Reframing Aural Skills Instruction Based On Research in Working Memory

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This article explores the implications of research on working memory for aural skills instruction. The first half of the article shows that the system of working memory unifies Karpinski (2000)'s "component" model of aural skills cognition and demonstrates working memory's fundamental importance to aural skills learning. The second half of the article adapts tests of working memory into exercises appropriate for the aural skills classroom.

Gary Karpinski's influential book *Aural Skills Acquisition* breaks down the process of melodic dictation into four components:

1. Hearing: the ability to pay sufficient attention, as well as the physical and neurological capability to perceive sounds appropriately;
2. Short-Term Melodic Memory, which is limited but can be extended through extractive listening and chunking;
3. Musical Understanding, or the ability to label or describe remembered musical materials; and
4. Notation: familiarity and facility with music notation.

These components are presented in roughly the chronological order in which they must occur in the process of dictation, and Karpinski urges instructors to keep them in mind since deficiencies in different stages of the process call for different methods of practice and remediation.[1]

While treating these components separately is indisputably useful and productive, we should recognize that doing so is also in a way misleading. Many, perhaps most, students have trouble with more than one stage of dictation, and working on individual stages is rarely as simple as it might seem in the abstract. For example, the ability to pay close attention to a melody seems intimately linked to our ability to store it in short-term memory; meanwhile, deficiencies in musical memory often keep students from improving their musical understanding, while quick encoding of scale degrees and rhythms through musical understanding often improves students' ability to store them in memory. Again, this is not to say that we should abandon

1 The full discussion is in Karpinski (2000, 64–91), but see also Karpinski (1990), which is entirely dedicated to this model of melodic dictation.

Karpinski's framework and methods, but rather that it would be useful to add to them a complementary perspective that recognizes the essential interconnectedness of these components.

Such a perspective is afforded by recent research into what is generally called "working memory." Different researchers define this term in slightly different ways, as discussed later in this article, but for right now, we might think of working memory as the system that coordinates the storage and processing of information. Working memory clearly underlies all four components of the dictation process, as described by Karpinski:

1. control of attention is either a component of working memory or strongly correlated with it;
2. short-term memory either is a supporting process to working memory or has been replaced by the concept of working memory, depending on the definition;
3. analysis for musical understanding relies on the ability to manipulate and focus on materials stored in memory, an essential component of working memory; and
4. the application of rules of notation stored in long-term memory must be brought to bear in the more active system of working memory to be effective.

Working memory thus provides a framework in which we can understand the connections among these components and think about ways to strengthen them all simultaneously.

Since working memory underlies so many musical processes, it is perhaps unsurprising that at least one study has found that working memory is enhanced in musicians as compared to the general population.[2] Indeed, many musical tasks are notable for the extent to which they involve control of attention and memory, two crucial aspects of working memory. To give but one example, Charles Chaffin describes in detail the cognitive load associated with instrumental conducting, which involves formulating a "mental representation of the score," a long-term memory construct which must be brought to bear in the moment; formulating gesture, which must respond in real time to the ensemble's playing; and "[analyzing] the performance

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2 Pallesen et al. (2010). Though subjects were tested with musical materials, the authors write that musicians' primary advantage was likely the ability to "recruit more [brain] resources for cognitive control," a non-music-specific ability. The authors also note that their study does not determine whether greater working memory capacity influenced musicians' choice of career, musical training improved musicians' working memory capacity, or some combination of the two, though they tentatively speculate that "development of cognitive control may benefit from focused musical training." (10)

of the ensemble," which requires error-detection, aesthetic judgment, appropriate mental constructs, and focused attention.[3] Clearly, improving working memory in students will be valuable for virtually any career in music.

Improving working memory in our students is also attractive for a nonmusical reason: working memory capacity has been the subject of much research and attention at least in part because it has been consistently found to correlate with performance on a wide range of higher-order cognitive tasks, including language-related tasks, reasoning, and logical thinking.[4] One study notes links between working-memory capacity and a "wide variety of real world skills" and "applications to issues in cognitive development and developmental cognitive disorders."[5] Thus it seems that improvements in students' working memory have the potential to increase not only students' dictation skills, but also their ability to deal with a broad range of musical and non-music-specific tasks.

