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Contents

Preface

This book describes a psychological theory of expectation. I call it the *ITPRA theory*—a name that will be explained in the first chapter. When I began this research, my interests were limited to music. I was aiming to better understand how listeners form music-related expectations, and how these expectations might account for various emotional responses. As the work progressed, the ITPRA theory evolved into a general theory of expectation and so expanded beyond my parochial concerns about music. Although my principal motivations remain musical, this book should prove informative to a more general audience of readers interested in cognitive science and evolutionary psychology.

For musicians and music scholars, this book offers psychologically based insights into such venerable topics as meter, syncopation, cadence, tonality, atonality, and form. Detailed accounts of musical tension, deception, and surprise are given, and I suggest how music is able to evoke emotions such as spine-tingling chills and musically induced laughter. I provide moment-by-moment analyses of the psychological effects of common musical devices such as the appoggiatura, suspension, and anticipation, and discuss the role of expectation in crafting effective performance interpretations. In addition, I suggest how the organization of the brain might account for the taken-for-granted aesthetic distinctions of *work*, *genre*, and *rendition*. The book offers psychological interpretations of various historical events in Western music, notably the advent of musical modernism as exemplified in the works of Wagner, Stravinsky, and Schoenberg. Finally, I speculate about how the psychology of expectation might be exploited to create entirely novel musics. In general, the book attempts to show how both biology and culture contribute to the subjective phenomenal experiences that make listening to music such a source of pleasure.

For psychologists and cognitive scientists, this book offers a general theory of expectation. I suggest how the phenomenon of surprise can lead to fear, laughter, frisson, or awe. I endeavor to reconcile competing theories of emotion, most notably cognitive appraisal theories with physiologically inspired theories such as the James–Lange theory. Along the way, I propose a new interpretation of the Mere Exposure effect and suggest that misattribution is an artifact of the biological world's response to the problem of induction. An important part of the book deals with the origin of auditory expectations. In general, the experimental evidence reported here supports the emerging consensus for statistical learning. Finally, I address the problem of how expectations are mentally represented. I note that the apparently chaotic patterns found in the research on musical development are consistent with neural Darwinist theories. I further note that the differences between innate and learned representations (such as those observed in auditory localization) can be explained by the Baldwin effect. In general, I attempt to tell an uninterrupted story, from the patterns of the objective world, through imperfectly learned heuristics used for predicting that world, to the phenomenal *qualia* we experience as we apprehend the world.

In retrospect, music provided me with a serendipitous starting place for theorizing more generally about the psychology of expectation, I think for three reasons: First, most everyday experiences are too complicated to provide fruitful cases for analysis. For example, one of the most important expectation-related experiences is *surprise*. Unfortunately, many of the surprises that people experience involve complex social contexts that are often difficult to interpret. Even the simple "peek-a-boo" surprise between parent and infant involves a social dynamic that makes it hard to study. Although music is not simple, there are often fewer confounding factors to consider. A second advantage is that many musicians actively seek to provoke emotional responses in their listeners. Although different musicians pursue different goals, manipulating expectations has been a common technique used to create an emotional effect. In general, without manipulation, causality is difficult to infer; so this aspect of music often provides helpful clues about the cascade of causal events. Finally, music typically provides detailed records (in the form of notated scores) that chronicle the precipitating events as they unfold in time. Musical scores provide a convenient database for testing specific hypotheses about expectation. In short, music offers a number of advantages as a case study of the psychology of expectation. My hope is that psychologists will find the theory engaging, even if they have no interest in music.

While my main audience is intended to be musicians, I have tried to make the underlying theory of expectation accessible to nonmusician readers. Where possible, I have bracketed the technical musical descriptions as independent chapters. In chapters 1 and 2 the theory itself is described in general terms with little reference to music. Chapter 3 describes the experimental methods used to study the phenomenon of expectation. Chapters 4, 5, and 6 identify five general patterns of expectation exhibited by listeners familiar with Western music. Chapters 7, 8, 11, and 12 expand on the basic theory. While the theory itself is described in general terms, the illustrations in these chapters are drawn almost entirely from the field of music. Parallel examples in visual perception, linguistics, social behavior, and ethology will readily come to mind for those readers who are knowledgeable in such areas. Nonmusicians may wish to skip the applied discussion of music, especially chapters 9, 10, and 13 to 16. The concluding chapter (17) provides an analytic summary of the basic theory.

For readers who don't read music, the notational examples may feel irksome or irrelevant. Let me assure readers that the musical examples are genuinely illustrative. The examples have been "field tested," and for most listeners they evoke fairly reliable phenomenal experiences. To help readers grasp them more fully, recorded versions of all of the notated examples are available on the World Wide Web.[1] Professional musicians themselves may want to refer to the recorded examples since they often include performance nuances that enhance the effect.

The purpose of this book is to describe a set of psychological mechanisms and illustrate how these mechanisms work in the case of music. Some of these mechanisms are able to evoke particular emotional responses. However, this book does not provide a comprehensive theory of music and emotion; there are many other factors that contribute to musically evoked emotion that do not arise from expectation. In discussing emotional responses to music, much of the book will concentrate on how expectations are able to generate *pleasurable* experiences for listeners. The discussion will focus on general principles and will not deal directly with individual differences, such as why a person might dislike a particular tune. The emphasis on pleasure may seem controversial to some readers. Although pleasure is recognized as an important psychological motivator, it is a factor that has sometimes been overlooked or denigrated by arts scholars as merely hedonistic. It should be noted that pleasure does not trump all other values: the best music is not necessarily music that fills its listeners with pleasure. But without a significant dose of pleasure, no one would bother about music.

Pleasure does not preclude effort. Minds need to *reach*, not simply *grasp*. Brains need to be *challenged*, not simply *pampered*. If the arts are to achieve all that can be achieved, it would be wrongheaded to focus on the limitations of human minds. But neither is it the case that anything is possible. Humans are biological beings living in a social and physical world. In pursuing some artistic goal, there are often constraints that must be taken into account if the goal is to be attained.[2] To ignore these constraining phenomena is to exist in a naive delusional world. One must not mistake ignorance for imagination. Nor should wishful thinking masquerade as artistic insight.

