# Chapter 2

## Classical Music and the Classical Mind

### 2.0 CHAPTER OVERVIEW

The classical approach dominates modern cognitive science. The classical approach is based upon the assumption that cognition is the rule-governed manipulation of mental representations. It adopts the sense–think–act cycle (Pfeifer & Scheier, 1999), assuming that the primary purpose of cognition is to plan future actions by thinking about information provided by perceptual mechanisms. One purpose of the current chapter is to provide a brief introduction to some general characteristics of classical cognitive science: the prevalence of logicism, the manipulation of content-laden formal structures, the disembodiment of thought, and the emphasis on central control mechanisms. A second purpose of the current chapter is to draw a parallel between classical cognitive science and the traditional notion of classical music. This is done by showing that these central characteristics of classical cognitive science are also fundamental to the Austro-German tradition of classical music.

At the end of Chapter 1, we raised the question of whether higher-order human cognitive phenomena were less rational than might be expected. This question is one of the central motives for focusing on classical music in Chapter 2. As the first part of Chapter 2 explores the analogy between classical cognitive science and classical music, it seems evident that classical cognitive science is ideally suited to explain the act of musical composition. However, the second part of Chapter 2 pursues the analogy in such a way as to challenge "classical explanations." First, we explore a number of reactions against Austro-German classical music that are evident in modern classical music. We also show how these reactions are analogous to the reactions of embodied cognitive science against classical cognitive science. In the end, we see that many non-classical characteristics (decentralized control, embodiment, emergence, and stigmergy) are fundamental to modern music, and may also be evident in older musical traditions. In this situation, classical cognitive science may not be well suited to explain musical composition after all. Alternative traditions, such as embodied cognitive science, may be better suited. If this is true for explaining the composition of music, then is it not reasonable to expect that many less sophisticated human achievements might be better explained by alternative approaches to cognitive science? A main goal of Chapter 2 is to motivate this question; the chapters that follow then attempt to explore alternative approaches. For instance, Chapter 3 will introduce the notions of situated cognition and *bricolage,* which are central to the robots that we begin to describe in Chapter 4.

## 2.1 THE BOOLEAN DREAM

### 2.1.1 Cognitive Science

Cognitive science is an interdisciplinary approach to explaining mental phenomena (Bechtel, Graham, & Balota, 1998; Dawson, 1998; Goldman, 1993; Lepore & Pylyshyn, 1999; Pylyshyn, 1980; Simon, 1980; Thagard, 1996; Von Eckardt, 1993). Cognitive science is dominated by the representational theory of mind (Fodor, 1975; Newell, 1980; Pylyshyn, 1984), which is frequently called the *classical approach*, which assumes that external behaviour is mediated by the contents of internal representations. Such representations are intentional (Brentano, 1874/1995), in the sense that they stand for, or are about, states of affairs in the external world.

According to classical cognitive science, thinking is the manipulation of mental representations by rules. Rules are sensitive to the formal nature of mental symbols (Haugeland, 1985). That is, a symbol's form is used to identify it as being a token of a particular type. When identified in this way, only certain rules can be applied to it. While the rules are sensitive to the formal nature of symbols, they act in such a way to preserve the meaning of the information that the symbols represent. That is, if one manipulates the symbols according to the available formal rules, then one will not be able to create a meaningless representation. This property derives from classical cognitive science's logicism, which is discussed below.

### 2.1.2 Logicism

Aristotle claimed rationality separated men from beasts: humans have minds, and can reason; animals are mindless, and therefore cannot reason (Oaksford & Chater, 1998). This view is called *logicism*, and it is strongly linked to classical cognitive science.

Logicism is evident in George Boole's *An Investigation of the Laws of Thought* (Boole, 1854). Boole noted, "it is unnecessary to enter here into any argument to prove that the operations of the mind are in a certain real sense subject to laws" (p. 3). Boole's purpose was to "investigate the fundamental laws of those operations of the mind by which reasoning is performed; to give expression to them in the symbolic language of a Calculus, and upon this foundation to establish the science of Logic and construct its method" (p. 1).

Boole's (1854) logicism equated thinking with applying logical rules. "There is not only a close analogy between the operations of the mind in general reasoning and its operations in the particular science of Algebra, but there is to a considerable extent an exact agreement in the laws by which the two classes of operations are conducted" (p. 6). Modern versions of logicism endorse this view as well. For instance, a famous introductory logic book (Kalish & Montague, 1964) viewed logic as mirroring everyday reasoning. Formal logic is also a powerful and popular tool for knowledge representation and manipulation in the field of artificial intelligence (Genesereth & Nilsson, 1987; Levesque & Lakemeyer, 2000).

### 2.1.3 The Boolean Dream

Boole's (1854) formalism attempted to explain reasoning without appealing to underlying biological mechanisms. This has been called the Boolean Dream of classical cognitive science (Hofstadter, 1995). "The traditional holy grail of AI has always been to *describe thoughts at their own level* without having to resort to describing any biological (i.e. cellular) underpinnings of them" (p. 125). The Boolean Dream reflects the classical approach's emphasis on the roles or functions of various system components (Cummins, 1983; Fodor, 1968), and recognizes that many different physical devices can produce identical functions (the multiple realization argument). As a result, classical cognitive science is logicist in nature, because it attempts to explain cognition by appealing to formal rules or a "language of thought" (Fodor, 1975; Fodor & Pylyshyn, 1988; Pylyshyn, 1984). "It would not be unreasonable to describe Classical Cognitive Science as an extended attempt to apply the methods of proof theory to the modeling of thought" (Fodor & Pylyshyn, 1988, pp. 29–30).

## 2.2 CLASSICAL COGNITIVE SCIENCE

### 2.2.1 A Classical Device

There is a long history of performing logical operations with special purpose diagrams or machines (Gardner, 1982). The first special-purpose "logic machine" was Charles Stanhope's demonstrator, built sometime before 1816.

Classical cognitive science's logicism results because the modern representational theory of mind was inspired by a much more general symbol-manipulating device, the digital computer. Symbol-manipulating computers were proven to be capable of solving any computable problem (Turing, 1936). Philosopher Kenneth Craik linked the operations of such machines to laws of thought (Craik, 1943): "My hypothesis then is that thought models, or parallels, reality—that its essential feature is not 'the mind', 'the self', 'sense data' nor 'propositions', but is symbolism, and that this symbolism is largely of the same kind which is familiar to us in mechanical devices which aid thought and calculation" (p. 57). It did not take long for prominent researchers to become convinced of the inevitability of machine intelligence (Turing, 1950).

The prototypical "mechanical device" for manipulating symbols is the *Turing machine* (Hodges, 1983; Turing, 1936). It uses tickertape as a medium for storing data. The tape is divided into cells, each of which can store a single symbol from a finite alphabet. The Turing machine's *machine head* moves back and forth along the tape, reading symbols, and rewriting the tape according to rules stored in a *machine table*.

A Turing machine is a device for answering questions. A question is written on the machine's tape, and is then given to the machine head. When the machine head halts, it has written an answer to the question on the tape. The kind of question that a particular Turing machine can answer is dictated by its machine table. To answer different types of questions, different machine tables are required, requiring a *hardware* change in the machine head (Dawson, 1998).

However, one notable exception to this is the *universal Turing machine*. It can pretend to be any possible Turing machine using *software*. The machine table of the desired Turing machine is written as a program on the ticker tape, along with the to-be-answered question. The universal machine simulates the actions of the desired Turing machine by moving back and forth between the program and the question, answering the question as if the universal machine's table was identical to the one programmed on the tape. "It followed that one particular machine could simulate the work done by any machine ... It would be a machine to do everything, which was enough to give anyone pause for thought" (Hodges, 1983, p. 104).

One result of Turing's universal machine was the Church-Turing thesis: "Any process which could naturally be called an effective procedure can be realized by a Turing machine" (Minsky, 1972, p. 108). This in turn has led classical cognitive science to both the computer metaphor and the methodology of computer simulation. Early cognitive scientists predicted that psychological theories would be expressed as computer programs (Simon & Newell, 1958). This view has remained with the modern classical approach (Johnson-Laird, 1983): "In so far as there can be a science of the mind it will almost be certainly restricted to accounts that can be formulated as computer programs" (p. 8).

