CHAPTER 11

# MEMORY FOR MUSIC

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## Introduction

This chapter focuses on musical memory: how listeners form mental representations of music. The chapter is divided into two main sections, which will outline general concepts of memory and listeners' ability to remember various aspects of music.

The study of memory in music listening is relatively recent, although the scientific study of human memory dates back to the end of the nineteenth century (Ebbinghaus, 1885/1964). The ways in which the mind/brain is used in the perception and comprehension of music appear to be much in line with the way they are used in processing in other domains (especially language; see Patel, 2010). It has also been proposed that music is partly modularized in cognition and brain organization (Peretz and Zatorre, 2005).

## Basic Memory Constructs

I shall begin by defining some basic constructs used in the study of memory. Human memory is *encoded*; events in the world (including events in the body and brain) cause changes in the microstructure of the brain that persist over varying amounts of time. These changes take the form of differences in the "strength" of connections at gaps (*synapses*) between nerve cells (*neurons*). These connections regulate the flow of electrical charges through neurons. The term encoding indicates that these changes form mental representations of events, which are created in a context of their meaning to a particular person. In order to persist, a memory must, to some extent, be related to what an individual already knows (see, e.g., Eichenbaum, 2008, pp. 267–268).

# Functional Types of Memory

## Echoic Memory

Memory has been defined in different ways that refer to different *modes of functioning* in relation to the times spans over which it may persist. Following research into very brief (250-millisecond) memory for visual images that yielded the concept of *iconic* memory (Sperling, 1960), an analogous concept of a very brief auditory or "echoic" memory was proposed (Crowder and Morton, 1969). Echoic memory is posited as very brief *sensory* image of an auditory stimulus that persists for a second or two at most. The distinction between echoic and auditory short-term memory is not always clear (Crowder, 1993).

## Short-Term Memory

A construct with a much more developed history is *short-term memory* (STM). STM exists on a timescale of seconds, ranging from approximately 4–30 seconds, though it is usually of the order of 4–8 seconds. STM has been called the "specious present" (James, 1890) and is the window of time within which immediate perception and thought occur. In addition to this *temporal* limit, STM also has a *capacity* limit (Cowen, 2005): an actual number of items that can persist as STM at one time. This number was originally proposed by Miller (1956) as 7±2, but has recently been reduced to a usual maximum of 4 or less (Cowen, 2005). This capacity can be increased by practice (Ericsson and Kintsch, 1995). This very small number seems to be contradicted by everyday experience. Part of the explanation for this lies in the *associative* nature of human *long-term* memory (LTM); memories for items and events contiguous in space or time may become connected, and the occurrence or recall of one such item may *cue* the recall of an associated item.

The idea that memory is associative has a history in Western thought, dating back to the mid eighteenth century. Associations are thought to consist of connections between networks of neurons in the brain (Hebb, 1949), whereby a group of items (representations) related by association can form a single consolidated network in LTM. This larger item can then be recalled (activated as STM), a process that can occur on multiple levels. In this way a kind of hierarchical compression occurs, which allows the most efficient use of the limited capacity of STM; George Miller used the term *chunking* for this process. *A memory chunk* is a group of 3–5 items related by association; a musical grouping consisting of 3–5 notes would be a chunk, and a phrase consisting of several of these groupings would be a higher-level chunk. The limitations of chunking are implicated in both the formation and recall of memories. Prominent items in chunks can be used to cue other chunks, allowing for the recall of longer sequences. Memorability is related to how "chunkable" a sequence is, which will depend on the amount of repetition, and on boundaries formed by discontinuities in a sequence. The more clearly a sequence can be "chunked," the more likely it is to be recalled. Chunking in music is related to perceptual grouping processes (Bregman, 1990; Lerdahl and Jackendoff, 1983). The idea of chunking accounts for how immediate memory can have such a limited capacity, yet be effective.

## Long-Term Memory

Everyday use of the term "memory" refers not to STM, but to *long-term* memory (LTM). LTM differs from STM in several ways. Long-term memories persist over a much longer time period, even a lifetime, as their formation involves lasting structural change in the brain. Moreover, unlike STM, almost all the contents of LTM are not conscious at any given moment, although cued memories may enter consciousness through associations.