It is essential that musicians understand that I am attempting to describe psychological processes, not aesthetic goals. My musical aim in this book is to provide musicians with a better understanding of some of the tools they use, not to tell musicians what goals they should pursue. If we want to expand artistic horizons and foster creativity there is no better approach than improving our understanding of how minds work.

Many artists have assumed that such knowledge is unnecessary: it is *intuition* rather than *knowledge* that provides the foundation for artistic creation. I agree that intuition is essential for artistic production: in the absence of knowledge, our only recourse is to follow our intuitions. But intuition is not the foundation for artistic freedom or creative innovation. Quite the contrary. The more we rely on our intuitions, the more our behaviors may be dictated by unacknowledged social norms or biological predispositions. Intuition is, and has been, indispensable in the arts. But intuition needs to be supplemented by knowledge (or luck) if artists are to break through "counterintuitive" barriers into new realms of artistic expression.

Accordingly, the best I can aim for in writing a book like this is to provide artists with some conceptual tools that might lead to something new. In the concluding chapter I highlight some of the opportunities afforded to both musicians and music scholars by taking the cognitive sciences to heart.

Acknowledgments

Research is never done in a vacuum and the research reported in this book is no exception. Much of this work was inspired by research carried out in my Ohio State University laboratory by postdoctoral fellow Paul von Hippel and doctoral student Bret Aarden. Paul von Hippel took my intuition about the possible influence of regression to the mean in melodic organization and wove a marvelous story about how listeners hear melodies. In particular, von Hippel's experiments made clear the discrepancy between what people hear and what they expect. Bret Aarden took my interest in reaction-time measures in judging melodic intervals and turned the paradigm into a truly useful tool for investigating musical expectation. His work has transformed the way we understand previous work on tonality. I am indebted to both Paul and Bret for being such tolerant listeners and for mentoring me as much as I mentored them.

Although I have always preferred so-called structural theories of tonality to functional theories, I have benefited enormously by having David Butler (the principal advocate of functional tonality) as a departmental colleague. Professor Butler's knowledgeable criticisms of structural theories led me to a better understanding of the importance of parallel mental representations. My discussion of rhythmic expectation builds on the research of another colleague, Dr. Mari Riess Jones. Along with her collaborator, Dr. Ed Large, she assembled a theory of rhythmic attending that provides the core for understanding the "when" of expectation.

Throughout the book I report a variety of statistical measures based on several databases of encoded musical scores. I am indebted to the late Helmut Schaffrath for making available his Essen Folksong Collection. I am also indebted to the Center for Computer Assisted Research in the Humanities at Stanford University for providing access to the MuseData electronic scores. Particular thanks go to Walter Hewlett, Eleanor Selfridge-Field, and Craig Sapp. In addition, my thanks go to Tom Recchia for encoding the database of pop chord progressions.

Without wishing to minimize my debt to my colleagues and collaborators, I must acknowledge that the most important people in any research program are one's critics.

Over the years, I have come to greatly value the preventive medicine provided by the peer review process. The sad truth about writing a book is that it is immensely difficult to cajole knowledgeable people into providing critical feedback. The distinguished hearing scientist, Georg von Békésy, once lamented that his successful career had resulted in the loss of his best critics. For von Békésy, former critics were ultimately transformed into friends, and with that, he felt that the quality of his research had suffered. One way to compensate for the paucity of critics is to encourage friends to put aside their affections and pull out their scalpels. I am grateful to those of my associates who recognize the value of mixing encouragement with pointed criticism. My thanks to Bob Snyder, Ian Quinn, Elizabeth Margulis, David Temperley, Fred Lerdahl, Zohar Eitan, Marc Perlman, Dirk-Jan Povel, Peter Desain, Ryan Jordan, Donald Gibson, William Conable, Peter Culicover, Kristin Precoda, Simon Durrant, James Wright, Jonathan Berger, Joy Ollen, Randolph Johnson, Joshua Veltman, Judy Feldmann, Marion Harrison, and Freya Bailes.

Sweet Anticipation

1 Introduction

The world provides an endless stream of unfolding events that can surprise, delight, frighten, or bore. Such emotions provide the intimate experiences that define our personal lives. Sometimes emotions are overwhelming—as when we experience great pleasure or great agony. More often, emotions add subtle nuances that color our perceptions of the world. Emotions add depth to existence; they give meaning and value to life.

How do emotions arise? What purposes do they serve? What accounts for the distinctive feelings we experience? These questions have stimulated philosophers for centuries. More recently, these questions have inspired the curiosity of psychologists and cognitive scientists. But they are also questions that attract the attention of the "practitioners" of emotion. Playwrights, novelists, poets, film directors, musicians, choreographers, comedians, and theatrical magicians all have a professional interest in what distinguishes delight from boredom. Therapists, game designers, carnival operators, and traffic engineers have good reasons to try to understand what causes people to be surprised or fearful. Even advertisers and politicians have practical motivations for understanding how the flux of events shape human emotional experiences.

It is no coincidence that the performing arts have figured prominently in attempts to understand the dynamics of emotion. Over hundreds of years, poets, actors, comedians, and musicians have developed a sort of folk psychology about how certain emotions can be generated. Of the many arts, music has perhaps faced the most onerous challenges. Where the poet or playwright can evoke sadness by narrating a recognizably sad story, musicians must create sadness through abstract nonrepresentational sounds. Where a comedian might evoke laughter through parody, wordplay, or absurd tales, musicians must find more abstract forms of parody and absurdity. Where magicians evoke awe by appearing to transgress the laws of physics, no comparable recipe exists for creating musical awe. Despite the difficulties, musicians have amply demonstrated an exquisite skill in evoking the profoundly sad, the twistedly absurd, and the deeply awe-inspiring.

In each of the arts, codes of practice, heuristic rules of thumb, and speculative theories have been passed from teacher to student across the generations. These folk psychologies are based on a combination of intuition and tried-and-true techniques. In music, composers absorb a number of clichés—useful devices that are most easily observed in film scores. Trained musicians will readily recognize some commonplace examples: *tragedy* can be evoked by using predominantly minor chords played with rich sonorities in the bass register. *Suspense* can be evoked using a diminished seventh chord with rapid tremolo. *Surprise* can be evoked by introducing a loud chromatic chord on a weak beat.

