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Working Memory in Music: A Theoretical Model

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Many psychologists have accepted a dual memory system with separate short- and long-term storage components. More recently, the concept of working memory, where short-term memory is composed of both storage and processing segments, has been considered. Baddeley (1990) proposes a model for working memory that includes a central executive controller along with two slave systems: the phonological loop and the visuospatial sketch pad. The model allows for both storage and manipulation of information. However, this model does not seem to account adequately for musical memory (Clarke, 1993). Through a review of relevant literature, a new model is proposed in which an additional slave system is added to the Baddeley model to account for musical information. Consideration of this kind of cognitive processing is important in understanding the significant demands placed on working memory in such activities as taking music dictation, where there would be a tradeoff between storage and processing functions.

NUMEROUS music psychologists have accepted a dual memory system similar to the model of Atkinson and Shiffrin (1968), in which there are separate short- and long-term storage components of information. Recently, many psychologists have addressed the concern that short-term memory (STM) may be in itself made up of more than one element; STM may consist of both storage and processing components—the composite unit labeled working memory.

Baddeley (1990) proposed a widely supported and important model for working memory that includes a central executive controller along with two slave systems: the phonological loop and the visuospatial sketch pad. This model allows for both storage and manipulation of information. The phonological loop is made up of two parts: a phonological store and an articulatory control process based on inner speech. This subsystem is responsible for the coding of speech, and presumably other sound information, whereas the visuospatial sketch pad centers around visual information.

The primary question to be addressed in formulating this new model,

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which is cast in light of the Baddeley model is: is the nature of working-memory in music different from working-memory of other acoustic information, and if so, how might the Baddeley model be adapted to meet this condition? In order to reach a conclusion about this question, two broad issues must be addressed: the nature of short-term storage of music versus other phonological (primarily verbal/textual) information, and actions that justify the existence of a processing component in STM in music. These two areas follow the two components of the phonological loop: storage and articulatory control.

Baddeley provides the following phenomena as evidence of the phonological loop: acoustic similarity, word-length effect (capacity), articulatory suppression, and perhaps most importantly for this study, unattended speech effect. Another primary consideration is the interaction between STM and long-term memory (LTM), especially as related to using LTM strategies to improve STM performance (e.g., chunking, rehearsal).

In order to reach conclusions about the nature of working memory in music, it is important to study research relevant to Baddeley's specific phenomena to determine if there are differences in the encoding and processing of verbal and musical information. These criteria will be discussed according to the two broad issues listed above (storage and processing).

The Nature of Short-Term Memory of Music

Before the 1970s, nonverbal information storage received little attention in human memory models, and the majority of experiments on the duration of sensory memory centered on visual storage (Deutsch, 1975b). Only a limited body of research defines STM capacity specific to music; most studies involve at least some processing elements. In studies that address broader research problems, some researchers have drawn some conclusions regarding the size and nature of STM in music. Long (1977) concluded that channel capacity reaches its processing peak between 11 and 15 pitches. Pembrook (1986) states that memory for an unfamiliar melody will not be accurate for melodies longer than 10 notes. Pembrook (1987) suggests a melodic memory capacity of approximately 7–11 notes, depending on various factors. Kauffman and Carlsen (1989) state that STM is at least 180 s in length with music; however, this is usually considered beyond STM with nonmusical information. Baddeley (1990) states that the phonological store will hold information for about 2 s.

Information held in STM is easily lost if not rehearsed. Tests of delayed melodic memory present a somewhat confusing picture (Dewitt & Crowder, 1986). Many of the melodies or parts of melodies are retained in LTM, resulting in the fact that long pieces of melodic information become chunked. In addition, different kinds of information seem to be retained over time better than others, such as contour versus intervallic content (Dewitt & Crowder, 1986). There is considerable debate over this issue (Dowling, 1978; Eiting, 1984). Davies and Yelland (1977) found that silent internal rehearsal did help to improve the ability to draw melodic contours of short tonal sequences.