### *Long-Term Memory: The Episodic/Semantic Distinction*

There are further distinctions within LTM. First, there is a distinction introduced by Endel Tulving (1972) between *episodic* and *semantic* long-term memories: a distinction between memories of specific situations and events (*episodic* or autobiographical memory), and general conceptual knowledge (*semantic* memory), the latter being more abstract and often developing through the experience of repeated similar episodes (Baars and Gage, 2010, p. 325; Eichenbaum, 2008, pp. 352–359; Hasselmo, 2012, p. 208). Semantic memories are categorical, and consist of aspects of music that can be categorized (Omar, Hailstone, Warren, Crutch and Warren, 2010).

Episodic memory is dynamic, and may be changed by the very act of remembering (Hupbach, Gomez and Nadel, 2013; Nadel, Hupbach, Hardt and Gomez, 2008). An example of musical episodic memory would be remembering a particular musical performance, while an example of musical semantic memory could be recognizing a familiar tune or composition, or the sound of a particular instrument.

Episodic and semantic memory constitute two ends of a continuum extending from recollections of specific episodes through increasingly general models of types of situations, to abstract knowledge representations that can no longer be traced to any particular experiences. There is evidence that musical episodic and semantic memories are related to different anatomical locations in the brain (Platel, 2005).

In music cognition research, *episodic* memory is typically tested in recognition or, more rarely, recall tasks. *Semantic* memory tests usually involve requiring participants to make judgments about types of events they think are likely in particular musical situations. This type of semantic memory is referred to as a *schema*, a general expectation about types and distributions of events (Bartlett, 1932/1995; Gjerdingen, 1988, pp. 3–10). Schemas reflect structural regularities in music such as tonality and meter, or established musical forms.

### *Long-Term Memory: The Explicit/Implicit Distinction*

A further distinction important in LTM is that between explicit and implicit memory (Cohen and Squire, 1980; Schacter, 1987), a distinction between memories that are accessible to consciousness and those that are not. One of the major discoveries of the last 150 years about the human mind is that much of the activity of the mind/brain is not available to awareness (Ellenberger, 1970) but remains *implicit*, evidenced particularly in the acquisition of *skills* (called *procedural* memory). Many kinds of physical skills, such as knowing how to play a musical instrument, require memory for their execution, but those memories are not available to consciousness, and often cannot be described verbally. More recently, another form of implicit LTM has been proposed: implicit *statistical* representations. This form of memory is thought to be involved in unconscious learning (Ettlinger, Margulis and Wong, 2011; Reber, 1993) of regularities (patterns) in the environment, and structures unconscious expectations about environmental events. This form of implicit memory has been demonstrated in relation to the "grammar" of melodic sequences (Loui, 2012). The above-mentioned schemas are describable in terms of this kind of memory, being involved in, for example, the unconscious generation of expectations about musical events as a piece unfolds. Making such schemas explicit is one of the goals of the formal study of music. Implicit perceptual memory is the basis for much of *recognition* memory. Many types of activities involving memory may have both explicit and implicit components which are not always easy to tease apart.

From a biological point of view, it seems that a primary function of LTM is not to construct highly detailed and accurate representations of the past, but to provide a generalized model of regularities in the world that will be useful to guide future behavior (Fuster, 2013, pp. 125–126; Roediger, Weinstein and Agarwal, 2010, p. 17). Long-term schematic memories tend to be structured in terms of generalized *categories* (McAdams, 1989; Snyder, 2000). Musical long-term memories and expectations are thus often structured in terms of categorical schemas like scale-steps, durational categories, etc. This means that listeners tend to not have exact detailed memories of music, but more generalized memories about what *kinds* of events were heard; hence a listener's repertoire of categories of musical events (semantic memory) will affect what they remember.