For many thoughtful musicians, such clichés raise the question, "Why do these techniques work?" To this question, an ethnomusicologist might add a second: "Why do they often *fail* to work for listeners not familiar with Western music?" And an experienced film composer might insist on adding a third: "Why do they sometimes fail to work, even for those who are familiar with Western music?" In addressing these questions, intuition and folk psychology provide important starting points. But if we want to probe these questions in depth, we must ultimately embrace a more systematic approach. In theorizing about music and emotion, it is inevitable that we must move beyond folk psychology to psychology proper.

Many of the arts achieve specific emotional effects through a sort of stylized depiction or representation of common emotional displays. The mime exaggerates human body language and facial expressions. The cartoonist distills these same expressions into a few suggestive pen strokes. Even when a dancer aims for a strictly formal performance, her body movements will still tend to imply natural gestures or socially defined expressions. Music too involves mimicry of some natural emotional expressions. But aesthetic philosophers and music commentators have long noted that music is not a "representational" art in the way that painting or sculpture can be. How is music so successful in evoking emotions when its capabilities for representing the natural world seem so constrained?

In the 1950s, the renowned musicologist Leonard Meyer drew attention to the importance of *expectation* in the listener's experience of music. Meyer's seminal book, *Emotion and Meaning in Music,* argued that the principal emotional content of music arises through the composer's choreographing of expectation. Meyer noted that composers sometimes thwart our expectations, sometimes delay an expected outcome, and sometimes simply give us what we expect. Meyer suggested that, although music does contain representational elements, the principal source for music's emotive power lies in the realm of expectation.[1]

As a work of music theory, Meyer's approach was pioneering in its frequent appeals to psychological explanations. Despite Meyer's interest in psychology, however, *Emotion and Meaning in Music* was written at a time when there was little pertinent psychological research to draw on. In the intervening decades, a considerable volume of experimental and theoretical knowledge has accumulated.[2] This research provides an opportunity to revisit Meyer's topic and to recast the discussion in light of contemporary findings. The principal purpose of this book is to fill in the details and to describe a comprehensive theory of expectation—a theory I have dubbed the "ITPRA" theory.

Of course, expectations are not the province of music alone; expectation is a constant part of mental life. A cook expects a broth to taste a certain way. A pedestrian expects traffic to move when the light turns green. A poker player expects an opponent to bluff. A pregnant woman expects to give birth. Even as you read this book, you have many unconscious expectations of how a written text should unfold. If my text were abruptly to change topics, or if the prose suddenly switched to a foreign language, you would probably be dismayed. Nor do the changes need to be dramatic in order to have an effect. Some element of surprise would occur if a sentence simply ended. Prematurely.

Any theory of musical expectation necessarily presupposes a general theory of expectation. The ITPRA theory is intended to provide such a general theory. The theory is ambitious in scope and aims to account for all of the main psychological phenomena related to expectation. In particular, the ITPRA theory endeavors to account for the many emotion-related elements of expectation. The theory attempts to explain how expectations evoke various feeling states, and why these evoked feelings might be biologically useful.

The story of expectation is intertwined with both biology and culture. Expectation is a biological adaptation with specialized physiological structures and a long evolutionary pedigree. At the same time, culture provides the preeminent environment in which many expectations are acquired and applied. This is especially true in the case of music, where the context for predicting future sounds is dominated by cultural norms. In attempting to understand expectation, it is essential to take both biology and culture seriously. Accordingly, my text will freely meander through such topics as physiological and evolutionary psychology, learning, enculturation, style, and music history.

From an evolutionary perspective, the capacity to form accurate expectations about future events confers significant biological advantages. Those who can predict the future are better prepared to take advantage of opportunities and sidestep dangers. Over the past 500 million years or so, natural selection has favored the development of perceptual and cognitive systems that help organisms to anticipate future events. Like other animals, humans come equipped with a variety of mental capacities that help us form expectations about what is likely to happen. Accurate expectations are adaptive mental functions that allow organisms to prepare for appropriate action and perception.

But what about the emotional "feelings" that are often conjured up as a result of expectations? What gives *anticipation* or *surprise* their distinctive phenomenological characters? The story of emotion is intertwined with the psychology of behavioral motivation. Emotions are motivational amplifiers.[3] Emotions encourage organisms to pursue behaviors that are normally adaptive, and to avoid behaviors that are normally maladaptive. In this regard, the emotions evoked by expectation do not differ in function from other emotions. As we will see, the emotions accompanying expectations are intended to reinforce accurate prediction, promote appropriate event-readiness, and increase the likelihood of future positive outcomes. We will discover that music-making taps into these primordial functions to produce a wealth of compelling emotional experiences. In this way, musicians are able to create a number of pleasurable emotional experiences, including surprise, awe, "chills," comfort, and even laughter.

The biological purpose of expectation is to prepare an organism for the future. A useful place to begin is to consider, in general, what it means to be prepared.

Preparation

When you switch on a light, electrical energy streams down a convoluted path of wires from a distant power station. The speed with which this happens is impressive. The electricity flows at nearly the speed of light, which means that the power you consume was generated less than one one-thousandth of a second earlier. There is no time at the power station to "gear up" for your demand. The turbine generators must already be producing the electricity that the power company thinks you (and other customers) might need. Any energy generated that is not used by current customers is simply wasted: fuel is burned for no good reason. Clearly, power companies have a strong incentive to anticipate precisely how much power should be produced at any given moment in time.

All biological organisms consume power—power to maintain metabolisms, to move muscles, and to spark nervous systems. This power is expensive. It must be generated from the food the animal consumes, and gathering food is difficult, time-consuming, and very often dangerous. As with the electrical grid, the amount of power required by an organism changes from moment to moment, so it is important for the animal to avoid waste by matching the amount of energy generated with the amount the animal needs.

Commercial power producers employ teams of statisticians whose sole job is to try to predict power demands. They estimate what time people will get up on Saturday morning, how many people are likely to watch the big game on TV, and whether the outside temperature will entice customers to turn on their air conditioners. The predictive models used by utility companies are elaborate and impressive feats of human ingenuity. But like so many other human creations, the complexity and efficiency of these predictive models pale when compared with the achievements of nature.