### 2.2.2 Three Key Characteristics

The link between logicism, classical cognitive science and the digital computer implies that classical theories will have three general characteristics. First, a classical theory will include a set of symbols for representing knowledge. Second, such a theory will include a set of rules for manipulating these symbols in a fashion analogous to a Turing machine. Third, a classical theory will stipulate some control procedure that chooses which rule to apply at any given moment in time.

## 2.3 CLASSICAL VIEWS OF MIND AND MUSIC

### 2.3.1 Mind and Music

Chapter 1 explored the notion that, in virtue of our rationality, humans create and control their environment, while (irrational) animals do not. Even when impressive architectural feats accomplished by social insects and other animals are considered, it can be argued that these accomplishments are products of mindless environmental control. This reassuringly supports the age-old idea that human mentality separates us from the beasts. However, it also raises an obvious question: to what extent might complex human behaviours also be the result of environmental control rather than rational thought? The current chapter explores this question by taking a prototypical example of human intellect—classical music—and examining the extent to which some of the ideas introduced in Chapter 1 can be applied to it. There are several reasons for using classical music to explore these ideas. First, classical music arguably embodies some of the highest accomplishments of human intellect. If such compositions could be explained by appealing to non-rational factors such as stigmergy, then this would provide a compelling reason to explore non-rational accounts of other cognitive phenomena. Second, classical music has been analyzed by a diverse range of thinkers, including composers, performers, critics, historians, philosophers, neuroscientists, and psychologists. As a result there is an extremely rich array of material that can be used to explore classical music as a cognitive product.

Third, there is an interesting analogy to draw between classical music and the classical notion of mind. This analogy is introduced below.

### 2.3.2 A Classical Analogy

There are many striking parallels between the classical mind and classical music, particularly the music composed in the Austro-German tradition of the eighteenth and nineteenth centuries. First, both rely heavily upon formal structures. That is, logicism can easily be found to apply to many aspects of classical music.

Second, both emphasize that their formal structures are content-laden. In classical cognitive science, mental representations have content, and we can predict the behaviours of others by ascribing mental content (Dennett, 1987). Classical music is also widely held to be meaningful (Meyer, 1956). Furthermore, its meaning is tightly linked to its formal structure: "One musical event (be it a tone, a phrase, or a whole section) has meaning because it points to and makes us expect another musical event" (Meyer, 1956, p. 35).

Third, both attribute great importance to abstract thought inside an agent (or composer), at the expense of contributions involving the agent's environment or embodiment. For instance, Mozart "carried his compositions around in his head for days before setting them down on paper" (Hildesheimer, 1983): in a letter that he wrote to his father in 1780, Mozart noted that "everything is composed, just not copied out yet." Fourth, both emphasize central control. In classical cognition, control is required to choose which rule to apply next. In classical music, a performance is also under strict control (Green & Malko, 1975): "The conductor acts as a guide, a solver of problems, a decision maker. His guidance chart is the composer's score; his job, to animate the score, to make it come alive, to bring it into audible being" (p. 7).

Fifth, the "classical" traditions of both mind and music have faced strong challenges, and many of the challenges in one domain can be related to parallel challenges in the other. Modern classical music is a reaction against the key attributes of Austro-German music (Griffiths, 1994, 1995), just as embodied cognitive science is a reaction against the central claims of classical cognitive science (Brooks, 1999, 2002; Clark, 1997; Varela et al., 1991).

## 2.4 MUSICAL LOGICISM

### 2.4.1 Musical Formalisms

Music's formal nature extends far beyond musical symbols on a sheet of staff paper. For example, some combinations of tones played in unison are pleasing to the ear while other combinations are not. This experience is easily related to the degree of separation between notes on a musical scale (Krumhansl, 1990). For instance, if one plays middle C on a piano, then a pleasing sound will be produced if the note F is played at the same time, because F is a perfect fifth (7 semitones) above C.

The consonance of two notes that are a perfect fifth apart can be explained by the physics of sound waves (Helmholtz & Ellis, 1954). Such physical relationships are ultimately mathematical. Indeed, there is an extensive literature on the mathematical nature of music (Assayag, Feichtinger, Rodrigues, & European Mathematical Society., 2002; Benson, 2007; Harkleroad, 2006). For instance, different approaches to tuning instruments reflect the extent to which tunings are deemed mathematically sensible (Isacoff, 2001).

### 2.4.2 Sonata-Allegro Form

Importantly, musical formalisms exist at levels beyond individual notes. A musical offering is expected to have a particular structure (Copland, 1939), "the planned design that binds an entire composition together" (p. 113). For Copland this structure is "one of the principal things to listen for," and much of his *What to Listen for in Music* describes structural variants. One important musical structure is *sonata-allegro form* (Copland, 1939). This is an example of three-part form in which there is an initial exposition of musical ideas, followed by their free development, and ending with their recapitulation as shown in Table 2-1.

Each of these parts has its own structure. The exposition introduces an opening theme in the tonic key (that is, the initial key signature of the piece), then follows with a second theme in the dominant key (a perfect fifth above the tonic), and finishes with a closing theme in the dominant key. The recapitulation uses the same three themes in the same order, but all are in the tonic key. The development section explores the exposition's themes, but does so using new material written in different keys.

The themes are expected to have certain characteristics as well. The opening theme is dramatic, the second theme is lyrical, and the third theme "may be of any nature that leads to a sense of conclusion … This juxtaposition of one group of themes denoting power and aggressiveness with another group which is relaxed and more song like in quality is the essence of the exposition section and determines the character of the entire sonata-allegro form" (Copland, 1939, p. 185).

Sonata-allegro form was historically important because it foreshadowed the modern symphony, and it produced a market for purely instrumental music (Rosen, 1988). Importantly, it also provided a structure, shared by both composers and their audiences, which permitted instrumental music to be expressive. Rosen notes the sonata became popular because it "has an identifiable climax, a point of maximum tension to which the first part of the work leads and which is symmetrically resolved. It is a closed form, without the static frame of ternary form; it has a dynamic closure analogous to the denouement of eighteenth-century drama, in which everything is resolved, all loose ends are tied up, and the work rounded off" (p. 10). In short, its formal structure provided a logical structure that permitted the music to be meaningful.

| **Exposition (A)** | | | **Development (B)** | **Recapitulation (A)** | | |
|---|---|---|---|---|---|---|
| *a* | *b* | *c* | *abc* | *a* | *b* | *c* |
| First theme in tonic key | Second theme in dominant key | Closing theme in dominant key | Free combination of the three themes, and new material in foreign keys | First theme in tonic key | Second theme in tonic key | Closing theme in tonic key |

Table 2-1 The hierarchial structure of sonata-allegro form.

## 2.5 A HARMONIOUS NARRATIVE

### 2.5.1 Representational Explanation

Classical cognitive science explains cognition by using mental representations. By noting that an agent has certain (semantically interpreted) goals, as well as beliefs about how these goals can be attained, it predicts the agent's future behaviour. "We can conclude that the representational, or semantic, level represents a distinct, autonomous level of description of certain kinds of systems" (Pylyshyn, 1984, p. 33).

Classical cognitive science's appeal to representations reveals its deep commitment to logicism. In order for the contents of representational states to predict behaviour, some general principles or laws must govern these states. One key principle is *rationality*, which is the notion that agents will use the content of their beliefs to achieve their goals. Rationality is at the foundation of Dennett's (1987) intentional stance: "This single assumption, in combination with home truths about our needs, capacities and typical circumstances, generates both an intentional interpretation of us as believers and desirers and actual predictions of behavior in great profusion" (p. 50). Similarly, Pylyshyn (1984, pp. 20–21) notes, "the principle of rationality … is indispensable for giving an account of human behavior."