This article thus presents a new understanding of the cognitive systems that all musical skills rely on. These systems are complex and interconnected, in contrast to the "component" model presented by Karpinski. Given the complexity of working memory and the impossibility of truly isolating any single component, it will be important to identify practical ways of working on the system as a whole. Thus, the core of this article is practical: after a discussion of definitions, models, and research on working-memory training, I will present exercises derived from working-memory research that activate and exercise working memory in different ways. These sections together serve to bring our attention to the unified underlying system that all musical skills rely on—one that is difficult to understand, but also one in which improvements will have benefits both for students' musical study and in their broader lives.

Defining Working Memory in Aural Skills Instruction

The common thread among all definitions of working memory is that it is the cognitive system responsible for short-term storage and manipulation of information.[6] It is most often described as a multi-component system: while researchers differ in the

3 Chaffin (2011, 73).

4 For an overview and speculation on reasons for this connection, see Engle (2002).

5 Melby-Lervåg and Hulme, (2013, 270).

6 This wording is based on Ma, Husain, and Bays (2014, 23): "Working memory refers to the short-term storage and manipulation of sensory information lasting on the order of seconds."

number of components they describe, the three most common are a "central executive" which coordinates the work of two dependent systems.[7] The dependent systems are the "visuo-spatial scratchpad," responsible for visual and spatial information, and the "phonological loop," for verbal information.[8] Many models now also include another component called the "episodic buffer," used for communication between the other systems and long-term memory.[9] Scholars differ on whether they still preserve "short-term memory" as a distinct concept: Alan Baddeley, who developed the most influential model of working memory, says, "The concept of working memory has increasingly replaced the older concept of short-term memory," but he still uses both terms.[10]

Another model, associated with Cowan, emphasizes working memory's role within a broader cognitive context.[11] In Cowan's words, "short term memory is derived from a temporarily activated subset of information in long-term memory... A subset of the activated information is the focus of attention, which appears to be limited in chunk capacity."[12] Other scholars point out that within this focus of attention, only one item at a time is "available as the target of cognitive processes."[13] Thus Klaus Oberauer describes this model of working memory as a "concentric structure," and visualizes it as shown in Example 1.[14] We might imagine, in taking dictation, that long-term memory (all nodes and dotted lines in the example) includes our internal representations of scale degrees, tone and duration relationships, schemata, etc.; that

7 This three-part model was proposed in the foundational work of Baddeley and Hitch (1974).

8 Music and environmental sound are associated with the phonological loop in the "speculative view of the flow of information from perception to working memory" presented in Baddeley (2012, 23).

9 An accessible description of this entire model of working memory can be found at https://www.simplypsychology.org/working%20memory.html.

10 Baddeley (1992, 556).

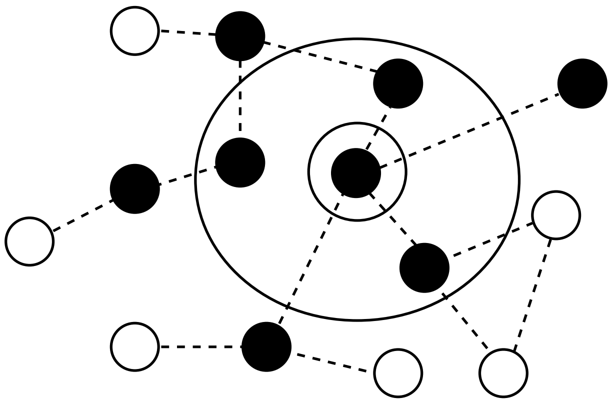
11 I purposefully do not characterize this as a competing model. Baddeley (2012, 20) explains, "At a superficial level, Cowan's theories might seem to be totally different from my own. In practice, however, we agree on most issues but differ in our terminology and areas of current focus. I see Cowan's model as principally concerned, in my terminology, with the link between the CE [central executive] and the episodic buffer."