Organisms are constantly trying to conserve energy. Bodies (including brains) drift toward low states of arousal when no action or thought is needed. In a static unchallenging environment, minds grow bored and bodies grow limp. We respond to these environments by invoking nature's all-purpose energy-conservation strategy—*sleep*. Of course, sometimes the events of the world do require some appropriate action, and so the body and mind must be roused in preparation. Like a machine that has been turned off, a certain amount of time is needed for us to "power up."

When you unexpectedly hear the sound of a barking dog, your heart will quicken and the volume of blood flowing to your muscles will increase. At the same time, an important hormone, norepinephrine, will be released in your brain making you more alert and attentive. In truly dangerous situations, this response, quick as it is, may prove to be too slow. Like a power "brown out," the demands of the body might momentarily exceed the supply of resources. Many animals have become another animal's dinner in the split second required to respond to danger. If only one could have known in advance to increase the power output and pay closer attention. If one could have anticipated the danger, a more effective response might have been rallied.

Over the eons, brains have evolved a number of mechanisms for predicting the future. The biological purpose of these mechanisms is to prepare the body and mind for future events while simultaneously minimizing the consumption of metabolic resources. From a physiological perspective, there are two interrelated systems that influence metabolic consumption: *arousal* and *attention*. The arousal system controls heart rate, respiration, perspiration, and many other functions associated with movement. The attention system is more subtle. Attention spurs the brain to be more engaged with the world. Instead of looking at nothing in particular, our gaze becomes focused. Instead of tuning out a conversation, we pay close attention to what is being said. Instead of daydreaming, we become grounded in the here and now. All of this takes energy.

Arousal and attention levels fluctuate according to both the actual and the anticipated demands of the environment. When we think of arousal and attention reacting to the environment, there is a tendency to think foremost of them as *increasing*. However, the arousal and attention systems can also *reduce* or *inhibit* responsiveness. The experiences of boredom and sleepiness are no less manifestations of metabolic fine-tuning than are the experiences of excitement and exhilaration.

We may also tend to think of arousal and attention as systems that deal necessarily with the uncertainties of life. But even if we knew with exact precision and certainty all of the future events in our lives, we would still need anticipatory mental and corporeal changes to fine-tune our minds and bodies to the upcoming events. Suppose, for example, that I know that at 9:18 A.M. I will encounter an obstacle on the path requiring me to steer my bicycle around it. This godlike foreknowledge does not absolve me from having to attend to the object and make the appropriate motor movements at the appointed time. Nor can I execute any of the needed mental or corporeal maneuvers before they are required. So perfect knowledge of the future would not change the fact that attention and arousal levels must fluctuate according to the moment.

Of course, such perfect knowledge of the future doesn't exist; we do live in a world in which the future is uncertain, and this uncertainty does make it more difficult to produce the optimum arousal and attention. How do we prepare for a future that has untold possibilities? Sometimes this uncertainty doesn't matter. There are some situations where the precise outcome is highly uncertain, but where all of the potential outcomes would require the same type of mental and physical preparation. In a casino, a roulette croupier has no idea which number will appear on the wheel, but the croupier's ensuing actions are highly practiced: collect the chips from the losing bets and reward any successful bets. While the croupier's actions are obviously guided by the result on the roulette wheel, the croupier's response depends very little on the specific outcome—unlike the responses of the gamblers!

These sorts of situations are not commonplace, however. More commonly, different outcomes will require different optimum responses. The body typically faces a quandary: which of several possible outcomes does one prepare for? In preparing the body and mind for these outcomes, our instincts are depressingly pessimistic. Like a grumbling naysayer, nature tends to assume the worst. Consider, for example, the slamming of a door. Even though we may see that the door is about to slam shut, it is difficult to suppress the impending startle or defense reflex. We know the door poses no danger to us, but the sound of the slamming door provokes a powerful bodily response anyway. Despite our annoyance, nature knows best: it is better to respond to a thousand false alarms than to miss a single genuinely dangerous situation.

As we will see later, nature's tendency to overreact provides a golden opportunity for musicians. Composers can fashion passages that manage to provoke remarkably strong emotions using the most innocuous stimuli imaginable. As every music-lover knows, simple sequences of sounds hold an enormous potential to shape feelings. As we will see, it is nature's knee-jerk pessimism that provides the engine for much of music's emotional power—including feelings of joy and elation.

The object of expectation is an event in time. Uncertainty accompanies not only *what* will happen but also *when* it will happen. Sometimes the *when* is certain but not the *what*. Sometimes the *what* is known, but not the *when*. Later, we will see how music manipulates both kinds of uncertainty, and how the different what/when combinations produce different emotional responses.

Along with *what* and *when,* brains also predict *where* and *why*—but these are more specialized operations. For sound stimuli, the *where* expectations are associated with physiologically ancient structures for sound localization. Musicians have sometimes manipulated the locations of sounds (as in the antiphonal works of Giovanni Gabrieli or the electroacoustic works of Karlheinz Stockhausen), but they have less often manipulated listener *expectations* of location. The *why* expectations are associated with physiologically recent structures associated with conscious thought. In contrast to the *what* and *when* of prediction, the *where* and *why* components of auditory expectation have played little role in musical organization and experience. But they represent opportunities for future enterprising composers.

Emotional Consequences of Expectations

As I have noted, the ability to anticipate future events is important for survival. Minds are "wired" for expectation. Neuroscientists have identified several brain structures that appear to be essential for prediction and anticipation. These include the substantia nigra, the ventral tegmental area, the anterior cingulate cortex, and the lateral prefrontal cortical areas.[4] Most people will regard such biological facts as uninteresting details. For most of us, the more compelling details pertain to the subjective experience. From a phenomenological perspective, the most interesting property of expectation is the feeling that can be evoked. What happens in the future matters to us, so it should not be surprising that how the future unfolds has a direct effect on how we feel.

Why precisely do expectations evoke various feeling states? I propose that the emotions evoked by expectation involve five functionally distinct physiological systems: imagination, tension, prediction, reaction, and appraisal. Each of these systems can evoke responses independently. The responses involve both physiological and psychological changes. Some of these changes are autonomic and might entail changes of attention, arousal, and motor movement. Others involve noticeable psychological changes such as rumination and conscious evaluation.