Classical cognitive science recognizes that there are no causal principles relating semantics to behaviour. This is why the digital computer is so important, for it illustrates how a symbolic system preserves meanings while at the same time existing as a purely causal, physical machine. Symbols in a representational system have two lives: semantic and physical (Haugeland, 1985). Physical manipulations of the symbols are systematic, and preserve the meanings of symbolic expressions. Haugeland describes this with the formalist's motto: *take care of the syntax, and the semantics will take care of itself.*

### 2.5.2 Musical Expressions

One of the central questions in the philosophy of music is whether music can represent. As late as 1790, the dominant philosophical view of music was that it was incapable of conveying ideas, but by the time that E.T.A. Hoffman reviewed Beethoven's Fifth Symphony in 1810, this view was rejected (Bonds, 2006). Nowadays most philosophers of music agree that it is representational, and are concerned with *how* musical representations are possible (Kivy, 1991; Meyer, 1956; Robinson, 1994, 1997; Sparshoot, 1994; Walton, 1994).

Composers certainly believe that music can express ideas. Aaron Copland (1939, p. 12) notes that "my own belief is that all music has an expressive power, some more and some less, but that all music has a certain meaning behind the notes and that that meaning behind the notes constitutes, after all, what the piece is saying, what the piece is about." John Cage believed that compositions had intended meanings (Cage, 1961); "It seemed to me that composers knew what they were doing, and that the experiments that had been made had taken place prior to the finished works, just as sketches are made before paintings and rehearsals precede performances" (p. 7).

How do composers convey intended meanings with their music? One answer is by using the conventions of particular musical forms. Such forms provide a structure that generates expectations, expectations that are often presumed to be shared by the audience. Indeed, Copland's (1939) book on music listening—which places such a strong emphasis on musical form—is designed to educate the audience so that it can better understand his compositions, as well as those of others: "In helping others to hear music more intelligently, [the composer] is working toward the spread of a musical culture, which in the end will affect the understanding of his own creations" (p. vi). The extent to which the audience's expectations are toyed with, and ultimately fulfilled, can manipulate its emotion. These manipulations can be described completely in terms of the structure of musical elements (Meyer, 1956). In this sense, the formalist's motto also applies to classical music as traditionally conceived.

## 2.6 THE NATURE OF CLASSICAL COMPOSITION

### 2.6.1 The Disembodied Mind

Classical cognitive science attempts to explain cognitive phenomena by appealing to a sense–think–act cycle (Pfeifer & Scheier, 1999). In this cycle, sensing mechanisms provide information about the world, and acting mechanisms produce behaviours that might change it. Thinking — manipulating mental representations — is the interface between sensing and acting (Wilson, 2004). Interestingly, the sense–think–act cycle does not reflect the true nature of the classical approach. Classical cognitive science places an enormous amount of emphasis on the "thinking" part of the cycle, with an accompanying under-emphasis on sensing and acting (Clark, 1997). Sensors are merely providers of information that can be manipulated; actors are simply devices that are capable of carrying out a well-thought-out plan of action.

One can easily find evidence for the classical emphasis on representations. Autonomous robots developed following classical ideas devote most of their computational resources to using internal representations of the external world (Brooks, 2002; Moravec, 1999; Nilsson, 1984). Most survey books on cognitive psychology have multiple chapters on representational topics like memory and reasoning, and rarely mention embodiment, sensing, or acting (see Anderson, 1985; Best, 1995; Haberlandt, 1994; Robinson-Riegler & Robinson-Riegler, 2003; Solso, 1995; Sternberg, 1996). Classical cognitive science's sensitivity to the multiple realization argument (Fodor, 1968, 1975), with its accompanying focus on functional (not physical) accounts of cognition (Cummins, 1983), underlines its view of thinking as a disembodied process.

### 2.6.2 The Thoughtful Composer

Composing classical music is also viewed as abstract, disembodied, and rational. Does not a composer first think of a theme or a melody, and then translate this mental representation into a musical score?

One example of this is the story of Mozart carrying around completed compositions in his head prior to writing them out (Hildesheimer, 1983). Similar examples are easily found. Benson (2007, p. 25) notes that "Stravinsky speaks of a musical work as being 'the fruit of study, reasoning, and calculation that imply exactly the converse of improvisation'." In the liner notes of his Grammy award–winning *Symphony No. 1* (Sony Classical Music, 1999), Joe Jackson recalls that "I had a handful of very simple musical themes in my head and wanted to see if they could be developed and transformed throughout four whole movements."

There is a general prejudice against composers who rely on external aids (Rosen, 2002). Copland (1939, p. 22) observes that "a current idea exists that there is something shameful about writing a piece of music at the piano." Rosen traces this idea to Giovanni Maria Artusi's 1600 criticism of composers such as Monteverdi: "It is one thing to search with voices and instruments for something pertaining to the harmonic faculty, another to arrive at the exact truth by means of reasons seconded by the ear" (Rosen, 2002, p. 17). The expectation (then and now) is that composing a piece involves "mentally planning it by logic, rules, and traditional reason" (Ibid). This expectation is completely consistent with the disembodied, classical view of thinking.

To appreciate this, consider composing from the opposite perspective. From the early 1950s, John Cage's compositions were non-intentional (Griffiths, 1994); he increasingly used chance mechanisms to determine musical events. He worked toward removing the composer from the composition, perhaps succeeding most with his 1952 "silent piece" *4'33"*. Cage was reacting against the Austro-German tradition of composition (Nyman, 1999). He advocated "that music should no longer be conceived of as rational discourse" (Nyman, 1999, p. 32). He explicitly attacked the logicism of traditional music, declaring "any composing strategy which is wholly 'rational' is irrational in the extreme" (Ross, 2007, p. 371).

## 2.7 CENTRAL CONTROL OF A CLASSICAL PERFORMANCE

### 2.7.1 Central Control

Herbert Simon argued that "an adequate theory of human cognitive processes must include a description of the *control system*—the mechanism that determines the sequence in which operations will be performed" (Simon, 1979, p. 370). In classical cognitive science, such control is typically central. There is a centralized mechanism that controls, at any given time, which rule will manipulate the symbols in memory. This is consistent with the digital computer metaphor. In a modern digital computer, the central processing unit (CPU) is responsible for determining what operation will be used to modify a specific memory location at every tick of the CPU's clock cycle. Central control is also characteristic of classical music, as is discussed below.

### 2.7.2 Conductor as Central Controller

Within the Austro-German tradition, a musical composition is a formal structure intended to express ideas. A composer uses musical notation to signify the musical events that, when realized, accomplish this expressive goal. An orchestra's purpose is to bring the score to life, in order that the performance will deliver the intended message to the audience (Benson, 2003). "We tend to see both the score and the performance primarily as vehicles for preserving what the composer has created. We assume that musical scores provide a permanent record or embodiment in signs; in effect, a score serves to 'fix' or objectify a musical work" (Benson, 2003, p. 9). However, it is generally acknowledged that a musical score is vague; it cannot completely determine every minute detail of a performance (Benson, 2003; Copland, 1939). As a result, during a performance the score must be interpreted in such a way that the missing details can be filled in without distorting the composer's desired effect. In the Austro-German tradition of music an orchestra's conductor takes the role of interpreter, and controls the orchestra in order to deliver the composer's message: "The conductor acts as a guide, a solver of problems, a decision maker. His guidance chart is the composer's score; his job, to animate the score, to make it come alive, to bring it into audible being" (Green & Malko, 1975, p. 7).

The conductor provides another link between classical music and classical cognitive science, because the conductor is the orchestra's central control system. The individual players are expected to submit to the conductor's control. "Our conception of the role of a classical musician is far closer to that of self-effacing servant who faithfully serves the score of the composer. Admittedly, performers are given a certain degree of leeway; but the unwritten rules of the game are such that this leeway is relatively small and must be kept in careful check" (Benson, 2003, p. 5). It has been suggested—not necessarily validly—that professional, classically trained musicians are incapable of improvisation (Bailey, 1992)!