12 Cowan (2008, 326). While Karpinski repeatedly cites the "magic number 7 plus or minus two" proposed by George Miller in 1956 in describing the number of "chunks" that can be placed in this short-term store, most modern scholars put the capacity limit closer to the "between three and four" proposed in Cowan, Chen and Rouder (2004, 639).

13 Janczyk and Grabowski (2011, 211).

14 Oberauer (2002, 412).

the "activated information" (filled-in nodes) represents the entire excerpt we have heard; that the "region of direct access" (outer circle) includes the section of the excerpt we are able to remember with integrity, and that the "focus of attention" (circled node) is the chunk that we are currently trying to identify with functional labels, rhythmic durations, etc.



Example 1
"Concentric" visualization of working memory based on Oberauer (2002, 412).

Regardless of model, all scholars on working memory place a heavy emphasis on the role of attention. Its focus is the central node of the concentric model, and in the multi-component model, the central executive—the driver of working memory—plays a crucial role in directing attention. Thus while Karpinski places control of attention in the "hearing" stage of dictation and storage in the "short-term memory" stage, models of working memory treat these components as interconnected. Several studies confirm this connection: Fukuda and Vogel (2009) demonstrated that individuals with higher working-memory capacity (storage) were better able to recover from distractions (through attentional control); de Fockert et al. (2001, 1805) provided evidence that "working memory serves to control visual selective attention," and Engle (2002, 22) declared that whatever it is that working memory tasks measure "is at least related to, and maybe isomorphic to, general fluid intelligence and executive attention." Thus attention is either a component of working memory (perhaps a function of the central executive) or strongly correlated with its capacity.

Though many scholars believe the number of elements that can be stored in working memory is limited, this is still a controversial element of the theory. Nelson Cowan and his co-authors, updating the work of George Miller, suggested that only three-to-four chunks could be placed in immediately available storage.[15] This model of "slots to be filled" suggests that objects are either remembered with integrity (placed into a slot) or not, leaving little room for "fuzzy memory" or remembering different objects with different levels of precision. Wei Ji Ma and his coauthors, on the other hand, have reviewed emerging evidence that working memory capacity might be a more continuous resource, though still of fixed capacity, that can be allocated according to perceived importance.[16] For example, upon being presented with five chunks, one might determine Chunk 5 to be of primary importance and allocate 50% of working memory capacity to it, spreading the remaining 50% of working memory capacity among Chunks 1–4 and thus remembering them with lesser precision. This model suggests that an important part of our role as aural skills instructors is helping students internalize mental models that encourage appropriate and efficient allocation of this resource.

It is difficult to determine exactly how we may apply these frameworks in re-imagining aural skills instruction and difficulties. Such a project will need to await a greater maturity of the field of working-memory research and more music-specific research in order to map aspects of these cognitive models onto different tasks and abilities. But it helps to explain the existence of student difficulties that are not clearly described in Karpinski's text. There are certainly students whose deficiencies fall neatly into one of Karpinski's four components of dictation. But many more have complex problems that involve multiple components, and we can now understand these as resulting from the interconnectedness of the complex system of working memory.

Effectiveness of Working-Memory Training

There is a large industry built on the idea that exercising working memory can increase its capacity. The companies Lumosity, CogniFit, CogMed, and Jungle Memory all operate on some variation of this principle. Yet this premise is not at this point clearly supported by research, and Lumosity settled with the Federal Trade Commision in early 2016, admitting they did not have settled science to support claims that their exercises improve school/work performance or reduce age-related cognitive decline.[17]

15 Cowan, Chen, and Rouder (2004, 639).

16 Ma, Husain, and Bays (2014).

17 The FTC's press release on this settlement can be read at https://www.ftc.gov/news-events/press-releases/2016/01/lumosity-pay-2-million-settle-ftc-deceptive-advertising-charges.