Outcomes matter, so the evoked emotions segregate into positive and negative kinds. That is, the feeling states are *valenced*. Positive feelings reward states deemed to be adaptive, and negative feelings punish us for states deemed to be maladaptive. The word "deemed" here is important. Positive feelings are evoked not by results that are objectively adaptive, but by results that the brain, shaped by natural selection, presumes to be adaptive. From time to time the evoked emotions are wrongheaded. For example, a family pet may experience acute distress when being taken to the veterinarian—despite the fact that the medical attention objectively increases the animal's well-being. Like the family pet, we can feel that our world is falling apart even while good things are happening to us. Each of the five response systems makes different assumptions about what is good or bad. So different emotions can be evoked by each of the five systems.

The five response systems can be grouped into two periods or epochs: *pre-outcome* responses (feelings that occur prior to an expected/unexpected event) and *post-outcome* responses (feelings that occur after an expected/unexpected event). Our discussion begins with two types of pre-outcome responses: those of the imagination and the tension systems.

1 Imagination Response

Some outcomes are both uncertain and beyond our control. The weather provides a good example. It may or may not rain, but you are helpless to influence either outcome. Other outcomes, however, may lie within our control. If it rains, you might get wet; but if you carry an umbrella you can reduce the probability of that outcome. In short, people have no control over "rain," but we sometimes have control over "getting wet."

At some point in animal evolution, the ability to predict aspects of the future led to the emergence of other mental mechanisms that attempted to ensure that particular future outcomes were more likely to occur than others. Once an animal is able to predict that some events are likely, there is a lot to be gained if one behaves in a fashion that increases the likelihood of a favorable outcome.

Imagining an outcome allows us to feel some vicarious pleasure (or displeasure)—as though that outcome has already happened. You might choose to work overtime because you can imagine the embarrassment of having to tell your boss that a project remains incomplete. You might decide to undertake a difficult journey by imagining the pleasure of being reunited with a loved one. This *imagination response* is one of the principal mechanisms in behavioral motivation. Through the simple act of day-dreaming, it is possible to make future outcomes emotionally palpable. In turn, these feelings motivate changes in behavior that can increase the likelihood of a future favorable result.[5]

Neurological evidence for such an imagination response is reported by Antonio Damasio, who has described a clinical condition in which patients fail to anticipate the feelings associated with possible future outcomes.[6] In one celebrated case, Damasio described a patient ("Elliot") who was capable of feeling negative or positive emotions after an outcome had occurred, but was unable to "preview" the feelings that would arise if a negative outcome was imminent. Although Elliot was intellectually aware that a negative outcome was likely, he failed to take steps to avoid the negative outcome because, prior to the outcome, the future negative feelings were not palpable and did not seem to matter. Damasio's clinical observations have established that it is not the case that we simply think about future outcomes; when imagining these outcomes, we typically are also capable of feeling a muted version of the pertinent emotion. We don't simply *think* about future possibilities; we *feel* future possibilities.

The imagination response provides the biological foundation for deferred gratification. Feelings that arise through imagination help individuals to forgo immediate pleasures in order to achieve a greater pleasure later. Without this imaginative emotional capacity, our lives would be dominated entirely by petty excitements. From time to time, pop psychologists and self-appointed spiritual advisors have advocated that people focus on living in the here and now and let go of their concerns for the future. Damasio's patients have achieved exactly such a state. For these individuals, the future is a gray abstraction that is irrelevant to the business of living. As a consequence, they lose their friends, go bankrupt, and live lives in which present-tense joys become increasingly hard to achieve because they are unable to plan ahead. It is important to pause and smell the roses—to relish the pleasures of the moment. But it is also crucial to take the imaginative step of planting and nurturing those roses.

If we think of positive and negative feelings as hills and valleys in a complex landscape, the imagination response helps us avoid getting stranded at the top of the nearest hill. Imaginative *thought* allows us to see the higher peaks that might be experienced if only we are willing to first descend into one or more valleys. But it is imaginative *emotions* that motivate us to undertake the difficult journey to reach those higher peaks.

2 Tension Response

A second form of pre-outcome emotional response originates in the mental and corporeal preparation for an anticipated event. At a party, a friend approaches you with a balloon in one hand, and a sharp pin poised for action in the other hand. The grin on your friend's face suggests that the balloon is not likely to remain inflated for long. You squint your eyes, put your fingers in your ears, and turn your face away.

Preparing for an expected event typically involves both motor preparation (arousal) and perceptual preparation (attention). The goal is to match arousal and attention to the expected outcome and to synchronize the appropriate arousal and attention levels so that they are reached just in time for the onset of the event. Usually, events require some increase in arousal. Heart rate and blood pressure will typically increase, breathing will become deeper and more rapid, perspiration will increase, and muscles will respond faster. In addition, pupils may dilate, eyes may focus, the head may orient toward (or away from) the anticipated stimulus, and distracting thoughts will be purged. These (and other) changes help us to react more quickly and to perceive more accurately.

If we want to conserve the maximum amount of energy, then we ought to wait until the last possible moment before increasing attention or arousal. If it only takes a second or two to reach an optimum arousal, then we shouldn't begin increasing arousal until a second or two prior to the outcome. This simple ideal is confounded, however, by uncertainty—uncertainty about *what* will happen, and uncertainty about *when* it will happen. When we are uncertain of the timing of the outcome, we must raise arousal or attention levels in advance of the earliest anticipated moment when the event might happen. If the actual event is delayed, then we might have to sustain this heightened arousal or attention for some time while we continue to wait for the event.

I once saw a couple moving from their second-storey apartment. Having tired of running up and down the stairs, they had resorted to dropping bundles of clothing from their apartment balcony. She would toss bags over the railing while her partner would try to catch them before they hit the ground causing the plastic bags to split. Unfortunately, the physical arrangement prevented the two of them from making eye contact. As a consequence, her partner stood on the ground with his arms perpetually outstretched, unsure of when the next bag would drop out of the sky. I recall this incident because the man looked so silly—like something out of a Laurel and Hardy film. At one point, I could see that the woman had gone back into the apartment to fetch some more bags, but the man was still staring intently upward, arms outstretched, rocking back and forth in anticipation. He was wasting a great deal of energy because the timing of expected events was so uncertain.