### 2.7.3 The Controlling Score

The conductor is not the only component of a performance's control structure. While it is unavoidably vague, the musical score of a composition also is designed to control the musical events generated by an orchestra. That is, if the score is a content-bearing formal expression, then it is reasonable to assume that it designates the musical events that the score is literally about.

Benson (2003, p. 5) describes this aspect of a score as follows: "The idea(l) of being '*treu*'—which can be translated as true or faithful—implies faithfulness to someone or something. *Werktreue*, then, is directly a kind of faithfulness to the *Werk* (work) and, indirectly, a faithfulness to the composer. Given the centrality of musical notation in the discourse of classical music, a parallel notion is that of *Texttreue*: fidelity to the written score." Note Benson's emphasis on the formal notation of the score. It highlights the idea that the written score is analogous to a logical expression, and that converting it into the musical events that the score is about (in Brentano's sense) is not only desirable, but also rational. This logicism of classical music perfectly parallels the logicism found in classical cognitive science.

## 2.8 DISEMBODIMENT AND THE CLASSICAL AUDIENCE

### 2.8.1 Disembodiment

An infinite number of different physical substrates can deliver the same set of information-processing functions (Putnam, 1967). For example, Turing machines can be created from brass gears (Swade, 1993), toy train sets (Stewart, 1994), artificial neural networks (McCulloch & Pitts, 1943; Siegelmann, 1999), mixtures of chemicals (Hjelmfelt, Weinberger, & Ross, 1991), or LEGO (Agullo et al., 2003). This possibility of multiple realizations makes classical cognitive science adopt functionalism (Cummins, 1983). That is, it explains systems by describing the functional roles of system components, and not by appealing to their physical nature. This is why simulations can be used in cognitive science: the physical differences between computers and brains are irrelevant, as long as functional correspondences are maintained (Pylyshyn, 1984).

Classical cognitive science's functionalism is one example of its move toward disembodiment: representational theories can ignore the physical substrate that is instantiating symbols and the rules that manipulate them. However, there is another form of disembodiment that characterizes much of classical cognitive science.

Classical cognitive science explains psychological phenomena by appealing to the representational states of agents. Different behavioural predictions must be grounded in different representational states. A representational theory of mind must therefore be capable of individuating different representational states. This could be done in terms of their content (i.e., different states must refer to different entities in the world), but there are well-known philosophical problems with this approach (Pessin, Goldberg, & Putnam, 1996). An alternative approach that has strongly influenced classical cognitive science is *methodological solipsism* (Fodor, 1980). In methodological solipsism, representational states are individuated only in terms of their relations to other representational states. Relations of the states to the external world—the agent's environment—are not considered. "Methodological solipsism in psychology is the view that psychological states should be construed without reference to anything beyond the boundary of the individual who has those states" (Wilson, 2004, p. 77).

### 2.8.2 Audience and Composition

Methodological solipsism provides another link in the analogy between the classical mind and classical music. As was noted in Section 2.7, when a piece is performed it is brought to life with the intent of delivering a particular message to the audience. Ultimately, then, the audience is a fundamental component of a composition's environment. To what extent does this environment affect or determine the composition itself?

In traditional classical music, the audience has absolutely no effect on the composition. Composer Arnold Schoenberg believed that the audience was "merely an acoustic necessity—and annoying one at that" (Benson, 2003, p. 14). Composer Virgil Thompson defined the ideal listener as "a person who applauds vigorously" (Copland, 1939, p. 252). In short, the purpose of the audience is to passively receive the intended message. It too is under the control of the score: "The intelligent listener must be prepared to increase his awareness of the musical material and what happens to it. He must hear the melodies, the rhythms, the harmonies, the tone colors in a more conscious fashion. But above all he must, in order to follow the line of the composer's thought, know something of the principles of musical form" (Copland, 1939, p. 17).

To relate this to methodological solipsism, consider how compositions are to be identified or differentiated from one another. Traditionally, this is done by referring to a composition's score (Benson, 2003). That is, compositions are identified in terms of a particular set of symbols, a particular formal structure. The identification of a composition does not depend upon identifying which audience has heard it. A composition can exist, and be identified, in the absence of its audience-as-environment.

## 2.9 CLASSICAL REACTIONS

### 2.9.1 Reacting to Music

Another parallel between the classical mind and classical music is that there have been significant modern reactions against the Austro-German musical tradition (Griffiths, 1994, 1995). Interestingly, these reactions parallel many of the reactions of embodied cognitive science against the classical approach. In the pages that follow we will consider some of these reactions, and explore the idea that they make plausible the claim that "non-cognitive" processes are applicable to classical music.

### 2.9.2 Classical Competitors

The modern interdisciplinary study of mind begins with the science of cybernetics in the 1940s (Ashby, 1956; Conway & Siegelman, 2005; de Latil, 1956; Hayles, 1999; Wiener, 1948), and its famous Macy conferences through the 1950s. Cybernetics had waned by the end of the 1950s. It was replaced by cognitive science, whose origin occurred on September 11, 1956 (Gardner, 1984; Miller, 2003). Cognitive science has since flourished, dominated by the classical approach.

The classical view is not without its competitors. *Connectionists* believe that cognitive science is not best served by the digital computer metaphor (Bechtel & Abrahamsen, 2002; Medler, 1998; Quinlan, 1991; Schneider, 1987). They argue that the serial, rule-governed, centrally controlled processing performed by digital computers is too slow, too inflexible, and too divorced from biology to meaningfully account for human cognition. They insist that the information processing is the result of the parallel processing of multiple, simple, intercommunicating units. They model such information processing with artificial neural networks. Connectionists use such networks to support the claim that cognition does not require explicit rules and symbols, but instead emerges from neuronally inspired processes best described using statistical mechanics (Clark, 1989, 1993; McClelland & Rumelhart, 1986; McClelland, Rumelhart, & Hinton, 1986; Rumelhart & McClelland, 1986).

A second competitor to the classical approach, called *embodied cognitive science*, has concerns similar to connectionism, but develops them within a fundamental attack on methodological solipsism.

Classical and connectionist cognitive science are both fundamentally representational in nature (Dawson, 1998, 2004), emphasizing internal information processing at the expense of environmental influences. Embodied cognitive science views this as a serious mistake. Embodied cognitive scientists argue that a cognitive theory must include an agent's environment, as well as the agent's experience of that environment (Agre, 1997; Clancey, 1997; Clark, 1997; Pfeifer & Scheier, 1999; Varela et al., 1991). They recognize that this experience depends on how the environment is sensed (*situation*), that an agent's situation depends upon its physical nature (*embodiment*), and that an embodied agent can act upon and change its environment (Webb & Consi, 2001). The embodied approach replaces the notion that cognition is representation with the notion that cognition is the control of actions upon the environment. In embodied cognitive science, the environment contributes in such a way that it can be said that an agent's mind has leaked into the world (Clark, 1997; Wilson, 2004). For example, research in behaviour-based robotics eliminates resource-consuming representations of the world by letting the world serve as its own representation, one that can be accessed by a situated agent (Brooks, 1999). This robotics tradition has also shown that non-linear interactions between an agent and its environment can produce surprisingly complex behaviour, even when the internal components of an agent are exceedingly simple (Braitenberg, 1984; Grey Walter, 1950b; Webb & Consi, 2001). This observation reconnects cognitive science with cybernetics.

In short, to the notions of emergence and biological plausibility, embodied cognitive science adds the ideas of situation and embodiment. Interestingly, we will see that these ideas can also be found in reactions to classical music.

## 2.10 MODERN MUSIC

### 2.10.1 Out with the Old

By the end of the nineteenth century, classical music had reached its zenith. Composers had invented a market for instrumental music that was fueled by their discovery and refinement of particular musical forms (Rosen, 1988). For example, in the early seventeenth century, the symphony was merely a short overture played before the raising of the curtains at an opera (Lee, 1916). The more interesting of these compositions came to be performed to their own audiences outside the theater. The modern symphony, which typically consists of four movements that each has an expected form and tempo, begins to be seen in the eighteenth-century compositions of Carl Philip Emmanuel Bach. Experiments with this structure were conducted in the later eighteenth century by Haydn and Mozart.