Indeed, an often-cited meta-analysis of prior research concluded that so-called "brain-training" programs have only been proven to give "near-transfer benefits," that is, improvement on the task practiced and related tasks but not on other related measures of cognitive ability, and that even such benefits may not be sustained once the training ended.[18]

Nevertheless, these conclusions are difficult to apply directly to aural skills instruction. Most aural skills courses are designed primarily to give "near-transfer" music-related benefits, so the lack of proven far-transfer benefits is not necessarily a problem. In addition, aural skills classes are quite different in format from the studies cited by in the meta-analysis. Classes often meet for up to 40 hours over the course of each semester for several semesters, and even summer breaks are not generally more than 4 months (though students may of course take breaks of their own). The meta-analysis, in contrast, considered studies to have used a "large dose" of training if the training period was more than 8 hours. While they found that the "large immediate gains on measures of verbal working memory" disappeared over time, the long-term follow-up test was usually given nine months after training had ended.[19] In short, it is not clear that the results of the meta-analysis have direct implications for working memory training in aural skills classes.

Karpinski's "Model for Music Perception and Cognition During Dictation" in *Aural Skills Acquisition* also treats the capacity of what he calls "short-term memory"—which he assumes is roughly equivalent to the "magical number seven plus or minus two" proposed by George Miller in 1956—as a limited number of slots that cannot be expanded with training. Karpinski's text thus asserts that the only ways to extend the capacity of short-term memory are through "extractive listening" and "chunking." In extractive listening, a listener focuses their attention on a certain part of a musical excerpt—say, the first half—and selectively memorizes it despite sonic interference from other parts of the excerpt. Understood with regard to the model of working memory, this clearly involves significant control of attention. In chunking, listeners use mental schemata to group music into larger "bits," allowing more notes to fit into each "slot" of musical memory.[20] As students learn more and more complex patterns, their relatively fixed number of memory slots is thus able to store greater and greater amounts of information. Nevertheless, since chunking is an invisible, mostly

18 Melby-Lervåg and Hulme (2013).

19 Melby-Lervåg and Hulme (2013, 276).

20 This discussion is in Karpinski (2000, 65–77).

unconscious process, it would take carefully designed experiments to determine whether the ability to remember longer melodies in more advanced musicians is indeed from increasing chunk size alone or whether it might also reflect an expanded working-memory capacity.

There are still reasons to focus on working memory, even without settled science on whether or not its capacity can be expanded. First, it does appear that music training and working memory have a strong correlation and that one might be able to affect the other: one study found that "training in rhythm, pitch, melody, voice, and basic musical concepts" improved students' verbal intelligence (a far-transfer benefit) compared to students who studied visual art.[21]

Second, and perhaps more convincing, while working-memory capacity may be fixed, it may also be possible to make this limited system more efficient, flexible, accurate, and quick. One study found that in a relatively easy task, while all subjects were able to complete the task, musicians "performed better as reflected in reaction times and error rates." The authors suggested that this is due to musicians' ability to recruit "more brain resources to sustain cognitive control"—in other words, musicians did not necessarily have a greater memory capacity but were able to use it more effectively.[22] The focus on "cognitive control" is probably significant: if working-memory capacity is fixed, then improvements will come in large part from the "central executive" component, which is "concerned with attentional control of behavior."[23] This is suggested also by the "continuous resource" model of working-memory capacity: if improvements in working memory performance come from better allocation of memory rather than from increases in capacity, this will likely require improved control of the system.

Therefore, my focus in the practical section below is not on increasing working-memory capacity, which may be fixed, but rather on improving the flexibility, speed, efficiency, and accuracy of the system through greater cognitive control—an essential part (perhaps *the* essential part) of what we often call "active listening." In his section on the "Hearing" component of dictation, Karpinski describes students who "have let entire playings pass by without the slightest sensory intake" as a result of "attention deficit disorder."[24] While this kind of problem can certainly be a sign of different

21 Moreno et al. (2011, 1429).

22 Pallesen et al. (2010, 1 and 10–11).

23 Baddeley (1992, 559).

24 Karpinski (2000, 65).

inherent learning abilities, in many students it and lesser forms of the same problem may come instead from a fixable lack of attentional control. If students have been especially well-trained in passive listening, the ability to decide beforehand what they will pay attention to and remember—and then to follow through on that plan—may be extremely difficult. Working-memory exercises give one way of forcing such students to find ways to regain control of their listening through attentional control and more efficient functioning of working memory.