Apart from uncertainty regarding *timing*, we may have difficulty tailoring the *level* of arousal or attention. When the exact nature of the outcome is uncertain, it can be difficult to match precisely the arousal and attention levels to the ultimate outcome. The safest strategy is to prepare for whatever outcome requires the highest arousal and/or attention level. In a baseball game, a fielder can clearly see the pitcher's windup and whether or not the batter swings. There is little doubt about the timing of outcomes. The uncertainty resides principally with the *what*: Will the batter hit the ball? And if so, will the ball be hit into the fielder's area of play? The actual probability of a batter hitting any given pitch into the vicinity of the fielder is comparatively low. Nevertheless, the fielder's best preparation is to assume the worst—namely, a hit into the fielder's area. Unfortunately, this vigilance comes at a cost. With each pitch, arousal and attention peak and then subside (presuming no action is needed). Maintaining high levels of arousal and attention will cause the player to expend a lot of energy. In an important championship game, a fielder is apt to be exhausted by the end of the game, even if the player never had to field a ball.

In the case of the man catching bags of clothing, the uncertainty relates mostly to the *when*, not the *what*: a bag of clothing would surely drop out of the sky, but the timing was uncertain. In the case of the baseball fielder, the uncertainty pertains mostly to the *what*, not the *when*: the ball can only be hit after the pitcher throws the ball. But the outcome of each pitch is uncertain.

The most uncertain situations are those where both the *when* and the *what* are unknown. A soldier on guard duty, for example, might have reason to fear a possible attack. Although the shift may pass uneventfully, the heightened attention and arousal engendered by the expectation of a possible attack is likely to produce acute mental and physical exhaustion.

As it turns out, the physiological changes characteristic of high arousal are also those associated with stress. Not all high arousal is stressful: positively valenced emotions such as joy and exuberance will evoke high arousal with little stress. But anticipating negative events is sure to be stressful. In dangerous situations, organisms respond with one of three classic behaviors: *fighting*, *fleeing*, or *freezing*. The greatest stress tends to occur when high arousal coincides with low movement. Consequently, it is the *freeze* response that engenders the most stress. Fighting and fleeing are active responses, while the freeze response is often symptomatic of helplessness. This is thought to be the reason why the worst health effects of stress are to be found in those people who are unable to do anything to alleviate their stressful conditions.

When anticipating some future event, our physiological state is often akin to that of the freeze response. We may experience elevated heart rate and perspiration without any motor movement. The word “dread” captures the stressful feeling that accompanies anticipating a bad future outcome. By contrast, anticipating something positive evokes a feeling something like being “heartened.” But even anticipating something positive has some accompanying stress. In the pre-outcome period, nothing is certain, and so our heartened state is likely to be mixed with a nagging fear that an anticipated positive result may not actually come to pass.

Since stress commonly accompanies the rise of anticipatory arousal, I have chosen the word “tension” to characterize these sorts of pre-outcome responses. Both the baseball fielder and the man catching bags of clothing were experiencing distinct physiological states in anticipation of future outcomes.

Unlike the imagination response, the tension response is linked to the period immediately prior to the anticipated moment of outcome. As the arousal and attention levels move toward an optimum level in anticipation of the outcome, the physiological changes themselves evoke characteristic feeling states. The feelings that accompany the tension response are artifacts. The evoked feeling states have no particular function by themselves, but are simply consequences of the physiological changes that accompany preparation for an anticipated outcome.

The “artifact” status of certain emotions was famously proposed by William James and Carl Lange roughly a century ago.[7] In an often quoted passage, James argued that fear was evoked by the act of trembling, sorrow was evoked by the act of crying, and so on.[8] This “James–Lange” theory of emotion has a checkered history. Some important research supports the theory.[9] One example is found in a simple experiment carried out by Fritz Strack and his colleagues where participants were asked to hold a pencil in their mouth.[10] In one condition, participants held the pencil using their teeth without allowing their lips to touch the pencil. In a contrasting condition, participants held the pencil with their lips only. Strack showed that the manner by which participants hold the pencil has a direct effect on how they feel. Grasping a pencil between your teeth causes you to feel happier than grasping it with your lips. The difference can be traced to the flexing of the zygomatic muscles: holding a pencil between your teeth produces something very similar to smiling. It is not just that you smile when happy—you can feel happy *because* you smile.[11]

The research by Strack and others notwithstanding, there is also research that is wholly inconsistent with the James–Lange theory.[12] It is probably the case that the sort of physiologically induced emotions described by James and Lange are limited to a handful of particular circumstances. I propose that the tension response is one of the circumstances in which the James–Lange theory holds. Simply flexing muscles in anticipation of catching a ball will change a person's feeling state. The evoked feelings will depend on which muscles are flexed. Flexing abdominal muscles will tend to evoke a different affect than squinting eyes, smiling, or clutching a steering wheel.

There are several factors that influence the character and magnitude of the tension response. These include the degree of uncertainty, the importance of the possible outcomes, the difference in magnitudes between the best and worst plausible outcomes, and the estimated amount of time before the outcome is realized. Sometimes outcomes are utterly certain and have little consequence. These situations evoke little tension. In other cases, we may have little idea about what will happen. If one or more of the possible outcomes involves a high stake (something very good or very bad), then we will tend to be more alert and aroused as the moment approaches when the outcome will be made known.

In general, organisms should try to avoid situations of high uncertainty. High uncertainty requires arousal and vigilance, both of which incur an energy cost. Consequently, it would be adaptive for an organism to experience high tension responses as unpleasant. That is, even if only positive outcomes are possible, high uncertainty will lead to a certain amount of unpleasant stress.[13]

3 Prediction Response

Once some event occurs, there ensues a convoluted sequence of physiological and psychological changes. It is useful to distinguish three post-outcome responses.

As you might suppose, organisms respond better to expected events than unexpected events. Accurate predictions help an organism to prepare to exploit opportunities and circumvent dangers. When a stimulus is expected, appropriate motor responses are initiated more rapidly and more accurately. In addition, a stimulus is more accurately perceived when it is predictable.

Since accurate predictions are of real benefit to an organism, it would be reasonable for psychological *rewards and punishments to arise in response solely to the accuracy of the expectation*. Following a snow storm, for example, I might predict that I will slip and fall on the sidewalk. In the event that I actually fall, the outcome will feel unpleasant, but the experience will be mixed with a certain satisfaction at having correctly anticipated this dismal outcome. This expectation-related emotion might be dubbed the *prediction response*. When the stimulus is expected, the emotional response is postively valenced; when the stimulus is unexpected, the emotional response is negatively valenced.