When Beethoven wrote his symphonies in the early nineteenth century, symphonic form was established, and Beethoven proved its enormous expressive power. "No less a person than Richard Wagner affirmed that the right of composing symphonies was abolished by Beethoven's Ninth'" (Lee, 1916, p. 172). What are some general characteristics of prototypical classical music, such as a Beethoven symphony? Consider the properties of sonata-allegro form, which is always used to structure a symphony's first movement. First, this form is based upon particular musical themes or melodies. Second, these melodies are associated with a specific tonality: they are written in a particular musical key (such as the tonic or dominant mentioned in the discussion of Table 2-1). The tonality of the form dictates harmonic structure; that is, within a musical key certain combinations of notes (chords) will be concordant, while others will not be played because they will be discordant. The form itself indicates an expected order in which themes and musical keys will be explored, and an established rhythmic structure (related to a time signature) will be used throughout.

Perhaps the key feature from this list is tonality: the use of particular major and minor musical keys to establish an expected harmonic structure in a composition. "Harmony is Western music's uniquely distinguishing element" (Pleasants, 1955, p. 97). In the early twentieth century, strongly affected by both world wars, classical music found itself in a crisis of harmony (Pleasants, 1955). Composers abandoned most of the features listed above in an attempt to create a new music that better reflected modern times. "'Is it not our duty', he [Debussy] asked, 'to find a symphonic means to express our time, one that evokes the progress, the daring and the victories of modern days? The century of the aeroplane deserves its music'" (Griffiths, 1994, p. 98).

### 2.10.2 In with the New

Griffiths (1994) places the beginning of modern music with the flute solo that opens the *Prélude à 'L'après-midi d'un faune'* composed by Claude Debussy between 1892 and 1894. The *Prélude* begins to break away from the harmonic relationships defined by strict tonality. It fails to logically develop themes. It employs fluctuating tempos and irregular rhythms. It depends critically on instrumentation for expression. Debussy "had little time for the thorough, continuous, symphonic manner of the Austro-German tradition, the 'logical' development of ideas which gives music the effect of a narrative" (Griffiths, 1994, p. 9).

"Debussy had opened the paths of modern music—the abandonment of traditional tonality, the development of new rhythmic complexity, the recognition of color as an essential, the creation of a quite new form for each work, the exploration of deeper mental processes" (Griffiths, 1994, p. 12). In the twentieth century, composers experimented with new methods that further pursued these paths. We shall see, in the progression of these experiments, those reactions to traditional classical music parallel reactions to classical cognitive science, particularly in exploiting notions of emergence, embodiment, and stigmergy.

## 2.11 DODECAPHONY

### 2.11.1 Tonality and Atonality

The crisis of harmony was addressed by composing deliberately atonal music. The possibility of doing this is illustrated in Table 2-2. The top row of this table illustrates the keys on a piano from the note A to a second A that is an octave higher than the first. On the piano, some of these keys are white, and others are black; the colour of each key is depicted in the table. The interval between adjacent keys (e.g., from B to C, or from C to C#) is a *semitone*. If one were to play the top row in sequence, the result would be a *chromatic scale*, in which thirteen different notes were played (from A to A), and each note that is played is a semitone higher than the previous note.

A *major scale* is a sequence of notes that is associated with a particular key; for example, the A major scale is associated with the musical key (or tonal centre) of A. The A major scale is played by starting with the low A at the left of the table, and by playing notes in sequence until the high A at the right of the table is played. This scale has a distinctive sound because not all of the notes in the chromatic scale are used. The second row of the table illustrates the subset of notes that, when played, produces the A major scale. If there is a checkmark beneath the key, then it is played in the scale; if there is no checkmark then the key is not part of the scale. By choosing a different subset of notes a very different-sounding scale is produced. The third row of Table 2-2 shows the subset of piano notes that would be used to play a *minor scale* beginning with the note A.

A scale's tonality is the result of only including a subset of possible notes. That is, to compose a piece that had the tonal centre of A major, one would only include those notes that belonged to the A major scale.

In contrast, to produce music that is atonal, one would include all the notes from the chromatic scale. Because all notes are included, it is impossible to associate this set of notes with a tonal centre. One method of ensuring atonality is the "twelve-tone technique," or *dodecaphony*, invented by Arnold Schoenberg.

### 2.11.2 The Twelve-Tone Method

When dodecaphony is employed, a composer starts by listing all twelve notes in a chromatic scale in some desired order. This creates the *tone row*. The tone row is the basis for a melody: the composer begins to write the melody by using the first note in the tone row (for a desired duration, possibly with repetition). However, this note cannot be reused in the melody until the remaining notes have also been used in the order specified by the tone row. This ensures that the melody is atonal, because all the notes that make up a chromatic scale have been included.

Once all twelve notes have been used, the tone row is then shifted to create the next section of the melody. At this time, the tone row can be manipulated to produce musical variation (e.g., by reversing its order, or by inverting the musical intervals between adjacent tones).

The first example of a dodecaphonic composition was Schoenberg's 1923 *Suite for Piano, Op. 25*. Schoenberg and his students (Alban Berg, Anton Webern) composed extensively using the twelve-note technique. A later movement in music, *serialism*, used similar systems to determine other parameters of a score, such as note duration and dynamics. It was explored by Olivier Messiaen and his followers, notably Pierre Boulez and Karlheinz Stockhausen (Griffiths, 1995).

| **Piano Keys With Note Name** | **A** | **A#** | **B** | **C** | **C#** | **D** | **D#** | **E** | **F** | **F#** | **G** | **G#** | **A** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A Major Scale | √ | | √ | | √ | √ | | √ | | √ | | √ | √ |
| A Minor Scale | √ | | √ | √ | | √ | | √ | √ | | √ | | √ |

Table 2-2. The top row illustrates keys (white and black) on a piano from one A to the A an octave higher. The last two rows provide the subsets of notes that define A major and A minor scales; checkmarks are used to indicate which notes are included in a scale.

## 2.12 REACTIONS TO ATONAL STRUCTURE

### 2.12.1 From Structure to Structure

Schoenberg wrote his original atonal works without the aid of dodecaphony. The lack of a guiding structure made it difficult to create large, coherent, atonal works. His invention of dodecaphony solved this problem. Schoenberg was "troubled by the lack of system, the absence of harmonic bearings on which large forms might be directed. Serialism at last offered a new means of achieving order" (Griffiths, 1994, p. 81).

The twelve-tone technique provides an alternative to the traditional forms of classical music. However, this new form still followed the Austro-German tradition's need for structure. "The new rules must be applied to the construction of forms and textures in the old manner" (Griffiths, 1994, p. 85). Composer Philip Glass recognized this situation: "To me, it was music of the past, passing itself off as music of the present. After all, Arnold Schoenberg was about the same age as my grandfather!" (Glass, 1987, p. 13). Critics accused serialist compositions of being mathematical or mechanical (Griffiths, 1994). Indeed, serialism made computer composition possible: in 1964 Gottfried Koenig created Project 1, which was a computer program that composed serial music (Koenig, 1999).

Serialism also shared the traditional approach's disdain for the audience. American composer Steve Reich (Reich, 1974) notes that "in serial music, the series itself is seldom audible" (p. 10), which appears to be a serial composers' intent (Griffiths, 1994). This music's opacity, and its decidedly different or modern sound, frequently led to hostile receptions. One notable example is music critic Henry Pleasants' *The Agony Of Modern Music* (Pleasants, 1955): "The vein which for three hundred years offered a seemingly inexhaustible yield of beautiful music has run out. What we know as modern music is the noise made by deluded speculators picking through the slag pile" (p. 3).

That serial music was derived from a new kind of formalism also fuelled its critics. "Faced with complex and lengthy analyses, baffling terminology and a total rejection of common paradigms of musical expression, many critics — not all conservative — found ample ammunition to back up their claims that serial music was a mere intellectual exercise which could not seriously be regarded as music at all" (Grant, 2001).

