponding physical and psychological representations. All three, and their interrelationships, will be considered in depth.

In the late twentieth century, music theory changed in response to trends variously described as postmodernism or new musicology. Old certainties were undermined: there was no longer a correct analysis of a piece of music,

nor was there a correct approach to analysis. The hermeneutic scope of analysis was expanded. The musical score was no longer regarded as the immutable and sacrosanct foundation upon which musicology was built. Instead, musical pluralism was embraced, along with performance and interpretation traditions, and the inherent subjectivity and context dependence of music-analytic decisions. Musicologists became more aware of the arbitrariness of social power and authority in determining academic opinion.

That development raised basic questions about the value and viability of music theory: "The history of musicology and music theory in our generation is one of loss of confidence: we no longer know what we know" (Cook and Everest 1999, v). How positivist, formalist, or purely musical should music theory be? To what extent should we construct or deconstruct existing music-theoretical concepts? What kind of questions should music theory answer? What is it for? Is music theory even a discipline? How valuable is an analysis of a piece of music that focuses on formalist elements (as this book does) and neglects socially mediated meanings? Similar questions can be asked of historical musicology: "What kind of truth can analysis of historical musicology reveal, and how might it relate to other kinds of truth about music? Should we be speaking of truth at all? Or does the act of engaging in analysis or the writing of history lock us into a predetermined epistemological stance?" (Cook and Everest 1999, xi).

These are serious questions, and as their formulation implies, clear answers are inherently lacking. A possible response to such a cascade of doubt is to try anew to articulate the discipline's scientific and formalist foundations, while at the same time remaining aware of the pitfalls of positivism. That is one of the goals of this book.

Tonality

Defining tonality is no easy task. Is it Western or cross-cultural? Is it part of the score, inherent in certain musical sounds, or a cognitive abstraction? Is it based on harmony and harmonic function (how chords progress from one to another), or melody and voice leading, or both? Is it based on a more general artistic or psychological principle, or is it unique?

Broadly speaking, any music is tonal, or has tonality, if some tones or pitches are perceived as psychological references by virtue of being repeated, accented, or sustained (cf. Hutchins and Palmer 2008). Those tones are called

tonal centers, and the effect is called pitch centricity (cf. Kleppinger 2011; Lewin 1968; Perle 1972; W. E. Thomson 1999). Almost all pitch-based music, including innumerable non-Western tonal styles, features melodic tonality in the sense that some tones or pitches are more likely to act as psychological anchors or reference points for the others—usually because they are sounded more often. These references may also be hierarchically structured (Kessler et al. 1984; Kolinski 1967).

Tones may be perceived as references if they lie near the middle of a melody's pitch range or ambitus. Since melodic phrases tend to have an arch-like shape, starting and ending relatively low and reaching a peak in the middle (Huron 1996), tonal centers may also lie in the lower part of the range. In "atonal" or "pantonal" styles, attention may be drawn to specific pitches by repetition or different kinds of accentuation (Parncutt 2003), creating temporary centers. Tonal centers can also be predicted from the frequency, occurrence, or duration of individual tones (Lantz et al. 2020; Oram and Cuddy 1995). Additional cues to tonality include loudness, timbre, and learned patterns (Ross and Knight 2019, 387).

Repetition is a characteristic feature of all music, and it is one feature that distinguishes music from speech (Margulis 2014). Repetition can even turn nonmusical sound into music: when a short snippet of speech is recorded and repeated several times, we start to hear the pitches of the phonemes as if they were part of a musical scale (Deutsch et al. 2008). Repetition is also an important aspect of music learning; it is how music is normally passed from one generation to the next. Repetition is related to a series of music-structural features, including tonic return and implication-realization. Tonic return implies repetition of the tonic after intermediate elaboration. Implication often means starting from musical element A and moving to B, and realization means moving back to (or toward) element A (cf. intervallic reversal and registral return according to Narmour 1990). In such cases, element A is repeated—often with some variation.

Tonality involves pattern recognition (Krumhansl 1990, 140; Wertheimer 1938). Again, that is related to repetition: by favoring a limited set of familiar patterns, tonality encourages a certain kind of repetitiveness. Richard Norton (1984, x) regarded tonality as "a decision made against the chaos of audible nature, a bewildering abundance of sonic potential that perhaps only the contemporary composer at his electronic synthesizer can fully appreciate," implying that musical repetition reduces natural chaos.

More narrowly, MmT is about major and minor keys and subdominant-dominant-tonic progressions in Western music of the eighteenth and nineteenth centuries. It's what François-Joseph Fétis called *tonalité moderne*, Hugo Riemann *Funktionsharmonik*, and Carl Dahlhaus *harmonische Tonalität*. The latter rests on two assumptions: first, that a triad constitutes a primary, direct unit; and second, that the progression of chordal roots establishes the key (Dahlhaus 1968; as cited in W. E. Thomson 1999, 17).