Psychological evidence in support of a prediction response is found in the classic work of George Mandler.[14] An abundance of subsequent experimental research has affirmed the importance of this response. In fact, this response is considered so important in the extant literature on expectation that it is commonly referred to as the *primary affect*.[15] Confirmation of expected outcomes generally induces a positive emotional response even when the expected outcome is bad. It is as though brains know not to shoot the messenger: accurate expectations are to be valued (and rewarded) even when the news is not good. We will devote an extended discussion to this important response in chapter 8.

4 Reaction Response

The most obvious emotions in the post-outcome epoch are those that pertain to the pleasantness or unpleasantness of the outcome itself. Once an outcome is known, our emotions reflect some sort of assessment of the new state. For example, we might experience fear when encountering a snake, sadness when receiving a poor grade, or joy when meeting an old friend. These emotional responses occur only after the outcome is known.

Extensive research has established that there are two types of responses to the advent of events. One type of response is very fast. The other type of response is more leisurely. The fast response represents a "quick-and-dirty" assessment of the situation followed by an immediate somatic (bodily) response. The second response represents a more "thoughtful" assessment of the situation—a response that takes into account complex social and environmental factors. I propose to call the fast response a *reaction response,* and the more complex slower response an *appraisal response*.

Reaction responses exhibit three characteristic features: (1) The response has a fast onset. Typically, the onset of the response begins less than 150 milliseconds following the onset of the outcome. Although the onset of the response is fast, the somatic changes arising from the response might continue for several seconds afterward. (2) The response is not mediated by consciousness. No conscious thought or rumination is involved. Some reaction responses can even occur when we are asleep. (3) The response is defensive or protective in function. The reaction assumes a worst-case scenario, and responds accordingly.

An example of a reaction response is a *reflex*. Suppose that you accidentally touch a hot oven. A well-documented reflex will cause your hand to be abruptly withdrawn from the hot surface. Surprisingly, this reflex is so fast that it happens in less time than it takes for a neural signal to travel from the hand up to the brain and then back down from the brain to the muscles of the arm. Physiologists have determined that the reflex originates in the spine rather than in the brain. So-called *reflex arcs* in the spine connect the sensory neurons in the hand to the motor neurons of the arm. You have withdrawn your hand before your brain even registers the sensation of the hot surface. The reflex has a fast onset, is not mediated by consciousness, and has a defensive function.

Reflexes are examples of reaction responses, but not all reaction responses are technically reflexes. As we will see later, reaction responses can also be *learned*—which is not the case with reflexes. More specifically, we will see that learned *schemas* are used in reaction responses. These learned reaction responses are easiest to observe in situations of surprise. By way of example, consider wrong with speak. Violations of grammar—such as in the preceding sentence—evoke a mild but rapid surprise. Of course English grammar is entirely learned, so the reaction can't be considered a reflex—despite its speed and automaticity. The surprise here arises from a discrepancy between an actual outcome and a highly practiced schema.

Learned schemas span a huge range of behaviors. Schemas can relate to practiced motor skills (such as brushing your teeth) or perceptual norms (such as watching traffic flows). Schemas can involve social norms (such as polite greeting rituals) or cultural norms (such as framing an object so that it is recognized as "art"). As long as the schema is well entrenched in a mind, it becomes possible to provoke reaction responses by violating the schematic expectation. In chapter 2 we will consider such reactive surprises in greater detail, and focus specifically on the feeling states that can be evoked.

5 Appraisal Response

Suppose you answer the phone and are pleasantly surprised to hear the voice of a close friend. Within a second, your pleasure turns to acute embarrassment as you realize that you have forgotten your friend's recent birthday. Or, imagine an experienced biologist is walking in a forest and is startled when a large spider drops onto the sleeve of her jacket. Her negative feelings immediately turn to joy as she realizes that she may have discovered a new species of spider.

Our initial reactions to events are susceptible to revision or augmentation. What we find initially exciting or startling may be completely transformed by further thought. The *reaction response* is quick and unconscious. Once conscious thought is engaged, the assessment of a situation is the province of the *appraisal response*. The above examples are illustrations of when the appraisal response and the reaction response evoke contrasting emotions. But the two responses may also reinforce one another. A near accident in an automobile might quickly evoke a feeling of fear. The subsequent recognition that you were not wearing a seat belt and that any accident would have likely proved fatal might provoke an even stronger sense of fear. Moreover, further conscious thought might lead you to realize that you are behind in your life insurance payments, and that had you died, your children would not have been adequately provided for—hence evoking even greater fear.

As you continue to ruminate about a situation, several successive appraisal responses might ensue. The important point is that appraisal responses can involve conscious thought that often draws on complex social and contextual factors. By contrast, the reaction response involves no conscious thought.

The reaction response and the appraisal response are independent and need not be consistent with each other. As we have seen, a single outcome can produce a negatively valenced reaction response and a positively valenced appraisal response (or vice versa). We will see many examples of such paradoxical feeling states in later chapters. In addition, different people may experience similar reaction responses, but contrasting appraisals. Consider, for example, two office workers who are both startled by the unexpected ringing of their telephones. After the initial start, the worker in the sales department may become excited because the call represents the possibility of making a sale (with an accompanying commission). But the worker in the customer service department might react more negatively, since the call likely represents a customer with a complaint.

In general, positive and negative emotions act as behavioral reinforcements. The pain caused by biting your tongue teaches you to chew carefully and avoid tissue damage. Bad tastes and bad smells reinforce the aversion to ingesting unhealthy foods. The pleasure caused by engaging in sex encourages procreation. The enjoyment of playing with our children encourages parental investment and nurturing. Positive emotions encourage us to seek out states that increase our adaptive fitness. Negative emotions encourage us to avoid maladaptive states.