### 2.12.2 Reducing Central Control

At issue was the fact that European composers were steeped in the centuries-old traditions of classical music, which made it difficult for them to break free of the old forms even when they recognized a need for new music (Griffiths, 1994). Schoenberg wrote, "I am at least as conservative as Edison and Ford have been. But I am, unfortunately, not quite as progressive as they were in their own fields" (Griffiths, 1995, p. 50).

American composers were certainly not drawn to the new atonal structures. Philip Glass describes his feelings about serialism: "A wasteland, dominated by these maniacs, these creeps, who were trying to make everyone write this crazy creepy music" (Schwarz, 1996). When Glass attended concerts, the only "breaths of fresh air" that he experienced was when works from modern American composers like John Cage were on the program (Glass, 1987). The new American music was more progressive than its European counterpart because American composers were far less shackled by musical traditions.

American composers were willing to relinquish the central control of the musical score, recognizing the improvisational elements of classical composition (Benson, 2003). Some were even willing to relinquish much of the composer's control over the piece (Cage, 1961). They recognized that many musical effects depended upon the audience's perceptual processes (Potter, 2000; Schwarz, 1996), and many examples of experimental music relied heavily upon the audience as an equal partner in bringing the composition to life (Nyman, 1999). It is these insights that provide links between the new music and the new cognitive science.

## 2.13 CONTROL AND EMERGENCE IN CAGE'S MUSIC

### 2.13.1 Silence

In 1937 composer John Cage declared, "The present methods of writing music, principally those which employ harmony and its reference to particular steps in the field of sound, will be inadequate for the composer, who will be faced with the entire field of sound" (Cage, 1961, p. 4). Cage was well versed in the twelve-tone technique (Ross, 2007), but did not see tonality (or atonality) as the defining characteristic of music. Instead, Cage emphasized rhythmic structuring, "since duration is the most fundamental musical characteristic, shared by both sound and silence" (Griffiths, 1994, p. 118). For Cage the entire field of sound included silence and sounds typically considered to be non-musical.

Cage's music was largely motivated by his desire to free it from the composer's will. He wrote, "when silence, generally speaking, is not in evidence, the will of the composer is. Inherent silence is equivalent to denial of the will" (Cage, 1961, p. 53). In Cage's compositions we see a composer who is willing to relinquish the central control so fundamental to traditional classical music.

Cage's most famous example of relinquishing control is in his composition *4'33"*, first performed by pianist David Tudor in 1952 (Nyman, 1999). It consists of three parts; the entire score for each part reads "TACET," which instructs the performer to remain silent. Tudor signalled the start of each part by closing the keyboard lid, and opened the lid when the part was over. When the composer relinquishes control in this way, what happens? *4'33"* also illustrates Cage's desire to place more responsibility upon his audience. Nyman (1999, p. 24) quotes Cage on this subject: "Most people think that when they hear a piece of music, they're not doing anything but something is being done to them. Now this is not true, and we must arrange our music, we must arrange our art, we must arrange everything, I believe, so that people realize that they themselves are doing it."

### 2.13.2 Chance and Emergence

The intentional uses of silence, and the expectation of an actively involved audience, were not the only innovations that Cage pioneered as he decentralized control in his compositions. From the early 1950s onward Cage also made extended use of chance operations when he composed.

His 1951 piece *16 Dances* (BMG Music, 1994) paved the way for Cage's use of chance. *16 Dances* was composed using an 8 × 8 sound chart. Each entry on the chart was a particular musical event. Only one entry on the chart could be played at any given moment. Each movement of *16*

*Dances* involved playing one chart entry after another; Cage varied the contents of the chart for each movement of *16 Dances*. The tabular arrangement of this piece suggested the possibility of making arbitrary moves in the sound chart. Cage used dice rolls to determine the order of sounds in his 1951 piano piece *Music of Changes* (Ross, 2007).

The stochastic nature of Cage's compositional practices did not produce music that sounded random. This is because Cage put tremendous effort into choosing interesting sound elements. "In the *Music of Changes* the effect of the chance operations on the structure (making very apparent its anachronistic character) was balanced by a control of the materials" (Cage, 1961, p. 26). Cage relaxed his influence on control (that is, upon which element to perform next) with the expectation that this, coupled with his careful choice of elements, would produce surprising and interesting musical results. Cage intended novel results to *emerge* from his compositions.

The combination of well-considered building blocks to produce emergent behaviours that surprise and inform is characteristic of the robotics research (Braitenberg, 1984; Brooks, 1999; Pfeifer & Scheier, 1999; Webb & Consi, 2001) that has inspired embodied cognitive science. It is also found in the works of the minimalist composers inspired by Cage.

## 2.14 EMERGENCE IN MINIMALIST MUSIC

### 2.14.1 Tape as Medium

Cage's interest in expanding the field of sounds was fuelled by modern technology. Cage was enthused about using magnetic tape "to make a new music that was possible only because of it" (Cage, 1961, p. 9).

Tape compositions were prominent in early *minimalist* music. Composer La Monte Young, described minimalism as "that which is created with a minimum of means" (Schwarz, 1996, p. 9). Young created works that had nearly no musical notation, but were instead performance instructions that *might* lead to the production of musical sounds. Philip Glass was shocked at one of Young's performances: "He wasn't playing music; he was just drawing a line" (Schwarz, 1996, p. 111).

Minimalist pioneer Terry Riley began working with tape technology in 1960 (Potter, 2000). He recorded a variety of sounds and made tape loops from them. A tape loop permitted a sound segment to be repeated over and over. He then mixed these tapes using a device called an echoplex that permitted the sounds "to be repeated in an ever-accumulating counterpoint against itself" (Potter, 2000, p. 98). Further complexities of sound were produced by either gradually or suddenly changing the speed of the tape to distort the tape loop's frequency. Riley's tape loop experiments led him to explore the effects of repetition, which was to become a centrally important feature of minimalist music.

### 2.14.2 *It's Gonna Rain*

Riley's work strongly influenced another minimalist composer, Steve Reich. One of the most famous minimalist tape compositions is Reich's 1965 *It's Gonna Rain*. Reich recorded a sermon of a famous street preacher, Brother Walter, who made frequent Sunday appearances in San Francisco's Union Square. From this recording Reich made a tape loop of a segment of the sermon that contained the title phrase.

Reich played two copies of this tape loop simultaneously on different tape machines (Reich, 2002), and made a profound discovery: "In the process of trying to line up two identical tape loops in some particular relationship, I discovered that the most interesting music of all was made by simply lining the loops up in unison, and letting them slowly shift out of phase with each other" (p. 20). He recorded the result of phase-shifting the loops, and composed his piece by phase-shifting a loop of this recording. Composer Brian Eno describes Reich's *It's Gonna Rain*: "The piece is very, very interesting because it's tremendously simple. It's a piece of music that anybody could have made. But the results, sonically, are very complex. … What you become aware of is that you are getting a huge amount of material and experience from a very, very simple starting point."

The complexities of *It's Gonna Rain* emerge from the dynamic combination of simple components, and thus are easily linked to the relinquishment of control that was begun by John Cage. However, they also depend to a large extent upon the perceptual processes of a listener when confronted with the continuous repetition of sound fragments.

"The mind is mesmerized by repetition, put into such a state that small motifs can leap out of the music with a distinctness quite unrelated to their acoustic dominance" (Griffiths, 1994, p. 167). From a perceptual point of view, it is impossible to maintain a constant perception of a repeated sound segment. During the course of listening, the perceptual system will habituate to some aspects of it, and as a result—as if by chance—new regularities will emerge. "The listening experience itself can become aleatory in music subject to 'aural illusions'" (Griffiths, 1994, p. 166). Minimalism took advantage of the active role of the listener, and exploited repetition to deliberately produce aural illusions. The ultimate effect of a minimalist composition is not a message created by the composer and delivered to a (passive) audience, but is instead a collaborative effort between musician and listener.