Working Memory Exercises

Researchers on working memory have an extensive battery of tests that are designed to test working memory understood as an integrated system. To the extent that these tests exercise working memory, they may be useful in helping to increase its capacity, or, more likely, in improving its control, speed, flexibility, and accuracy. They also suggest new, interesting ways of exercising aural skills regardless of new benefits. This section will describe common tests of working memory and my own adaptations of these tests into aural skills exercises. Each test may suggest multiple exercises, and the ones given are intended as a starting point for developing variations suitable to different instructors and goals.

Most of these tests involve objects or stimuli, which in working memory research are generally verbal (sentences, words, or letters), spatial (e.g., shapes placed in different locations on a 3 x 3 grid), or numeric. In music, these objects could be tones, scale degrees, chords, functions, durations, rhythmic cells, dynamics, registers, timbres, etc. In some cases, teachers will need to help students understand how the objects are defined. For example, two chords could be considered instances of the same object based on quality, root, inversion, or voicing/spacing, or any combination of these.

In many cases, students do not need to label these objects in order to complete the tasks: for example, to determine whether two tones are the same, one does not necessarily need to know their solfege syllables or letter names; to compare two rhythmic cells, one does not necessarily need to know their rhythmic values.[25] This is a distinct strength of these exercises, as they may be used at various stages of learning. Instructors may also decide whether or not to use labels themselves in presenting the objects. For example, in presenting a melody for an N-back test (defined below),

25 Throughout this article, movable-do solfege is assumed. Instructors using other methods or terminology will know how to adapt the exercises accordingly.

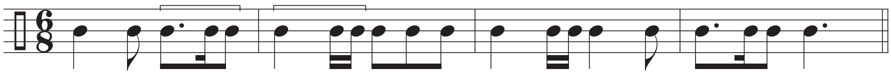
an instructor may or may not choose to sing the melody on solfege. If the purpose is simply to strengthen working memory, solfege may give students more ways to encode the information accurately as it is presented. Of course, if the instructor wishes for students to practice their scale-degree identification at the same time, they will want to omit solfege and sing or play on a neutral syllable.

Sternberg task. In this method, which derives from the work of Saul Sternberg in the late 1960s, one presents a "list of items for memorization" (in music, for example, this could be a series of chords or a rhythm composed of rhythmic cells), then asks the subjects questions about this list, usually about whether a "probe item" (say, a specific chord or rhythmic cell) was contained within that list.[26] The value of this rather simple task in music is at least two-fold. First, it is a way to work with musical materials and musical memory without the need for labels and notation. Second, it encourages active listening, encoding, and then re-hearing, in order to answer the questions.

Change detection. In a change detection test, a subject is presented with two stimuli—for example, two melodies—in series and asked to determine whether they are the same or different. This is similar to classic aural skills error detection, though in traditional error detection an aural stimulus is usually compared with a written stimulus. The stimuli in a more broadly-defined change detection test can of course both be aural, requiring neither knowledge of notation nor skill in solfege for a correct answer. A natural way to follow up would be to ask students what exactly was different, though this would of course require some kind of descriptive system (such as solfege).

Counter updating task. In this similarly simple task, subjects are given a small number of objects to keep track of, then presented with a series of stimuli including but not limited to those objects. As the series is presented, subjects count the number of times each of their assigned objects appears. For example, an instructor who wishes to draw students' attention to the distinction between the often-confused rhythmic cells that occupy the end of the first measure and beginning of the second measure in Example 2 might write them on the board, then ask students to count the number of times each occurs in the course of the rhythm. (In Example 2, each occurs twice.) Or an instructor might sing or play a melody, asking students to count the number of times scale degrees 1 and 5 occur.

26 Sternberg (1969, 424). Sternberg found that reaction times for both positive and negative responses correlated linearly with the size of the list even though one might expect some subjects to discover positive answers partway through their mental list search, suggesting the counterintuitive result that subjects search the entire list before answering even if they have already found a positive result.



Example 2
Sample counter-updating rhythm.