Both these points are interesting, but both can also be challenged. The idea that harmonic tonality is based on the tonic triad is supported by evidence that the music is perceived relative to that triad. One form of evidence is the high correlation between Krumhansl's key profiles and the pitch-class salience profile of the tonic triad (Parncutt 2011; figure 1.1). Another is more intuitive: diatonic-tonal melodies can often be perceived relative to the tonic triad. Each tone in such a melody falls on one of seven scale degrees, of which three belong to the tonic triad ($\hat{1}$, $\hat{3}$, or $\hat{5}$) and four do not ($\hat{2}$, $\hat{4}$, $\hat{6}$, or $\hat{7}$). Those that do not are a step away from a tone in the tonic triad and so can be perceived as a neighbor tone. Typical neighbor decorations of tonic-triad tones include $\hat{3}-\hat{4}-\hat{3}$ and $\hat{5}-\hat{6}-\hat{5}$. In that way, a melody can be perceived relative to the tonic triad that is imagined in the background.

Dahlhaus also argued that progression of chordal roots establishes the key. Whereas that is usually true, it also contradicts the idea that harmonic tonality is based on the tonic triad alone. Sometimes, tonality can be established simply by prolonging the tonic triad in the sense of repeating it for a long time, such as in the opening of Richard Wagner's *Rheingold* or the entirety of Led Zeppelin's *Whole Lotta Love*.

The term "tonality" was first used by French musicologist Alexandre-Étienne Choron at the start of the nineteenth century. His ideas were adopted and elaborated by his more influential Belgian colleague Fétis. The French *tonalité* refers to *ton*, which among other things is the key of a piece of music. Early definitions focused on the scale in which a piece of music is written, and the distinction between church modes (which Fétis called *tonalités anciennes*) and major/minor keys (*tonalités modernes*; Simms 1975).

The tritone interval (augmented 4th; diminished 5th; half octave; six semitones) played an important role in Fétis's theory. He regarded it as a consonance when part of a diatonic scale, but also as appellative, given its tendency to resolve to a more consonant interval. The role of the tritone can be clarified in modern pitch-class set theory. The standard diatonic scale can

be represented as [024579L], where the numbers are intervals in semitones relative to the tonic in a major key, and L = 11. The scale has an interval vector of <254361>: it includes two minor 2nds, five major 2nds, four minor 3rds, three major 3rds, six perfect 4ths, and one tritone. The relative rareness of the tritone means that a diatonic scale can be unambiguously defined by playing just three tones, provided two of them span a tritone. That rule can help listeners keep their bearings as tonal music modulates from one key to another (H. Brown and Butler 1981; Browne 1981; Butler and Brown 1984).

But listeners often spontaneously perceive the tonic without the help of a tritone. Annabel Cohen (1991) presented excerpts from the Preludes in J. S. Bach's *Well-Tempered Clavier*. Listeners could usually identify the tonic after only four tones, regardless of whether a chord was sounded or a tritone was included. Piet Vos (1999), noticing that pieces of tonal music often begin with an ascending 4th or a descending 5th between melodic tones or roots, showed that listeners easily identified the second sound as the tonic—again, in the absence of any tritone.

The *tonalité moderne* of Fétis included the tonic, dominant, and subdominant harmonies, as previously explained by Jean-Philippe Rameau, and later called *Funktionen* by Riemann (1893). According to Fétis, *tonalité moderne* was born when Monteverdi (in the madrigal *Cruda Amarilli*) sounded what later became known as unprepared dominant 7th chords and resolved them. The dominant 7th, according to Fétis, was natural to the extent that it represented ratios of small integers (4:5:6:7). Fétis also developed a theory of modulation that included remote key areas. Later, Louis Lambillotte spotted dominant 7th chords in Palestrina's *Pope Marcellus Mass* (Christensen 2019).

Fétis also used the term *tonalité* in a more general way to refer to relationships between scale degrees. For him, those relationships were ultimately mysterious, metaphysical, and culture specific—not acoustic or physiological in origin (Simms 1975). Each scale degree had its own character (an idea taken up later by Huron 2006) that was shared by the triad that could be built upon it; in that sense, melodic and harmonic functions were inseparable. *Tonalité* was determined by these tones and harmonies and by the relationships between them (Ceulemans 1990).

Jumping to the mid-twentieth century, Manfred Bukofzer (1947, 12; as cited in W. Thomson 1958, 37), having experienced various post-tonal styles and experiments, defined tonality as "a system of chordal relations based on the attraction of a tonal center. This tonic formed the center of gravitation

for the other chords." He went on: "It is no mere metaphor if tonality is explained in terms of gravitation. Both tonality and gravitation were discoveries of the Baroque period made at exactly the same time." The idea of tonal gravitation comes from Rameau (Christensen 1987) and was inspired by Newton; it seems appropriate, given expectations that certain tones will move in certain directions. Needless to say, there is no actual gravitation here; in a scientific approach, music has nothing to do with the motion of the planets, despite what has been believed for millennia. Psychological expectation can nonetheless be studied scientifically in its own right, even if the reasons behind the expectations cannot be explained by analogy to gravitation in physics. It is true that we expect, based on our experience of the world, that a high object will fall to the ground. It is also true, based on our experience of music, that we expect a leading tone to rise by a semitone.