## Working Memory

STM and LTM appear qualitatively different, yet there are commonalities across both domains of memory. The idea of STM has thus been augmented by a more complex notion of *working memory* (Baddeley, 1986). Developing research on STM has revealed that most uses of this type of memory draw on LTM in various ways (e.g., Cowen, 2005). Generally when we use STM, we draw on already existing knowledge, and this knowledge is in the form of long-term memories. In the prevailing theory, working memory (Baddeley, 1986) consists of several parts thought of as separate memory systems. These are a "visuospatial sketchpad" (used for visualization), a "phonological loop" (involved in speech production), and a "central executive" (which sequences thinking and planning—this last part is perhaps the least elaborated of the constructs associated with working memory). The originator of these ideas, Alan Baddeley, has recently suggested a new component, the episodic buffer (Baddeley, 2003). There are probably other forms of working memory as well: for example, for motor movements, nonspeech sounds, and so on (Jonides and Smith, 1997, pp. 263–265), and some aspects of pitch memory mentioned later in this chapter. It may well be that the construct of working memory is an umbrella for a number of distinct memory phenomena that all share a time limit of several seconds; indeed, it may simply be a particular type of persistence in many different processing systems in the brain (Crowder, 1993).

At any given time, most of LTM is not accessible to consciousness. In order to explain certain kinds of memory phenomena, it is suggested that there are degrees of unconsciousness, expressed in the construct of *activation* (Cowen, 1988). The neural networks that are the basis for LTM can be active to a greater or lesser degree. At any particular moment, most will be inactive; some will be in a state of activity but not involved in current consciousness;

and some will be active *and* involved in consciousness, a situation that will change from moment to moment. So, memory can be *semi-activated* (Chafe, 1994) and memories at this lower degree of activation may be involved in mental activity but not in consciousness. Experiments have shown that prior exposure to stimuli can affect later performance *even when a participant is unaware of having experienced the original stimulus* (Bornstein, 1989). Memory networks established by the original stimulus have been *primed* into semi-activity, which, although remaining below the level of consciousness, can affect ongoing thought and perception, providing a basis for *expectation*. An expectation (which may be more, or less, conscious) is thought to be a group of networks (a *schema*) that have been *cued* and *primed* into semi-activity by current ongoing experience. The concept of expectation is important here because it is a primary mode in which listeners utilize memory in listening to music, and because it is thought to be one of the sources of emotional responses to music (Huron, 2006; Meyer, 1956).

# Music and Memory

## Melody

Experiments conducted by Deutsch (1999) suggest that auditory *working memory* may consist of several parallel subsystems that retain different aspects of musical sounds with outputs of subsystems being combined in later stages of processing. Individual musical pitches use at least one of these subsystems. Listeners presented with two pitches the same or a half-step apart accurately judged pitches as same or different when the pitches were up to 6 seconds apart in time, but accuracy decreased when other pitches were interpolated in the empty time interval. This interference effect was strongest when the intervening tones were in the same octave as the original two pitches and the average interval between the intervening pitches was large (Deutsch, 2012). This latter effect may be a basis for the fact that the majority of pitch intervals in virtually all melodies are small—a major third or less (Dowling and Harwood, 1986).

A familiar melody can be presented at almost any tempo and at any pitch level and remain recognizable; hence memory encoding of familiar melodies is not an exact (episodic) copy of particular pitches and time intervals, but a higher-order abstraction (schema) of particular features of the melody. Possible features of pitch encoded in memory include *interval, contour*, and *scale-step context* (position in a scale). Which features are more salient in melody recognition (as opposed to recall) has been tested in several ways. One technique for separating aspects of a remembered melody is *octave scrambling*, which destroys musical interval structure, but preserves the scale-step order of the pitches in a melody (Deutsch, 1972). When familiar melodies are presented with their pitches randomly scrambled to different octaves, they are generally unrecognizable. However, if the contour (up and down pattern) of the melodic line is preserved, they are more frequently recognized (Dowling, 1978).

Listeners are often unable to tell the difference between exact and contour-preserving transpositions of novel melodies (Dowling, 1994), for both tonal and atonal melodies. However, the importance of contour versus interval seems to decline the more well learned a melody is. This is in line with results of studies that have found that processes of memory formation in listening are highly dynamic, not just as a consequence of longer-term learning processes but also in the very process of real-time listening itself. As Dowling, Tillmann and Ayers (2002, p. 273) note, "The processing of a phrase, once heard, continues automatically [in memory] even while the listener hears new phrases. What the listener can remember having heard continually changes during continued listening." In an unusual study of melodic *recall* (Sloboda, 1985) it was concluded that recall of simple melodies "was never note-for note perfect." In recalling these melodies, participants produced small variations that were harmonically and metrically consistent with the originals (musically trained participants relying somewhat more than did untrained participants on harmonic structure). This study seems to confirm the idea that episodic memory for melody typically consists of an underlying abstract schema in which not all surface detail is retained.