## 2.15 A MINIMALIST SCORE

### 2.15.1 *In C*

In the early days of minimalism, composers were able to discover the power of such techniques as repetition and phase shifting by working with electronic media. However, they felt a need to find a method that would transport these ideas into more traditional media (i.e., the creation of scores to be performed by musicians). The means of doing so was provided by Terry Riley.

Riley's 1964 composition *In C* is 53 bars of music written in the key of C major, indicating a return to tonal music. Each bar is extremely simple, and the entire score fits onto a single page. Performers were instructed to play each bar in sequence. However, they were to repeat a bar as many times as they liked before moving on to the next. When they reached the final bar, they were to repeat it until all of the other performers had reached it. At that time, the performance was to be concluded.

Riley's *In C* can be thought of as a tape loop experiment realized as a musical score. Each performer is analogous to one of the tape loops, and the effect of the music arises from their interactions with one another. The difference, of course, is that each "tape loop" is not identical to the others, because each performer controls the number of times that they repeat each bar. Performers listen and react to *In C* as they perform it. In his performance instructions, Riley notes "one of the joys of *In C* is the interaction of the players in polyrhythmic combinations that spontaneously arise between patterns. Some quite fantastic shapes will arise and disintegrate as the group moves through the piece."

### 2.15.2 Minimalism and Stigmergy

There are two compelling properties that underlie a performance of *In C*. First, each musician is an independent agent who is carrying out a simple act. At any given moment each musician is performing one of the bars of music. Second, what each musician does at the next moment is largely under the control of the musical environment that the ensemble of musicians is creating. A musician's decision to move from one bar to the next depends upon what they are hearing. In other words, the musical environment being created is literally responsible for controlling the activities of the agents who are performing *In C*. This is a musical example of *stigmergy*, a concept introduced in Chapter 1.

In stigmergy, the behaviours of agents are controlled by an environment in which they are situated, and which they also can affect. The performance of a piece like *In C* illustrates stigmergy in the sense that musicians decide what to play next on the basis of what they are hearing right now. Of course, what they decide to play will form part of the environment, and help guide the playing decisions of other performers.

The stigmergic nature of minimalist music contrasts with the ideal of a composer transcribing mental representations (see Section 2.6). One cannot predict what *In C* will sound like by simply examining the score. Only an actual performance will reveal what *In C*'s score represents. "Though I may have the pleasure of discovering musical processes and composing the musical material to run through them, once the process is set up and loaded it runs by itself" (Reich, 1974, p. 9).

Reich's idea of a musical process running by itself is reminiscent of the synthetic approach introduced in Section 1.11. In the synthetic approach, one includes a set of primitive processes in an agent. Typically there are non-linear interactions between these building blocks, and between the building blocks and the environment (in which the agent is embodied and situated). As a result, complex and interesting behaviours emerge—results that far exceed behavioural predictions based on knowing the agent's makeup (Braitenberg, 1984). Human intelligence is arguably the emergent product of simple, interacting mental agents (Minsky, 1985). The minimalists have tacitly (and presciently) adopted this view, and have created a mode of composition that reflects it.

## 2.16 MUSICAL STIGMERGY

The continual evolution of modern technology has had a tremendous impact on music. Some of this technology has created situations in which musical stigmergy is front and centre.

### 2.16.1 Musical Swarms

Consider a computer program called Swarm Music (Blackwell, 2003; Blackwell & Young, 2004a, 2004b). In Swarm Music there are one or more swarms of particles. Each particle is a musical event: it exists in a musical space where the coordinates of the space define musical parameters (e.g., pitch, duration, loudness); its position defines a particular combination of these parameters. The swarm of particles is dynamic, and is drawn to attractors that are placed in the space. The swarm can thus be converted into music. "The swarming behavior of these particles leads to melodies that are not structured according to familiar musical rules, but are nevertheless neither random nor unpleasant" (Blackwell & Young, 2004a, p. 124). Swarm Music is made dynamic by coupling it with human performers in an improvised—and stigmergic—performance. The sounds created by the human performers are used to revise the positions of the attractors for the swarms, causing the music generated by the computer system to change in response to the other performers. The human musicians then change their performance in response to the computer.

Performers who have improvised with Swarm Music provide accounts that highlight its stigmergic nature. Singer Kathleen Willison "was surprised to find in the first improvisation that Swarm Music seemed to be imitating her: '[the swarm] hit the same note at the same time—the harmonies worked'. However, there was some tension; 'at times I would have liked it to slow down … it has a mind of its own … give it some space'. Her solution to the 'forward motion' of the swarms was to 'wait and allow the music to catch up'" (Blackwell, 2003, p. 47).

### 2.16.2 The ReacTable

Another new technology in which musical stigmergy is evident is the *reacTable* (Jordà, Geiger, Alonso, & Kaltenbrunner, 2007; Kaltenbrunner, Jordà, Geiger, & Alonso, 2007). The reacTable is an electronic synthesizer that permits several different performers to play it at the same time. The reacTable gained widespread acclaim when Björk featured it in performances for the tour of her 2007 album *Volta*.

The reacTable is a circular, translucent table upon which objects can be placed. Some objects generate wave forms; some objects perform algorithmic transformations of their inputs; some objects control others that are nearby. Rotating an object, and using a fingertip to manipulate a visual interface that surrounds it, modulates a musical process (e.g., changes the frequency and amplitude of a sine wave). Visual signals displayed on the reacTable—and visible to all performers—indicate the properties of the musical event produced by each object, as well as the flow of signals from one object to another. At the time this section was written, a number of demonstrations of the reacTable were available on YouTube (e.g., ReacTable: Basic Demo #1, found at http://www.youtube.com/watch?v=0h-RhyopUmc).

The reacTable is an example of musical stigmergy because when multiple performers use it simultaneously, they are reacting to the existing musical events. These events are represented as physical locations on the reacTable itself (i.e., the positions of objects), the visual signals emanating from these objects, and the aural events that the reacTable as instrument is producing. By co-operatively moving, adding, or removing objects the musicians collectively improvise a musical performance. The reacTable is an interface intended to provide a "combination of intimate and sensitive control, with a more macro-structural and higher level control which is intermittently shared, transferred and recovered between the performer(s) and the machine" (Jordà et al, 2007, p. 145). That is, the reacTable—and the music that it produces—provides control analogous to that provided by the nest-in-progress of an insect colony as discussed in Chapter 1.

## 2.17 FROM HOT TO COOL

### 2.17.1 The Conduit Metaphor

Cybernetics began with the study of communication (Shannon, 1948; Wiener, 1948). Classical cognitive science developed when many cybernetic ideas were explored in a cognitivist context (Conrad, 1964; Leibovic, 1969; Lindsay & Norman, 1972; MacKay, 1969; Selfridge, 1956; Singh, 1966). As a result, the cybernetic notion of communication—transfer of information from one location to another—is easily found in the classical approach's literature.

The classical study of communication is dominated by the *conduit metaphor* (Reddy, 1979). According to the conduit metaphor, language provides containers (e.g., sentences, words) that are packed with meanings and delivered to receivers, who unpack them to receive the intended message. Reddy provides a large number of examples of the conduit metaphor, including: You still haven't *given me any idea* of what you mean; You have to *put each concept into words* very carefully; The *sentence was filled with emotion*.

The conduit metaphor also applies to the traditional view of classical music, which construes this music as a "hot medium" to which the listener contributes little (McLuhan, 1994). The composer places some intended meaning into a score, the orchestra brings the score to life exactly as instructed by the score, and the (passive) audience unpacks the delivered music to get the composer's message. If traditional music were a "cool medium," then much of the meaning would be contributed by an active audience. The conduit metaphor breaks down in modern music. If control is taken away from the score and the conductor; if the musicians become active contributors to the composition (Benson, 2003); if the audience is actively involved in completing the composition as well; if music is actually a cool medium, then what is the intended message of the piece?