When Dahlhaus pointed out that the progression of chordal roots establishes the key, he was thinking of subdominant-dominant-tonic progressions. It is true that they define and reinforce the tonic common-practice tonal music from the eighteenth and nineteenth centuries. But today, it may be appropriate to broaden the definition of MmT to include music with harmonic progressions that do not conform to that mold. Christopher White and Ian Quinn (2018) applied hidden Markov modeling to corpora of notated tonal music; on that basis, they questioned the generality of Riemann's theory of harmonic function (in which all chords have a tonic, dominant, or subdominant function) and highlighted harmonic differences between different repertoires.

Given the lack of a simple, clear definition of tonality, we need to be open to somewhat vague and multifaceted definitions. Tonality can be split into quasi-objective and subjective aspects, also called structural versus cultural. Regarding the cultural aspect, Norton's (1984) concept of mass tonality or mass tonal consciousness is appropriate from a psychological or sociological perspective:

> In none of the current literature has anybody admitted that the phenomenon of mass tonality is the single most pervading component of those forms of mass culture which in any fashion whatsoever are involved with music: specifically radio, television, film, and the making of live and recorded music. This tonality is understood on both the unconscious and the conscious level by hundreds of millions of people around the world. This tonality easily accounts for *all* the popular music of

> the last two centuries—from the waltz, brass-band music, operetta, and the Victorian hymn in the nineteenth, to American band music, ragtime, jazz, blues, swing, rock, and the Broadway musical in the twentieth. There is no form of popular music in the modern, industrialized world that exists outside the province of mass tonal consciousness. It is the tonality of the church, school, office, parade, convention, cafeteria, workplace, airport, airplane, automobile, truck, tractor, lounge, lobby, bar, gym, brothel, bank, and elevator. Afraid of being within it while on foot, humans are presently strapping it to their bodies in order to walk to it, run to it, work to it, and relax to it. It is everywhere. It is music and it writes the songs. (271)

Today, decades after Norton's book, his claims and observations are still largely valid. If anything, the number of people across the world who are engaged in "mass tonal consciousness" has increased. Pop and rock, which seem to have become even more triadic (based on major and minor triads) in recent decades (or at least more conventional; Serrà et al. 2012), are surely just as "common practice" as classical music and just as worthy of analysis—even if "traditional constructs of scale-degree theory and harmonic functionality" must be "modified to address elements of rock music that do not conform to tonal norms" (Biamonte 2010, 95). Technology has become even more portable, reinforcing the social importance of recorded music by comparison to live performance. In the academic world, meanwhile, although schools of composition have become stylistically and aesthetically more diverse, moving away from postwar modernism (Guldbrandsen and Johnson 2015), Norton's general claims remain valid. Consequently, my goal in this book is similar to that of Philip Tagg (2009): to develop a "tonal theory of what most people hear"(i).

In the West today, and increasingly elsewhere, most music is based on major and minor triads and tonalities. That is remarkable, given the musical creativity of recent centuries and the number of brilliant and influential modernist twentieth-century composers who devoted their lives to expanding, undermining, and replacing MmT. Although those many composers achieved an impressive diversity of tonal styles—each of which departs more or less, and in different ways, from MmT—MmT remains the dominant style of musical pitch organization, at least in the everyday lives of most people.

In the world of popular music (e.g., indie pop), each generation seems to reinvent or rediscover the same old chord progressions and present them as if they were new. In May 2022, I listened to the top five hits in Austria according to radio station Ö3. For teaching purposes, I noted the opening

or main chord progressions that I heard (denoting a major tonic triad as I, a minor tonic triad as i, and so on in the usual way):

- *We Made It* by t-low and Miksu/Macloud: i v VI iv
- *As It Was* by Harry Styles: ii V I IV
- *Sehnsucht* by Miksu/Macloud and t-low: i VI VII i
- *First Class* by Jack Harlow: i (VI III)
- *Heat Waves* by Glass Animals: ii I vi V (IV I vi V)

Were these chord progressions stolen from Mozart? Hardly. Did Mozart steal them from his contemporaries and predecessors? No. Triadic, diatonic chord progressions of this kind are a part of Western (or perhaps now global) culture and identity. For centuries, people have been performing, hearing, and loving these harmonic clichés. At the same time, musicologists (including music theorists and music psychologists) have been trying to explain their origin and appeal—with mixed success.