***N*-back test.** In an *N*-back test, subjects are presented with a series of stimuli one after another and asked to respond in some way whenever the currently-presented stimulus is identical to the stimulus *N*-back in the series. For example, an instructor could present a melody in even note values and ask students to hum the currently sounding note when it is identical to the note two earlier in the series ($N = 2$). If the melody in Example 3 were sung, students should hum along (or raise their hands, or indicate in some other way) at notes 4, 9, and 10, since they match (respectively) notes 2, 7, and 8. As the value of *N* increases, the task gets exponentially more difficult for both instructor and student: even at $N = 2$, I have found it useful to plan a melody beforehand rather than improvising on the spot. Students also take time to adjust to this unfamiliar task, but do improve with practice.

Example 3
Sample *N*-back melody.

There are notable similarities between the *N*-back test and the kind of on-the-spot canon singing advocated by several scholars with an interest in historically-based pedagogy.[27] These scholars present canon improvisation primarily as a theoretical/historical exercise for the person improvising the *dux*, who must follow rules that create acceptable harmonic intervals when a following voice is added, and secondarily as an aural skills exercise for the singer of the *comes*, who must listen and imitate at a given time and pitch interval. Those who are less interested in the historical/theoretical value of this exercise may still appreciate the aural skills value of having a following voice sing the note *N*-back in a series (melody) sung by another student or the instructor. One may choose whether or not to try to follow traditional rules

27 Schubert (2013); Cumming (2013); and Collins (2008).

of counterpoint in this case; unprepared dissonances will likely increase the level of difficulty.

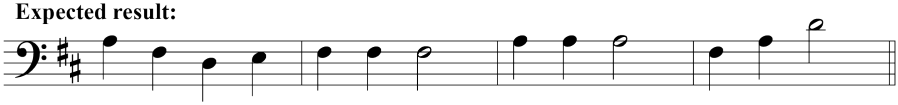
Word (or melody, chord progression, etc.) updating task. In a word updating task, subjects are first given a word. They are then instructed to mentally replace certain letters in the word with specific new letters over and over to create new words.[28] In music, we might imagine giving students a melody, either in notation (for students who are fairly fluent at auralizing from a score) or aurally. Then we might ask them to silently replace specific tones in that melody with other tones. After a (probably small) number of such swaps, students could be asked to compare their results with their neighbor or sing them for the teacher. Example 4 gives a sample instance based on a familiar melody.[29]

Original melody:

Verbal instructions:

1. "Replace the final note with high do." [Silence while students mentally rehearse]
2. "Replace the opening mi-re-do with sol-mi-do." [Silence while students mentally rehearse]
3. "Replace the re-re-re with sol-sol-sol." [Silence while students mentally rehearse]

Expected result:



Example 4

Sample melody-updating task based on the first line of "Mary Had a Little Lamb."

Stroop task. In the famous Stroop effect, subjects presented with a list of colors spelled out in colors not denoted by their names (e.g., the word "pink" printed in purple) have greater difficulty naming the printed colors of the words than if they were printed in their designated color. This suggests a possible musical application, though this will likely be most effective with students who are already fairly proficient

28 This process is described in Janczyk and Grabowski (2011). In their experiments, Janczyk and Grabowski's implementation employed real words exclusively. Given the much greater flexibility of musical grammar, this is not likely an issue in aural skills adaptations.

29 This exercise bears more than a passing resemblance to the "quick switch" exercises in David Damschroder's textbook *Listen and Sing*, in which students are directed to perform closely-related melodies in succession.

with solfege. An instructor could either sing a melody with incorrect solfege syllables (admittedly difficult!) or present a notated melody with incorrect syllables written below, and then ask students to sing the melody back with correct solfege. Of course, this is not so different from the kinds of error dictation that many instructors already use.

Running memory span. As described by Cowan, this is "a procedure in which a list of an unpredictable, long length is presented, the task being to recall as many items from the end of the list as possible after the list terminates."[30] In music, the "list" could be a string of any of the objects mentioned above: tones (a melody), scale degrees (a tonal melody), chords (a chord progression), rhythmic cells (a rhythm), etc.