Information held in STM is subject to disruption. Much of the earliest research in the study of retention of pitch examined various factors that would cause interference between a given and comparison pitch—this similar to articulatory suppression. Several studies have shown that the interpolation of a tone during the retention interval between a given and a comparison tone decreases performance accuracy (Bull & Cuddy, 1972; Elliott, 1970; Wickelgren, 1966, 1969). Increasing the number of interpolated tones when the retention interval is held constant decreases performance (Massaro, 1970; Rimm, 1967), this finding is very similar to the phenomena experienced with verbal information. Deutsch (1970b, 1975b, 1977) required subjects to compare pitches when different numbers of tones or spoken numbers were interpolated under various conditions and secondary demands. The interpolated tones caused considerable disruption in performance while the spoken numbers had little effect. In addition, the actual tonal relationship of the interpolated tones played an important role in either helping to facilitate or further disrupting performance (Deutsch, 1970a, 1972a, 1972b, 1973, 1974, 1975a; Deutsch & Feroe, 1975; Shatzkin, 1984). Based on these lines of research, Deutsch stated that: "one must conclude that a specialized system exists for the storage of tonal pitch" (1975b, p. 113). This research also implies that subjects call on LTM strategies and/or traces held in LTM when inputting into STM.

Modality, suffix, and recency effects are considered to be important characteristics of short-term auditory memory. In a study of melody recognition in STM, Dowling (1973) found a "J-shaped" serial position curve—typical of STM for verbal material. Roberts (1986) found similar recency effects (the term used to describe the enhanced recall of the most recently presented item) for both melody and harmony. Roberts, Millen, Palmer, and Tartter (1983) found that highly trained musicians demonstrated a recency effect for both visual and auditory presentation when tested on immediate serial recall of notes; moderately trained musicians demonstrated this effect only for the auditory presentation. In addition, recency effects were noted for both auditory and visual presentation of music, with the explanation that musicians form both visual and auditory representations for written music. Roberts (1986) found that modality (advantage of aural over written presentation) and recency effects, when linked together, differ between music and language.

Influence of Long-Term Memory on Short-Term Memory

To overcome the limitations of STM capacity, a listener presumably would have to chunk information or use some other type of LTM strategy. The listener must draw on previously learned material or on syntactical rules presumably held in LTM. This would imply that there is a processing demand in addition to simple short-term storage. This is regarded as a prime justification for the proposed model of working memory.

In an important study of STM in music, Pembrook (1987) asked subjects to compare melodies (same or different) with differing times and differing rehearsal strategies used between hearings. Subjects in the first group heard the two melodies without pause; subjects in the second group were presented with a melody followed by a pause of 19 s; subjects in the third group rehearsed the given melody between playings by singing. He found that the singing rehearsal strategy was the least effective, concluding that the subjects were trying to sing beyond their memory limits, causing interference that impaired performance. An additional conclusion might be that the actual act of singing may take too long to be effective—that the trace might be lost between the time of perception and the time of vocal performance. Either conclusion would seem to show that too much stress in terms of storage and processing demand is placed on STM (or working memory), causing retrieval problems. Although not directly related, these conclusions are consistent with findings related to the articulatory suppression found with verbal information.

A number of studies have investigated perception and memory of melodies that are altered in some fashion, thereby increasing the processing component of working memory. There are two separate discriminations of melody: contour and intervallic content. Attneave and Olson (1971) found that subjects were not successful when presented with isolated intervals and asked to transpose them to other pitches ranges; this contrasts with the subjects' success when they were asked to transpose a familiar tonal melody. This points out a clear difference between processing of melodic material held in STM versus LTM; individuals were able to process (transpose) the information held in LTM but were unable to both process and store the information held only in STM. Dowling and Fujitani (1971) found that subjects were able to distinguish between exact repetitions of brief atonal melodies and imitations, but were unable to distinguish between exact transpositions and imitations at a new pitch level. In terms of the significant processing demands required in such tasks as inverting intervals, Dowling (1971) found that the exact interval size becomes lost with inversion, retrogradation, and with retrograde inversion. This concept was tested further with melodies in inversion, retrograde, or retrograde inversion by Dowling (1972); this study suggests that melodic contour rather than discrete intervallic relationships is remembered and that inversion is perceived more successfully than retrograde or retrograde inversion. Memory is not strong enough to retain the more information-intensive trace of exact intervals.