Some definitions of tonality are relatively broad, while others are narrower. I am taking a middle path by defining MmT as tonality that is based on major and minor triads but which does not necessarily conform strictly to the rules of tonality developed by nineteenth-century theorists, inspired by Bach, Mozart, Beethoven, and Brahms. Tagg (2009) defined tonality similarly broadly as "the system or set of norms according to which tones are configured in any musical culture" (54); "tonality includes such phenomena as key, melody, tonal polyphony, chords, and harmony" (61). In an approach of that kind, MmT includes:

- nonclassical Western cultures such as Renaissance polyphony, heard retrospectively as progressions of mainly major and minor triads within major and minor scales (cf. Long 2018), as well as all music composed in the (long) European nineteenth century;
- most jazz, pop, and rock from the twentieth century in all its diversity, from soft rock to heavy metal, from musical to video game music; all improvisations of Thelonius Monk, all songs by Adele, all Brazilian popular music, all K-Pop;
- most modern pop, including music that is confined to a diatonic scale and treats the three major and three minor triads in that scale (e.g., C, Dm, Em, F, G, Am) as equally important (cf. Clement 2019; Ferrandino 2022);

- urban contemporary music and Black genres, including hip-hop, contemporary R&B, quiet storm, electronic dance music (EDM), reggae, Latin music, Chicano rock, and brown-eyed soul; and
- (harmonic) tonalities in diverse non-Western musics, such as African choral and a cappella styles (Ofosu and Ofosu 2020).

MmT includes diverse tonal structures beyond classical chord progressions in major and minor keys. It includes planing in the music of Debussy—parallel chords conforming to a diatonic or pentatonic scale, or parallel Mm7 chords (for examples, see Uchida 1990) and similar developments in post-bop jazz (Pamies 2021). It includes passages that are based on or confined to standard pentatonic scales or quartal harmonies (chords created by stacking 4ths rather than 3rds; Day-O'Connell 2007), insofar as perceptible links to triadic or tertian (stacked-3rd) harmony remain (e.g., a 7th being perceived as a stack of 3rds although constructed from two 4ths).

In this way, MmT can be defined as any musical structure that is primarily based on major and minor triads and scales. This definition is broad in the sense of not insisting on a (clear) tonal center, but it is narrow in insisting on the role of major/minor triads or scales, or their extensions or derivatives.

The definition excludes music that is commonly described as atonal, pantonal, or post-tonal, insofar as the boundaries of those categories can be defined, while at the same time acknowledging a continuous transition between tonal and atonal. Relative to classical major and minor keys, the pitch structures of planing, pentatonicism, or quartal harmony tend to ambiguate tonality, but if they are based on relatively consonant interval patterns, as in tertian harmony and major/minor scales, they may be included in a broad definition of MmT. The definition also includes diverse non-Western styles that have been influenced by Western MmT and regards MmT as a phenomenon that—mainly for geopolitical reasons—is now widespread outside of the West (however defined).

Different scales can be classified as major or minor, given the size of the 3rd interval above tonic or reference pitch—even if the distinction is not entirely clear. MmT therefore includes diatonic modes (Dorian, Phrygian, and so on) and most (other) jazz scales. It might even include symmetrical scales such as the diminished scale, when the scale appears in tonal contexts with tonal implications.

Many borderline cases could be listed. One might argue, for example, that Indian classical music should be included because it is based on scales that have major or minor 3rds. But that music often does not imply major or minor triads—depending, perhaps, on who is listening. In any case, my knowledge of this wonderfully evocative and complex musical tradition is far too rudimentary to justify considering it here. Other similarly unclear examples could be provided, but it is beyond my scope to cover different stylistic possibilities systematically or to define a gray zone. Instead, my aim is to focus on basic principles that might allow the various stylistic possibilities within mainstream MmT to be explained.

As a psychologist, I could operationalize my definition of MmT by saying that for most Western or Westernized people, MmT practically means the same as music. That is because most of the music that most Western people hear is MmT, as broadly defined here. For that reason, many psychological studies of music are, on closer examination, studies of MmT. "Music" is preferred if it expresses values and identity (Schäfer and Sedlmeier 2009). "Music" preferences depend on gender and self-esteem (Shepherd and Sigg 2015) as well as personality (Dunn et al. 2012). "Music" that is somewhat unusual may be preferred (Chmiel and Schubert 2019; Miles et al. 2021). One "music" preference study found the following five genre groups (factors): Intense and Electronic; Devotional and Cultural; Emotional and Melodious; Spiritual and Reflective; and Contemporary and Rhythmic; all were examples of MmT, although the study was carried out at an Indian university (Upadhyay et al. 2016).

Nicholas Temperley (1987) argued that preference for tonality is a middle-class phenomenon. I beg to differ. In my experience, MmT is surprisingly independent of class, but different social classes may prefer different styles and genres. Adrian North and David Hargreaves (2007) found that "liking for 'high-art' music was indicative of a lifestyle of the upper-middle and upper classes, whereas liking for 'low-art' music was indicative of a lifestyle of the lower-middle and lower classes" (473); of course, the music was tonal in both cases. In addition, we can say that in Western and Westernized cultures, more or less everyone likes MmT.