The ITPRA Theory of Expectation

To summarize: I have distinguished five expectation-related emotion response systems. Each response system serves a different biological function. The purpose of the *imagination response* is to motivate an organism to behave in ways that increase the likelihood of future beneficial outcomes. The purpose of the *tension response* is to prepare an organism for an impending event by tailoring arousal and attention to match the level of uncertainty and importance of an impending outcome. The purpose of the *prediction response* is to provide positive and negative inducements that encourage the formation of accurate expectations. The purpose of the *reaction response* is to address a possible worst-case situation by generating an immediate protective response. The purpose of the *appraisal response* is to provide positive and negative reinforcements related to the biological value of different final states. All of these goals are biologically adaptive. Table 1.1 summarizes these five response systems and presents them in their approximate order in time.

Table 1.1

Response system	Epoch	Biological function
(I) *imagination response*	pre-outcome	future-oriented behavioral motivation; enables deferred gratification
(T) *tension response*	pre-outcome	optimum arousal and attention in preparation for anticipated events
(P) *prediction response*	post-outcome	negative/positive reinforcement to encourage the formation of accurate expectations
(R) *reaction response*	post-outcome	neurologically fast responses that assume a worst-case assessment of the outcome
(A) *appraisal response*	post-outcome	neurologically complex assessment of the final outcome that results in negative/positive reinforcements

Informally, we might characterize the "feeling" components to these responses by posing five questions:

1. What do you think might happen, and how do you feel about that prospect?
2. Are you ready for what's about to happen? How do the preparations make you feel?
3. Did you "place a good bet"—did you predict the outcome accurately? Are you pleased or disappointed by the accuracy of your wager?
4. Assuming the worst, how have you reacted? How does this reaction make you feel?
5. Upon reflection, how do you feel about how things have turned out?

Once again, these five response systems are evoked at different times in the expectation cycle. The imaginative function may begin years prior to an expected event. A person might imagine the sense of achievement associated with graduating from college or paying off a mortgage. As an anticipated event approaches, the emotions evoked by the imagination become dwarfed by the feelings evoked by the mental and corporeal preparations for the actual event—especially if the outcome is uncertain. These preparatory responses relate predominantly to a sense of stress or tension. Once the outcome is known, three response systems are set in motion. One component simply responds to the accuracy of the prediction. In tandem with this prediction response are the emotional states evoked by the reaction and appraisal responses. A short-lived reaction response is typically replaced by the more nuanced appraisal response. Like the imagination phase, the appraisal emotions have the potential to last for years. One may still feel good about some long-ago success, or feel regret about some long-ago failure. The time course of these different emotional responses is illustrated in figure 1.1. It is this time-course that leads to the acronym ITPRA: Imagination–Tension–Prediction–Reaction–Appraisal. Since the prediction and reaction responses

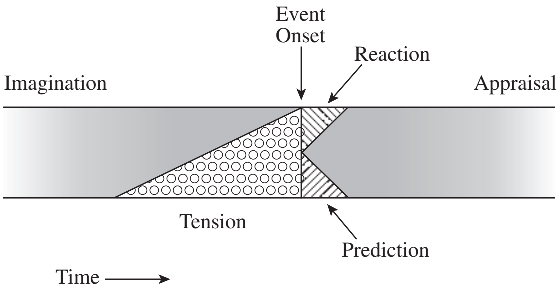

Figure 1.1
Schematic diagram of the time-course of the "ITPRA" theory of expectation. Feeling states are first activated by imagining different outcomes (**I**). As an anticipated event approaches, physiological arousal typically increases, often leading to a feeling of increasing tension (**T**). Once the event has happened, some feelings are immediately evoked related to whether one's predictions were borne out (**P**). In addition, a fast reaction response is activated based on a very cursory and conservative assessment of the situation (**R**). Finally, feeling states are evoked that represent a less hasty appraisal of the outcome (**A**).

occur in tandem, one might equally call it ITRPA (reversing the R and P), but I prefer the more pronounceable ITPRA.

As I have noted, I propose that these five response systems arise from five functionally distinct neurophysiological systems. Each response system solves an important problem in tailoring behavior so that it is optimally adapted to a given environment. Since each response system addresses a different biological problem it is possible that each system represents a distinct evolved adaptation. One might even propose a plausible order of evolution for these systems. The oldest response system is probably the (unconscious) reaction response. Clearly, an organism must take appropriate actions in response to what actually happens in the world; outcomes (and our responses to them) are what matter most. An organism that always assumes the worst outcome has a better chance of surviving those occasional situations that are truly dangerous. Since these hasty reaction responses are commonly exaggerated, some basic elements of the appraisal response probably evolved next. This would have begun as an (unconscious) inhibitory function, suppressing those reaction responses that are excessively conservative. The tension response was likely next to evolve. Simple classical conditioning might allow an organism to anticipate what happens next, and there are clear advantages to tailoring the arousal and attention to the expected event. Since the prediction response provides a way to evaluate the predictions implicit in the tension response, the prediction response must have appeared after the advent of the tension response. Finally, the imagination response is probably the most recent evolutionary addition. Once one achieves some modicum of success in predicting the future, there is obvious value in trying to change the future through our own actions.

Each of these five proposed systems is able to evoke various feeling states—although some systems are more constrained than others. The tension and reaction responses, for example, have a limited range of affective expressions. By contrast, the appraisal response is able to evoke a huge range of feeling states, from jealousy, contempt, or loneliness, to compassion, pride, or humor.[16] For any given situation, these five proposed systems combine to create a distinctive limbic cocktail. Actually, "cocktail" isn't quite the right word, because it is a dynamic phenomenon rather than a simple static mixture. Expectation-related emotions can begin long before an event occurs and can linger long afterward. Within this time span, a dynamically evolving sequence of feelings can arise.

As we will see later, these systems combine to produce a wealth of different feeling experiences in different circumstances. Of all the "practitioners" of emotion, musicians, I believe, have proved the most adept at manipulating the conditions for these different dynamic responses. Although I have used nonmusical examples in this chapter, the principal focus of this book will be on using the ITPRA theory to explain many aspects of musical organization. In chapters 13 to 15 we will see how musicians make use of these psychological systems, and in chapter 16 we will see how the psychology of expectation has shaped a major event in Western music history. But before we apply the ITPRA theory to specific musical circumstances, there are a number of supporting topics that need to be addressed. How does a listener know *what* to expect? How are expectations acquired? Are all expectations learned, or are some innate? How are expectations mentally represented? How are expectations tailored to a particular context? How do the different response systems interact? These and other questions will occupy the next several chapters.

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