In the perception of melodic intervals, each culture creates a set of melodic intervals that become perceptual categories that determine the tuning of tones occurring in its music. These intervals are categorical in that there are limits to what is considered an acceptable rendition of a particular interval. Exactly how much leeway is acceptable is a cultural variable (Arom, Leothaud and Voisin, 1997). Perception of interval categories is much clearer to musically trained than to untrained listeners (Burns, 1999).

Tonality—the organization of music into sets of pitches around a central pitch which is established by its frequent occurrence and appearance at salient points—has significant ramifications for musical memory. Sets of pitches constitute scales; groups of pitch categories or scale "steps" to which a passage or piece of music is limited. The steps of a scale have varying degrees of structural stability (Tillman, Peretz and Samson, 2011, p. 378), serving as cognitive landmarks in establishing a framework for listeners (Dowling, 2010, p. 234; Krumhansl, 1991). Knowledge of scale-step categories is a kind of implicit statistical memory acquired by members of a musical culture through exposure to its music (Burns, 1999).

The above-mentioned stability may not be operative in music that does not conform to tonal principles. In the experience of atonal melodic sequences the anchoring effects of tonality cannot be operative, leading some authors to maintain that atonal music theory has little basis in human perception (Francès, 1988; Lerdahl, 1988). Experiments by Francès (1988) using groups of musicians familiar and unfamiliar with atonal idioms, showed that both groups had great difficulty identifying varied repetitions of a 12-tone series, especially in an actual musical context. Further experiments (Krumhansl, Sandell and Sergeant, 1987) indicate that the structures of 12-tone music are slightly more transparent to musically trained listeners familiar with the style.

## Rhythm

As noted above, to form a perceptible pattern, the events that comprise a rhythm must seem connected together in the present. Therefore, rhythm can be defined as the patterning of events within the time limits of working memory. It is not yet entirely clear how rhythmic sequences are encoded in memory, various models proposing different levels of hierarchical coding. As mentioned above, listeners attempt to establish a framework for rhythms by inferring beats at a regular time interval from events in the music (Povel, 1984). Most rhythm experiments involving memory are recall tests where listeners are asked to reproduce a heard rhythm. As with pitch, memory for duration appears to be a categorical phenomenon (Clarke, 1987); out of many possible durations, memory seems to gravitate toward a few simple durational relationships, with considerable leeway as to what constitutes a particular duration. Foundational research by Fraisse (1982) established that when rhythmic patterns involve more than one duration, listeners tend to hear durations as either long or short, with long durations being over 400–600 milliseconds. In addition, there appears to be a strong tendency for the long and short durations to be reproduced or remembered in a ratio of 2:1, a relationship that has been described as a durational schema (Povel, 1981).

In general, listeners are better able to reproduce sequences of durations when they can be interpreted as having an underlying regular sequence of beats, often involving the use of one particular duration as the basis for the others (Povel, 1984). It is also the case that sequences of durations are much easier to remember and reproduce when shorter durations are integral subdivisions of the longer durations. Although the perception and reproduction of rhythms is categorical, small within-category deviations of event onset times (nuances) can give performed rhythms a particular feel (Snyder, 2000), referred to as expressive timing (Gabrielsson, 1999). This means that a particular rhythmic pattern can be performed in different ways without losing its identity as a pattern, as in swing in jazz (Collier and Collier, 2002). This type of nuanced information is generally not a part of the episodic memory of rhythm in music. Although subtle, such nuances are important parts of what makes rhythms dynamic and emotionally charged.

## Long-Term Memory and Musical Form

Musical form can be defined as the timescale of musical phenomena that requires some kind of lasting mental representation (LTM) for their comprehension. The process of chunking can lead to hierarchical organization in LTM, and most theories of the structure of long-term representations of music use the concept of hierarchy to varying degrees. Hierarchical levels in music may range from phrase groupings up to entire pieces.