For modernists and lovers of contemporary music, the continuing dominance of MmT in Western music (and increasingly outside the West) is regrettable. But it also gives basic questions about MmT a quasi-timeless character. I sympathize with those who yearn for more music-structural complexity and diversity, my own musical taste being rather eclectic. For the purpose

of scientific research, however, it is not my task to evaluate the continuing preference for MmT. That is simply the way things are. A music psychologist should try to explain how music works and why it is the way it is, without judging.

Prolongation

Heinrich Schenker proposed that any tone or sonority (interval or chord) can be prolonged (*auskomponiert*, *verziert*, *ausgefaltet*, *fortgesponnen*, composed out, unfolded, unpacked, embellished, decorated, elaborated, spun out . . .) such that a passage of music is heard relative to that tone or sonority, whether it is actually sounding or not (Forte and Gilbert 1982). Prolongation is happening constantly in almost all the music we listen to. It can happen on different hierarchic levels simultaneously, such that a component of a prolongation is itself prolonged.

Simple prolongations can be divided into three parts: a statement of a pitch pattern A, an intermediate elaboration B, and a final repetition of A (Jonas 1982). The classical sonata form of exposition, development, and recapitulation is a high-level ABA pattern that can be regarded as thematic and tonal prolongation of A. The "organic unity" of a musical work of art, as appreciated by many music theorists, including Schenker, can be seen as a form of high-level prolongation.

MmT can be regarded or even defined as prolongation of the tonic triad. The idea can be illustrated with familiar examples of diatonic music in major keys. For better or for worse, we might start with some well-known national anthems:

- The melody of *God Save the King* starts like this: $\hat{1}\,\hat{1}\,\hat{2}\,\hat{7}\,\hat{1}\,\hat{2}$, $\hat{3}\,\hat{3}\,\hat{4}\,\hat{3}\,\hat{2}\,\hat{1}$, $\hat{2}\,\hat{1}\,\hat{7}\,\hat{1}$ (using commas to separate the phrases). In the first phrase, $\hat{2}$ and $\hat{7}$ ($\hat{7}$ being a semitone below $\hat{1}$) are perceived as upper and lower neighbors to $\hat{1}$; in the second phrase, $\hat{4}$ is perceived as an upper neighbor to $\hat{3}$, and $\hat{2}$ to $\hat{1}$; and the third phrase is like the first. Later in the melody, $\hat{6}$ is perceived as an upper neighbor to $\hat{5}$. In that way, the melody can be heard as a prolongation of the tonic triad $\hat{1}-\hat{3}-\hat{5}$.
- *La Marseillaise* starts with a flourish based on an arpeggiated tonic triad, like this: $\hat{5}\,\hat{1}\,\hat{2}\,\hat{5}\,\hat{3}\,\hat{1}$. In this context, $\hat{2}$ can be heard as either an upper neighbor to $\hat{1}$ or a passing note to $\hat{3}$. In the next phrase, a low $\hat{6}$ appears,

which becomes an upper neighbor to a low $\hat{5}$. The subsequent $\hat{4}$ can be heard an upper neighbor to $\hat{3}$, although its resolution to $\hat{3}$ is delayed to the start of the next phrase.

- At the start of the German national anthem *Einigkeit und Recht und Freiheit* ($\hat{1}\,\hat{2}\,\hat{3}\,\hat{2}\,\hat{4}\,\hat{3}\,\hat{2}\,\hat{7}\,\hat{1}$), $\hat{2}$ can be heard as an upper neighbor to $\hat{1}$ or a passing note to $\hat{3}$; $\hat{4}$ is an upper neighbor to $\hat{3}$; and $\hat{7}$ is a lower neighbor to $\hat{1}$. In the second phrase, the high $\hat{6}$ becomes an upper neighbor to $\hat{5}$.

Countless tonal diatonic melodies can be analyzed in this way, from themes of classical sonatas to popular songs. Every tone in such a melody can be perceived as either belonging to the tonic triad or related to it by stepwise neighbor relations. People do not necessarily hear melodies in MmT that way, but it is often reasonably possible to do so.

The concept of harmonic prolongation is embedded in a broader music-theoretical discourse. Steve Larson (1997) explained:

> Prolongation and musical forces are both related to "stability," a term whose operational definition depends on three more terms: "auralize," "trace," and "displace." To auralize means to hear internally sounds that are not physically present. A trace is the internal representation of a note that is still melodically active. However, a trace is more than a memory. A trace can be displaced by subsequent notes. If I play one note and then another that is a step away, you may be able to recall both notes. But there is some sense in which the second note will displace the trace of the first (Komar 1971). (104)

> In a melodic step, the second note tends to displace the trace of the first, leaving one trace in musical memory; in a melodic leap, the second note tends to support the trace of the first, leaving two traces in musical memory. (105)

Larson's "displacement" is related in psychological research to auditory scene analysis and in particular to the trill threshold, according to which two alternating tones one or two semitones apart create a trill (one auditory stream), whereas they create a shake (two streams) for intervals of three semitones or more. The idea is both intuitively clear in musical practice and psychologically testable (G. A. Miller and Heise 1950). It is also related to Jamshed Bharucha's (1996) melodic anchoring.