Untrained subjects do not find contour recognition much more difficult than do trained subjects (Burns & Ward, 1978; Dowling, 1978), however training seems to be important in interval recognition (Cuddy & Cohen, 1976). Perhaps trained subjects are able to draw on a richer LTM, allowing more efficient LTM strategies to be applied in order to chunk information so that storage can be increased.

Tonal structure is certainly an organizational element that influences melodic recall. In fact, tonality might be one the greatest of all syntactical organizers in Western music. This would seem to suggest a processing of information held in STM with structures kept in LTM and would seem to strongly support the model of working memory. As music is heard, the listener would attempt to place the information in some kind of organizational framework. Dowling and Harwood (1986) state that pitch information in melodies might be stored in a schema consisting of the contour plus an indication of where that contour should be hung on a tonal scale. Sloboda and Parker (1985) concluded that memorizing simple, well-formed tonal melodies involves building a mental model of the underlying structure in which not all of the surface detail is necessarily retained. Edworthy (1985) concluded that contour can be encoded independently of tonal context; interval information becomes more precise as a tonal framework is established. Dewar, Cuddy, and Mewhort (1977) found that recognition memory, even for individual pitches, seems to be context dependent. This is echoed by Cuddy (1971), who found that sets of notes with triadic and octave relationships were learned more rapidly by music students than were sets of tones without such relationships, again suggesting the use of LTM information and strategies.

In an early study, Ortmann (1933) attempted to identify the specific determinants of melodic memory through a dictation test of "immediate recall" (p. 454) in which students wrote on printed forms what they had heard after only one hearing; the examples were five notes long—certainly within the limits of STM. Ortmann isolated the factors of repetition, contour (note direction, conjunct-disjunct motion), and interval size (degree of disjunctiveness) as primary determinants; order, chord structure, and contraction were deemed as miscellaneous determinants. Taylor and Pembrook (1983) attempted to test the validity of components of Ortmann's melodic determinants. Ortmann's melodies and a random sequence of 20 melodies were presented to three groups of students, each group possessing varying amounts of musical experience. Inexperienced listeners responded through singing; experienced listeners responding through singing and two written modes. They found that Ortmann's four major determinants, when cast in the structure of their experiment, generally seemed to elicit responses similar to those in the original research. They did express some new concerns, especially in terms of melodic organization, that Ortmann did not address; Ortmann did not account for syntactical structures in some of the melodies that might have served as strong mnemonic (LTM strategy) reinforcers in melodic dictation, such as common scale segments and/or triads. The authors concluded that a number of perceptual and memory factors are used when remembering short melodies.

Related to this line of research, Pembrook (1986) investigated the effect of various strategies of rehearsal on performance of dictation exercises, with a particular interest in the simultaneous coding and performance tasks required in many approaches to dictation versus separation of coding and performance. There was a dramatic increase in scores when subjects were given a second presentation. Pembrook concluded that it was possible that the first hearing provided a schemata or a sense of expectancy that allowed more meaningful perception and coding of the second playing; an alternative explanation was that the information might be encoded in some longer-term storage area and eliminated from short-term stores, allowing for a greater amount of new information than might have been expected. In terms of methods used in melodic dictation, writing while hearing and listening before writing proved superior to listening, singing, and writing. In explaining this result, Pembrook states that this may be a result of singers attempting more notes than can be remembered accurately; exceeding STM limits presumably would cause disruption of the original trace. The indication of singing being a poor rehearsal technique in STM was again found in another study by Pembrook (1987); only in certain circumstances did singing appear to be a good strategy in the conversation of melodic material.

Deutsch (1980) presented musically trained listeners with sequences of 12 tones and required them to notate the tones (dictation) after hearing. She found that listeners perceive hierarchical structures that are present in tonal sequences and use these structures in recall. Sequences in which tonality was easily identified and therefore easily coded were recalled with a high level of accuracy; more errors in recall were found in sequences that were not easily encoded. Temporal segmentation was found to have a substantial effect on performance. This would seem to imply that melody is encoded in a variety of ways in some hierarchical fashion depending on its structure and on the experience of the listener.