### 2.17.2 Audible Processes

Minimalist composers adopt a McLuhanesque view of their compositions: the music doesn't deliver a message, but is itself the message. After being schooled in the techniques of serialism, which deliberately hid the underlying musical structures from the audience's perception, the minimalists desired to create a different kind of composition. In their compositions the audience would hear the musical processes upon which the pieces were built. Reich (2002, p. 34) is "interested in perceptible processes. I want to be able to hear the process happening throughout the sounding music."

Reich's made processes perceptible by making them gradual. But this didn't make his compositions any less musical. "Even when all the cards are on the table and everyone hears what is gradually happening in a musical process, there are still enough mysteries to satisfy all. These mysteries are the impersonal, unintended, psychoacoustic by-products of the intended process" (Reich, 2002, p. 35).

Reich's recognition that the listener contributes to the composition—that classical music is a cool medium, not a hot one—is fundamental to minimalist music (see also Section 2.14.2). Philip Glass was surprised to find that he had different experiences of different performances of Samuel Beckett's *Play* (for which Glass composed music) (Glass, 1987). He realized that "Beckett's *Play* doesn't exist separately from its relationship to the viewer, who is included as part of the play's content" (p. 36). Audiences of Glass's *Einstein on the Beach* had similar experiences. "The point about *Einstein* was clearly not what it 'meant' but that it was *meaningful* as generally experienced by the people who saw it" (p. 33).

In the cool medium of modern music, the composition has appeared to "leak" from the composer's mind, and requires contributions from both the performers and the audience. Imagine the goal of explaining the psychological processes that produced such a composition. Could classical cognitive science accomplish this goal, or would alternative theories and methods be required?

## 2.18 THE SHOCK OF THE NEW

### 2.18.1 Classical Value

While new theories seem necessary to explain how modern music is composed, a classical theory might be able to explain the composition of traditional classical music. Some consider modern music not to be music at all (Pleasants, 1955): perhaps there is no need for a non-classical cognitive science of music.

One reason for considering this view is that in the cool medium of modern music, where control of the composition is far more decentralized, a modern piece seems more like an improvisation than a traditional composition. "A performance is essentially an *interpretation* of something that already exists, whereas improvisation presents us with something that only comes into being in the moment of its presentation" (Benson, 2003, p. 25). Jazz guitarist Derek Bailey notes that the ability of an audience to affect a composition is expected in improvisation (Bailey, 1992). "Improvisation's responsiveness to its environment puts the performance in a position to be directly influenced by the audience" (p. 44). Such effects, and more generally improvisation itself, are presumed to be absent from the Austro-German musical tradition: "The larger part of classical composition is closed to improvisation and, as its antithesis, it is likely that it will always remain closed" (Bailey, 1992, p. 59).

Perhaps modern music will require alternative theories to explain composition because it is improvisational, while traditional classical music is not.

### 2.18.2 A Tradition of Improvisation

However, there is a problem with this dismissal. Modern music suggests that the composition, performance, and perception of music can involve processes that are not easily included in the theories of classical cognitive science. Are such possibilities true of traditional music as well? Perhaps one of the shocks delivered by modern music is that many of its characteristics also apply to traditional classical music.

For instance, Austro-German music has a long tradition of improvisation, particularly in church music (Bailey, 1992). A famous example of such improvisation occurred when Johann Sebastian Bach was summoned to the court of German Emperor Frederick the Great in 1747. The Emperor played a theme for Bach on the piano, and asked Bach to create a three-part fugue from it. The theme was a trap, probably composed by Bach's son Carl Philipp Emanuel (employed by the Emperor), and was designed to resist the counterpoint techniques required to create a fugue. "Still, Bach managed, with almost unimaginable ingenuity, to do it, even alluding to the king's taste by setting off his intricate counterpoint with a few *galant* flourishes" (Gaines, 2005, p. 9). This was pure improvisation, as Bach composed and performed the fugue on the spot.

Benson (2003) argues that much of traditional music is improvisational, though perhaps less evidently than in the example above. Austro-German music was composed within the context of particular musical and cultural traditions. This provided composers with a constraining set of elements to be incorporated into new pieces, while being transformed or extended at the same time. "Composers are dependent on the 'languages' available to them, and usually those languages are relatively well defined. What we call 'innovation' comes either from pushing the boundaries or from mixing elements of one language with another" (p. 43). Benson argues that improvisation provides a better account of how traditional music is composed than do alternatives like "creation" or "discovery," and then shows that improvisation also applies to the performance and the reception of pre-modern works.

The possibility that classical music shares many of the properties of modern music—improvisation, decentralized control, dependence upon the audience-as-environment (Benson, 2003)—raises a challenge to classical cognitive science's ability to explain musical composition. If much of classical music (modern or not) is cool, then what kinds of theories are required to explain how it is composed?

## 2.19 MUSICAL METHODS AND THE MIND

### 2.19.1 Characteristic Questions

Earlier in this chapter it was hypothesized that there was a strong analogy between classical cognitive science and classical music. As a result, the classical approach seemed ideally positioned to provide a cognitive science of music. However, the nature of modern music raises serious doubts about the validity of this analogy, and of what the analogy implies.

Classical music relied heavily upon formal structures (Copland, 1939). However, modern music rejects this reliance, and can develop in the absence of formal notation. "Stravinsky did not set out to produce a compendium of new rhythmic ideas; they came unbidden, and he found that he was inventing music which he did not at first know how to notate" (Griffiths, 1994, p. 41).

Classical music depended upon tonality, harmony, and conventional formats to communicate meanings to a passive audience (Meyer, 1956). Modern music abandons these ideas, content with communicating musical processes, but expecting aesthetic results to emerge from the interactions of a score, musicians, and an audience (Glass, 1987; Potter, 2000; Reich, 2002; Schwarz, 1996). "Minimalism was marked by a spirit of discovery: the discovery of models in extra-European music [...], and the discovery of how extended musical structures could be created out of rudimentary ideas" (Griffiths, 1994, p. 188).

Classical music adhered to the ideal of the disembodied composer, capable of creating themes in his or her mind alone, to be later committed to a score (Hildesheimer, 1983). To modern music this is not an ideal, but a myth. "It is also enlightening that Mozart refused to compose without a keyboard at him, for the traditional view is that he was able to compose everything in his head'" (Benson, 2003, p. 59). Modern music recognizes that the responsibility of a composition has "leaked out" of the composer's mind (Clark, 1997; Wilson, 2004) into an environment that includes the conductor, the performers, and even the audience.

Classical music placed total control of a performance in the hands of a conductor whose mission was to deliver the message contained in a score. "Presence of mind is among his [the conductor's] central attributes; law-breakers must be curbed instantly. The code of laws, in the form of the score, is in his hands" (Canetti, 1962). Modern music recognizes that there is no central control, and uses this recognition to explore the full range of musical possibilities. "One way of thinking about a musical work is that it provides a world in which music making can take place. Performers, listeners, and even composers in effect dwell within the world it creates. And their way of dwelling is best characterized as 'improvisation'" (Benson, 2003, p. 32). If ideas like decentralized control, emergence from musical agents, and stigmergy can plausibly be applied to a complex psychological phenomenon like the composition of classical music, then is it not also plausible that these ideas can be applied to more mundane aspects of cognition? If this is the case, then what new kinds of theories are needed in cognitive science? And what new kinds of methods are required to permit these theories to flourish?

### 2.19.2 The Synthetic Approach

Classical cognitive scientists prefer to locate the source of complicated behaviour within the organism, and not within its environment (Braitenberg, 1984). This has been called the *frame of reference problem* (Pfeifer & Scheier, 1999), whose implications were long ago highlighted in the parable of the ant (Section 1.12). A consequence of the frame-of-reference problem is that relatively simple systems can surprise us, and generate far more complicated behaviour than we might expect. To take advantage of this, Braitenberg has called for the adoption of the *synthetic approach*. In the synthetic approach, one takes an interesting set of building blocks, creates a working system from them, and then sees what the system can or cannot do (Dawson, 2004). The next chapter explores the relationship between the synthetic approach and the new alternatives to classical cognitive science.