Larson (1997) also commented that "prolongation—and only prolongation—always determines which notes are heard as stable in a given context" (112) and "the act of *hearing* a passage of music *as* containing a prolongation I call (after Salzer 1952) 'structural hearing.' Accordingly,

Schenker's term *Fernhören* means global structural hearing" (115; italics in original). Moreover, "prolongation *is* embellishment; embellishment (and only embellishment) determines the relationships between tones that make some tones of lesser and greater structural weight than others" (130, italics in original).

Any musical tone or sonority can be prolonged, provided it is perceived to be *consonant*. In some early post-tonal music (e.g., Scriabin's *Vers la flame*, Berg's song Op. 2 no. 2, Debussy's *Voiles*, Weber's song Op. 3 no. 1), harmonies related to the harmonic series were prolonged (Väisälä 2002). Much medieval counterpoint can be understood as prolongations of single tones or perfect 5th intervals—with implications for tonality in a broad sense. Felix Salzer (1967) even claimed that "by the middle of the twelfth century, the basic principle of tonality had been created. This principle can be defined as directed motion within the framework of a single prolonged sonority" (54). He continued: "Tonality is chord prolongation. This means that the horizontalization of a sonority or the motion around a sonority is the unifying element of the contrapuntal voice-leading texture. This is the common denominator within the totality of a single language expressing itself in a rich variety of styles" (98). But there is a danger of overgeneralizing. The term "tonality" should be applied with caution to music before about 1600 (Sanders 2003).

Ernst Krenek (1940, cited by W. E. Thomson 1999, 18) argued that "a tone becomes the tonic only when the central triad is built over it." In other words, the tonic is a triad, not a tone. If MmT is a prolongation of the tonic triad, every tone in the diatonic scale is perceived relative to that triad. That idea is consistent with the high correlation coefficients ($r \approx 0.95$) that have repeatedly been found among the following three independently determined vectors of twelve numbers (Parncutt 2011; see figure 1.1):

- the pitch-class stability vector of a musical key (Krumhansl's key profiles),
- the pitch-class prevalence vector of a musical passage (how often each pitch class happens in typical musical scores in MmT), and
- the pitch-class salience vector of the tonic triad (according to Parncutt 1988, 1993).

The correlation coefficients are high for both major and minor keys but sometimes higher in major case, consistent with the minor key's greater ambiguity (Parncutt 1989, 1994).

Salience versus Stability

When examining the idea that MmT is a prolongation of the tonic triad, we will compare and contrast two concepts: tonal stability in music theory and pitch salience in psychoacoustics.

In music theory, stability is about tone-by-tone expectations. If a piece of music suddenly stops on a tone, that tone's stability is its closure or finality—the degree to which we perceive it as the end of the piece. Conversely, its instability is the degree to which we expect it to move up or down in subsequent music. In music theory, familiar examples of stability and instability include scale degrees $\hat{1}$ and $\hat{7}$ of the major or minor scale—the tonic and leading tone, respectively. The tonic is stable because it creates closure at the end of a passage, whereas the leading tone is unstable because we expect it to move (usually to rise through a semitone to the tonic).

The salience of a pitch in psychoacoustics is its ability to attract the listener's attention, or simply how important it sounds—how much it stands out in our sonic experience within the musical surface. It is the perceived clarity of a pitch or the probability of noticing a tone or directing attention to it. It depends on chord voicings, voice leadings, and accentuations. Musicians are constantly manipulating tone salience in performance. The easiest way to attract attention to a tone is to play it louder; other techniques include playing it more quietly (in a surprising or unexpected way, *subito piano*), changing its timbre, playing it out of time relative to its rhythmic context, varying its intonation, and so on. Musical expression is often about using performed accents (loudness, delayed onset, etc.) to attract attention to immanent accents (harmonic, melodic, grouping, etc.; Parncutt 2003).

The salience of a voice-leading pattern in music analysis is its likelihood of being noticed. But in hierarchical-reductive approaches to analysis, inspired by Schenker, the contents of the next-deeper level tend to depend more on stability than salience: events that are tonally stable at one level are more likely to appear at the next level down (Pellegrin 2013).

In performed music, there are big differences between salience and stability. Unstable tones can be salient when accented (e.g., appoggiatura and harmonic accent). Performers often expressively attract attention to unstable elements, making them salient. Stable tones are often not salient (e.g., scale degree $\hat{1}$ as an unaccented passing tone between $\hat{2}$ and $\hat{7}$).