Cohen, Trehub, and Thorpe (1989) asked adults, grouped according to musical training, to listen to three repetitions of a five-note melody followed by a final melody with either the same tune as those preceding it or differing in one position by one semitone. Systematic presentations of melody would involve less uncertainty and therefore lower demands on processing resources and lead to high performance. Increasing uncertainty leads to increased errors in identification of melodic change. Trained listeners may encode musical material at a higher level, such that experience reduced uncertainty with well-structured stimuli. Long (1977) found that music training tended to improve memory performance of short melodies, presumably because listeners are able to draw on a richer and more varied schemata from LTM. Stoffer (1985) proposes that musically trained listeners are able to chunk more efficiently than novices. This would imply that they are calling on LTM strategies developed through training. This would also seem to indicate that there is definitely a musical processing component connected in some fashion to the memory task.

Unattended Music Effect

Baddeley (1990) states that the unattended speech effect provides evidence for the existence of his working memory model; attention is divided between competing information, illustrating that there is some kind of processing of the information held in STM. A controller is determining which of the competing information streams takes precedence. Therefore, study of attention is of great importance in formulating the proposed model.

Much of the research related to unattended speech effect in music addresses the effect of background music on performance in some other area—most notably some verbal task; the findings of this research are sometimes vague and often contradictory, attributed in part to possible conflicts between attention and arousal properties in music.

In a literature review, Uhrbrock (1961) cites numerous examples in which music tends to improve vigilance, focusing attention and relieving boredom in the workplace. In a study of attention in an academic setting, Daoussis and McKelvie (1986) noted that extroverts who regularly studied with background music scored higher on a reading comprehension test than did individuals from other populations. Kiger (1989) found that high information-load music disrupted attention more than did low information-load music in a study of reading comprehension. Wolfe (1983) asked 200 undergraduate nonmusic majors divided into four populations to perform mathematical problems with background music of differing volumes. The results indicated that the experimental conditions had little significant effect on task performance. Madsen (1987) studied competition for focus of attention with an emphasis on how background music affects performance. Madsen concluded that music used as a background might inhibit discriminatory listening—a fairly logical conclusion. Reading comprehension did not seem to be adversely affected. He points out that the nature of the music itself in terms of such factors as volume and changes in character (volume, tempo, timbre) may affect attention in different ways. In fact, some background music may help to mask other, more disruptive, backgrounds.

Some evidence suggests that background music with words interferes with reading comprehension. Henderson, Crews, and Barlow (1945) found that classical, instrumental music had no effect on reading comprehension, whereas popular music with lyrics decreased reading performance. Martin, Wogalter, and Forlano (1988) found that unattended speech, but not music (instrumental music or random tones), interfered with reading comprehension. In fact, in one experiment, instrumental music seemed to actually improve performance, whereas vocal music did seem to impair reading comprehension. In a separate experiment, college music majors identified short excerpts from musical scores (visual task) with differing aural backgrounds. Unattended music had a greater interfering effect than did speech on this task. It is interesting to note that although unattended speech did have an effect on a visual music task, unattended instrumental music did not cause a reduction of reading comprehension. In a study of background music on phonological STM, Salame and Baddeley (1989) found that although all music impaired performance on a serial recall test of digits, instrumental music had much less impact than did music with words.

A Theoretical Model Of Working Memory

Many psychologists have accepted that memory is not a unitary system. Many have accepted the modal model of Atkinson and Shiffrin (1968), in which there are separate components for short- and long-term storage. Although there are differing theories about the capacity and nature of STM, most would agree that STM is limited in both size and duration. One model of STM—working memory—holds that the short-term store is actually itself a multicomponent system. Whereas STM has been assumed to be purely a passive buffer system, working memory is assumed to have both storage and processing functions.

Additionally, the role of memory in musical listening does not seem to be fully explained under Baddeley's model. The dissimilar relationships between modality and recency effects in language and music would suggest that music is encoded differently than is verbal language (e.g., Roberts, 1986). The differing degrees of disruption caused by language and music in a variety of experimental memory storage tasks also supports the view that musical information is held in a different area of STM than is verbal information.