When memory passes beyond the limits of STM, it is thought to persist in a more schematic form: to become a kind of reduction. Exactly what remains of actual musical details in musical LTM is an important question. Typically, theories of musical LTM reduction involve ideas of hierarchies of structural importance (Deutsch and Feroe, 1981; Lerdahl and Jackendoff, 1983), in which certain events in music are structurally more important than others, and these constitute the *gist* of a listener's memory representation. These salient structurally important events are said to constitute a "deep" level of structure in music, more rapidly changing details forming the musical *surface* or foreground.

The musical surface is segmented into units of cognitively manageable size (chunks)—the actual groupings, phrases, and so on of the music. Typically in tonal music the proposed deep structural events occur on metrically strong beats, are of longer duration, and are located on an important scale degree (Serafine, Glassman and Overbeeke, 1989). The metaphor of hierarchical depth may be more applicable to some types of music than to others (Fink, 1999). It should be noted that although the metaphor of deep and surface structure originated in generative linguistics, music is not held, in general, to embody specific semantic meaning like language. Current models of musical representation differ considerably as to the importance, and indeed the cognitive reality of deeper levels of structure.

## Theories of Long-Term Musical Representation

Two prominent theories of musical mental representation (LTM) are Lerdahl and Jackendoff's (1983) generative theory of tonal music (GTTM) and the "cue abstraction" theory of Deliège (Deliège and Melen, 1997). The GTTM is a hierarchical theory of tonal music, and involves four different types of reduction: segmentation analysis, metrical analysis, time-span reduction, and prolongational reduction. The first two act as "inputs" to the formation of the latter two, which involve larger time spans and constitute a reduction of the most important tonal events, and a tonal tension-release structure. The mental representations posited by the GTTM represent an idealized "final state" of largely unconscious memory by a "perfect" experienced listener (Lerdahl and Jackendoff, 1983, p. 3).

Cue abstraction theory is more general, and is proposed as being applicable to a wider range of music than to classical tonal music. In this theory, units of memory may be created by any strikingly distinctive features in the surface of the music (called *cues*) over a range of time spans, rather than just tonally significant events; these cues act as memory markers that define larger segments of music. Cue abstraction theory proposes a simpler and looser hierarchicality than the GTTM, a set of *event* hierarchies rather than tonal hierarchies. It privileges prominent surface details over deep structural events in the formation of musical LTM, and the importance of perceptual salience over tonal stability, though its operation at a range of time spans allows it a degree of hierarchicality.

Because of the limitations of working memory, music can be immediately comprehended only on the timescale of 5–8 seconds. Hence the first step in a listener's construction of the form of a piece of music is the segmentation or chunking of the musical surface by identification of boundaries formed by points of change in the music. Many of the same factors that articulate musical units on lower levels such as phrases also operate on higher structural levels; just as a musical phrase will be articulated by a change in the flow of events, a sectional boundary delineating a larger time span may be articulated by an even stronger change, usually involving more aspects of the music.

Both the GTTM and cue abstraction theory propose that segmentation is a foundation for the establishment of LTM representations, a proposal confirmed empirically by Deliège (1987). Experiments by Clarke and Krumhansl (1990), Krumhansl (1996), Deliège (1989), and Deliège, Mélen, Stammers and Cross (1996) involving both classical and contemporary music established that listeners (both musicians and nonmusicians) are often in considerable agreement about the location of major segmentation points in pieces of music.

## Questions about Long-Term Musical Memory Representations

Although an unconscious memory reduction is a theoretical entity, several experiments have been conducted to try to determine whether listeners actually have such representations. Building on an earlier experiment by Serafine (Serafine et al., 1989), experiments by Dibben (1994) and Bigand (1990) using composed reductions of short musical examples have produced some evidence of the cognitive reality of reductions in tonal music, at least on a modest timescale. Dibben's results led her to conclude that cognitive representations of atonal music are *associational* rather than strictly hierarchical, echoing Imberty (1993).

Experiments by Deliège and Melen (1997) established that listeners, both musicians and nonmusicians, use surface features of music as memory cues. These experiments involved organizing randomly reordered segments of a previously heard piece on a timeline representing their original order (Clarke and Krumhansl, 1990: Deliège, 1993; Deliège and Melen, 1997). Unlike segmentation experiments, where the performance of musicians and nonmusicians are often comparable, in many of these experiments, musicians tended to do better than nonmusicians, though for both groups judgments about segment location were more accurate near the beginning and end of pieces.