If we take the expression (timing and dynamics) out of a music performance and imagine that all tones are played such that they would be equally salient if sounded alone (as in a well-controlled but ecologically invalid psychological experiment), we can ask how the stability of a tone depends on context in MmT—without distinguishing stability and salience. In standard tonal theory, there is a hierarchy of stability. The tonic ($\hat{1}$) is the most stable tone; then comes the dominant ($\hat{5}$), followed by the 3rd of the tonic triad ($\hat{3}$). After that, there are the other tones in the diatonic scale ($\hat{2}$, $\hat{4}$, and $\hat{6}$), then the leading tone ($\hat{7}$), and finally the remaining chromatic tones.

Carol Krumhansl and Edward Kessler (1982) encapsulated this hierarchy mathematically by measuring and quantifying the stability of each chromatic scale step to create key profiles with twelve elements. They did that by presenting three-chord key-defining cadences to listeners, followed by individual tones, and asking "how well, in a musical sense, each probe tone fit into or went with the musical element just heard" (342). Tones corresponding to stable tones in the tonality were perceived to go well, whereas those corresponding to unstable tones went poorly.

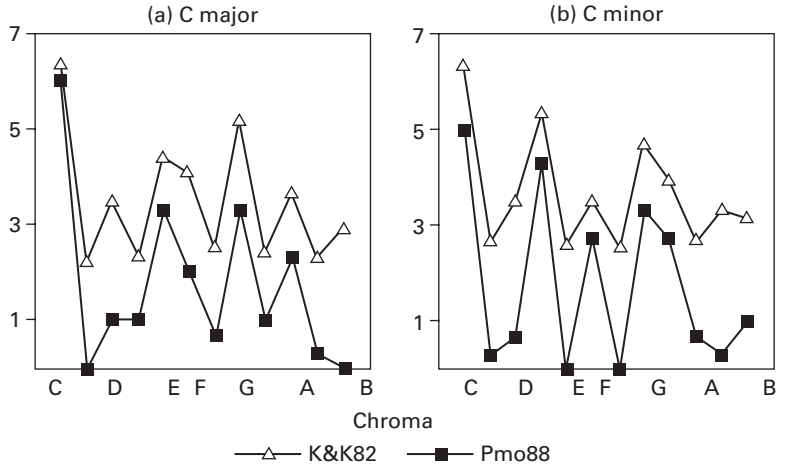

Figure 1.1
Comparison of the stability of scale degrees (key profiles; Krumhansl and Kessler 1982) with pitch salience within the tonic triad (pitch-class salience profiles of major and minor triads; Parncutt 1988 with revised root-support weights, divided by 3 for ease of comparison). From Parncutt (2011) by permission of University of California Press.

The concept of MmT presented in this book involves comparing (correlating) the stability of musical scale steps (Krumhansl's key profiles) with their salience within the tonic triad (the pitch-class salience profile of the tonic triad), as shown in figure 1.1. The pitch-salience profile is calculated using a simplified, octave-generalized version of the pitch algorithm of Terhardt et al. (1982b). The peaks in the profile are virtual pitches evoked by the tonic triad. They correspond to the fundamentals of harmonic patterns of audible partials (spectral pitches). The comparison is consistent with the Schenkerian idea that a passage of music in a major or minor key is a prolongation of its tonic triad.

The idea is not new. Some have argued that of seven pitch classes of a major or minor scale, the three that correspond to the tonic triad are consonances and the others are dissonances (Mickelsen 1977, 67; Riemann 1882; Tartini 1754). That is a good first approximation. Quantitatively, there may be little difference between the "consonance" of pitches in a major or minor scale, their tonal stability, and their salience within the tonic triad.

A triad can be performed in many different ways, including voicings (inversions, spacings, and doublings) and expressive interpretations (timbres and dynamics). When comparing the tonic triad with the key profile, we understand the comparison to involve an average or representative version of the triad, including typical voicings, and with all tones played equally loudly. Terhardt's pitch model implies that the harmonic relationships between the tones in the tonic triad cause some tones to sound more perceptually salient than others, even if all tones would have been equally salient if played separately.

Consonance and Dissonance

Consonance and dissonance (C/D) are central concepts in the history of Western music theory. If we want to understand MmT, we need to understand C/D. A sonority can only be prolonged, creating a tonal space, if it is perceived to be consonant.

The Latin roots of the word "consonance" refer to how different sounds sound together. That does not necessarily imply that the component sounds sound together in a particular way. Nor does it imply that the sounds are individual tones or groups of tones, or that the comparison is simultaneous or successive. Seen that way, the word is quite general. Nor does

it necessarily apply to Western music. Although C/D may be important for some non-Western musics, it is irrelevant for others (McDermott et al. 2016). So, considerations in this book will be confined to the Western tradition. I will adopt a broad definition of C/D that includes simultaneous and successive pitch relations and encompasses the diverse approaches of different historical periods and academic disciplines.