Numerous studies have shown that there is a direct link between storage and processing of musical information. There is a significant body of research that supports the idea that the encoding of musical information is influenced by various types of organizational factors or schemata, which are held presumably in LTM. This use of LTM schemata for musical information in STM would seem to show that there are both processing and storage components in STM.

Probably the greatest evidence for a separate component for musical working memory is shown by the unattended music effect. If there was a singular acoustic store, unattended instrumental music would cause the same disruptions on verbal performance as would unattended speech or unattended vocal music; this was shown not to be the case. Salame and Baddeley (1989) state that "the fact we can hear and remember sounds that are very unlike speech means that there must be some—presumably additional—form of acoustic storage system capable of dealing with such material" (p. 121).

Not only does the Baddeley (1990) model (central executive controller with two slave systems) not account for the musical processing, it also does not account for other coding requirements experienced in human behavior as well. For example, the model ignores information storage about smell, touch, and taste. Certainly, individuals retain these kinds of sensory memories. There are probably several other slave systems attached to the central controller to account for these traces.

A slave system in addition to those proposed by Baddeley probably exists, one that is used to store and process musical information. However, unlike possible additional loops added to account for other sensory information like taste and smell, the actual attachment of the music loop is open to some question even though the existence of the loop does seem fairly clear. The loop could be a totally separate component or could possibly be attached to the phonological loop, allowing the processing and storage of musical stimuli separate from the verbal or visual component. If, as Gardner (1983) suggests, there was less of a difference linguistically between music and verbal language at some time during early human history, the connection of the musical loop to the phonological loop might be supported in at least a very loose manner.

The degree of separation between the processing of verbal and musical that is portrayed in the research literature does not fully justify an attachment of the musical to the phonological loop (Figure 1). If there is an attachment, it would have to be very loose indeed. The existence of a separate loop seems more justified. The nature of the musical memory component itself would be very similar to the phonological loop of Baddeley's model with a musical store and a control process based on inner speech, in this case, a musical inner speech. This might follow Gordon's (1988) definition of audiation.

Consideration of this model of working memory is important in under-

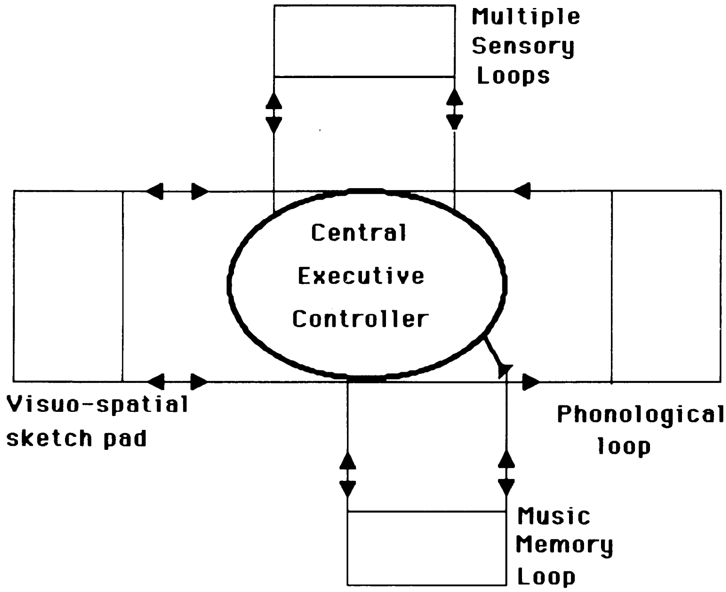

Fig. 1. Theoretical model of working memory based on the model of working memory by Baddeley (1990).

standing the significant demands placed on working memory in such activities as music dictation, in which there would be competition between storage and processing functions. Being able to have readily available strategies and information (e.g., verbal labels, musical syntax) in LTM would greatly improve performance in these areas.

Working memory would also seem to have an impact in music aptitude testing. In many aptitude tests, subjects are asked to remember and compare musical examples. Training seems to improve subjects' abilities in many memory tasks, especially in the ability to chunk information; they are able to draw on more better LTM traces and strategies. Individual differences portrayed in some music aptitude tests may then represent not talent or musical intelligence but ability, reflecting differences in working memory capacity.

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