Other experiments have explored the development of listeners' schemas for musical elements in particular pieces by requiring judgments about the similarity of fragments of music from the same piece. This approach proposes that thematic variants are categorized around abstract *prototypes* (Rosch, 1975) (generalized representations of thematic material) and that variants of a theme can be heard as similar (Zbikowski, 1999). Deliège (2001) and Krumhansl (1991) performed experiments investigating listeners' ability to identify as yet unheard fragments of a partially heard piece. In both cases listeners were able to use what they had heard to identify unheard examples as being similar and as coming from the same piece.

In a further experiment, Deliège (1996) asked listeners (musicians and nonmusicians) to compare a large set of small (1–2 measure) "cells" from a Bach violin sonata to two different reference or "prototype" cells. In general, listeners were able to identify the variants with the correct prototypes, although the nonmusicians had narrower definition of similarity. From results of a similar experiment using pieces by Beethoven and Schoenberg, Lamont and Dibben (2001) concluded that the listeners had in fact used *surface* features to relate fragments. In summary, it appears that both musicians and nonmusicians use surface features in constructing long-term mental representations of music.

The existence and utility of larger-scale hierarchical memory reductions has not been firmly established, though most experiments on tonal structures have investigated relationships between events adjacent in time rather than those separated by large spans of music. The use of deep structural features in ordinary (not analytically oriented) listening has been called into question by the results of a number of experiments. These experiments have explored the question of the role of memory in the perception of an entire piece of music, in part by addressing the question of what sort of information seems to be available in memory over the total duration of a piece as it unfolds in time. The results of these experiments would suggest that, for most listeners, the types of relationships between constituent parts of a piece that are described in theories such as that of Lerdahl and Jackendoff are not accessible in memory.

Experiments by Cook (1987) explored whether the initial key of a piece was still accessible in listeners' memories at the end of the piece. Some evidence was found that listeners were able to undertake this task successfully, but only for pieces shorter than approximately 30 seconds. This supports the view that tonal closure may be perceived most strongly over short time spans (Levinson, 1997; but see also Gjerdingen, 1999, for a critique of Cook's study).

The results of several other studies (e.g., Karno and Konecni 1992) support the view that long-range relationships between musical materials are neither particularly accessible nor stable in memory. Further experiments by Clarke and Krumhansl (1990), Deliège (1993), Deliège et al. (1996), and Deliège and Mélen (1997) explored the ability of musically trained and untrained listeners to remember the order in which events had occurred after hearings of classical and post-tonal pieces. Although listeners' judgments of location of segments and segment order were roughly accurate, they were less so for segments toward the middle of pieces (Mishra, 2010), although musically trained participants appeared better able to use higher-level schematic knowledge to achieve greater accuracy. It has to be noted that the results of these experiments do not prove that large-scale musical relationships cannot be encoded in memory. It is still hypothetically possible that the memory processes of expert listeners, or more likely, performers, are capable of dealing with musical relationships over large timescales. However, for most listeners, it seems likely that memory does not accurately encode these longer-term, larger-scale, longer-duration hierarchical relationships.

## Conclusion

Much about musical memory still remains to be understood, indeed, explored. New fields of research are continuing to extend what is known, as well as throwing up new questions. The field of neuroscience and the methods of neuroimaging have already shown great promise in identifying the areas and networks in the brain that are implicated in memory for music. Frontal, parietal, and premotor cortical areas, together with the cerebellum, are associated with working memory for musical pitch, while processing and representation of musical meaning appear to rely on an area of the middle temporal gyrus and left anterior temporal lobe (Koelsch and Siebel, 2005). Similarly, the study of the effect of emotion on cognitive and memory processes is very much at an early stage, but can be expected to provide fruitful insights into the nature of musical memory. Many studies have shown that emotion, or affect, might be one of the most significant factors that determine how and what we remember (see Dolan, 2002, for an overview), and given that music is strongly associated with the modulation of emotional state, it can be expected that the study of musical memory will provide critical evidence about the nature of human memory in general (see Juslin and Sloboda, 2011).

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