In the humanities and the history of ideas, C/D is often understood to be categorical. Intervals are divided into consonances and dissonances, consonances are divided into different kinds of consonances, and so on. Scientists, including music psychologists, tend to think of C/D as a continuous variable or real number, which has the advantage of flexibility: no matter how consonant or dissonant a sound, it is possible to imagine a more consonant or dissonant one (depending on definition). If the terms "consonance" and "dissonance" are exact opposites, Joe Monzo (n.d.) argued that C/D should have a single name and proposed the term "sonance." But the two words can also be asymmetrical if, for example, consonance is promoted by one factor (harmonicity) and dissonance by another (roughness).

Both simultaneous and successive tones can be either consonant or dissonant. A major-2nd interval is normally considered consonant when the tones are successive (it is the most common melodic interval) and dissonant when they are simultaneous (due to roughness). In discussions of early monophonic (pre-polyphonic) music, C/D refers primarily to successive tones; in polyphony, it refers to simultaneous tones. The term "C/D" can be used in a more general sense, according to which an entire passage of music has C/D that depends among other things on its tonality and voice leading. In making that claim, I am assuming that music listeners tend to hear music holistically, drifting along with the music's emotion and imagery, allowing the music to change their state of consciousness (Herbert 2016), and without analyzing different aspects of C/D.

Researchers in psychology and psychophysics have often confused consonance with pleasantness. Sometimes, the two overlap, but not always. We may find complex jazz chords with bitonal upper structures "pleasant," although they are dissonant from a music-theoretical perspective. By the same token, we may find four-part harmony more "pleasant" than unison singing when listening to a choir, although chords are rougher than single tones according to psychoacoustic models.

Psychohistory

From a retrospective modern standpoint, music history can be seen as a process of collective creativity, in which composers approached aesthetic goals by a sophisticated form of trial and error: "The principles of sonata form, for example, which governed music of the late eighteenth and early nineteenth centuries were not enacted; they were arrived at by a trial and error process, reflected in the music of K. P. E. Bach, Johann Stamitz, Josef Haydn, and others during the period from 1750–1770" (Manns 1994, 88). Musicians were and still are trying out new sound patterns and evaluating the results. The final arbiter of what is good music is fundamentally subjective and may override existing conventions or rules, which, on the one hand, makes it possible for musical styles to evolve and, on the other, makes it difficult to study the underlying principles scientifically. One result of this historic process is that music perception changes as listeners become familiar with new or changing musical styles (Parncutt 2012).

In an attempt to do justice to this historic complexity, I will regard musical structures such as intervals, scales, and chords as psychohistoric entities. Although we can investigate their perception today in psychological experiments, and the results of those experiments depend on the physical properties of the sound, the results also depend on musical familiarity, and that depends in turn on cultural processes that span hundreds or thousands of years. Familiarity can often be evaluated by statistical analysis of musical databases on the assumption that listeners are familiar, either directly or indirectly, with the sound of the contents. In that sense, my explanations of musical elements and structures will often have a psychohistoric character, speculating about the history of music perception and its effect on the history of musical syntax. I will assume that the structure of music depends on unconscious or ineffable perceptual processes in the history of music perception, as well as the history of music theory and compositional convention.

This is not a book about the history of music theory, although there are many references to it. In any case, the history of music theory is not what I mean by psychohistory. I will not, for example, attempt to survey historic contributions to the theory of major and minor chords and tonalities systematically (cf. Parncutt 2011). Instead, I will engage with selected highlights in the history of music theory: the ancient idea that musical intervals are ratios

of small integers, milestones in the history of C/D theory, and the emergence of concepts such as sonority, chord, root, progression, and tonality.

Questions about enharmonic spelling (such as G♯ versus A♭) can be seen from a psychohistoric perspective. To understand enharmonics, we need to look at both historic and psychological contexts, combining different ways of thinking in humanities and sciences. We need to ask whether and how enharmonics affect the real-time music experience of modern listeners and performers (see chapter 12).

A psychohistorical approach may be controversial. The attempt to combine history and psychology is problematic for psychologists because it is not possible to perform psychological experiments on people who died long ago. Conversely, any attempt to identify music-structural principles that apply equally to such diverse styles as medieval chant, Renaissance polyphony, common-practice tonality, jazz harmony, and even post-tonal music is problematic for humanities scholars, given the enormous stylistic differences and historic changes in both music and the history of ideas. It is nevertheless relevant that, at all times and in all places, humans have communicated acoustically using harmonic complex tones and fricatives produced by their vocal tracts. Humans also use linguistic cognitive structures that have global commonalities and are in some ways similar to musical cognitive structures. Such quasi universals in speech communication and song are consistent with a psychohistorical approach to music perception that considers historical changes in musical vocabularies, patterns, and fashions, and their relationship to unchanging perceptual universals.

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