Dichotic listening task. Since control of attention is either important to or strongly correlated with working memory capacity (and, of course, an important skill on its own), a significant number of working-memory tests examine subjects' ability to focus on desired information and tune out irrelevant information. In a classic dichotic listening task, for example, subjects listen, usually through headphones, to two usually unrelated streams of speech and are instructed to pay attention to and remember one and ignore the other. This task is already exercised in many aural skills classrooms when students are asked to do dictation in a room with less-than soundproofed walls, but it is probably more effective and less stressful when the task is set up with purpose and planning. The most obvious musical adaptation would be for two sound sources (performers, speakers, etc.) to be set up to play/sing unrelated musical excerpts simultaneously on opposite sides of the room; students would be asked to ignore one and listen to the other in order to sing it back, similar in some ways to two-voice dictation. This task can be altered in many ways, however, while preserving the desired goal of taxing control of attention. For example, students could be asked to sing a melody over and over while the instructor plays increasingly loud conflicting music over a sound system or on an instrument, or two groups of students could sing in different keys, or sing different melodies, simultaneously.

While these adaptations of control-of-attention tasks may seem useful only for students with a fairly high level of confidence and accomplishment, they can be adapted to students at any level of the curriculum. In fact, one of the most useful adaptations I have implemented also helps beginning students to develop their internal hearing. I first give them a single pitch to hum for a long time, breathing as necessary, and ask them to use the position of my hand to determine their dynamics,

30 Cowan et al. (2005, 47).

from high (loud) to low (silent). After students have dealt with some periods of silence (a kind of distractor), I start introducing soft irrelevant tones and music first while they are humming, then also in the silences. Finally, I combine these with a kind of tone-updating task by asking them, in the silences, to think up a half step, then up a whole step, then sing the resulting pitch. These valuable exercises have given some of my beginning students their first clear experience of internal hearing.

Among all these exercises, I have found those intended to improve control of attention to be especially useful in the classroom. Students often have difficulty controlling their attention, whether from mental and attentional habits encouraged by modern media or from distracting events in students' outside-the-classroom lives. *N*-back exercises and control-of-attention tasks in particular may help students be fully (attentionally) present in what they are doing and able to control what they listen to.[31] Beyond these benefits, the exercises are often fun and provide a welcome contrast to traditional sight-reading and dictation tasks. Increases in working memory capacity, if they occur, might thus be the most valuable benefit of the exercises, but they are far from the only ones.

Assessment

As with any aspect of our teaching, we must think about assessment. Should we directly assess students' working memory? There is a spectrum of approaches one might take. On one (probably easier) end, one could decide not to test working memory. The exercises suggested above could still be used in class as fun, short warmups or breaks from other activities. On the other end of the spectrum, most of these activities could be adapted into assessments. For example, the instructor could use a running-memory-span-based test: play a long melody and instruct students that when it stops, they must write down the last five scale degrees they heard. A melody-updating task, on the other hand, would be more appropriate for an individual hearing. Testing can communicate to students that these exercises are valued and that they might want to practice them outside of class. In between these two extremes are any number of middle positions, including requiring students to pass a pass/fail working memory hearing by a certain point in the semester or to spend a certain amount of time on these outside of class each week.

31 Indeed, we could reframe many aural skills tasks as relying on control of attention. Dictating bass lines relies on the ability to train one's attention to lowest-sounding pitches; hearing chromatic chords relies on the ability to notice changes in diatonic system; labelling chord progressions aurally relies on the ability to attune to holistic aspects of a simultaneity; etc.

When designing assessments, however, it is important to keep in mind that stress has consistently been shown to have a negative effect on working memory performance.[32] In particular, Qin and his co-authors noted that stress induced "reallocation of resources away from executive function networks" in favor of "adaptive and habitual responses," which will certainly be destructive to the kind of focused listening and attentional control that aural skills tasks typically require.[33] Since the most promising benefit of working-memory training is that it may increase attentional control, pushing students into "habitual responses" will be particularly destructive to efficiency, speed, and accuracy of working memory performance and can develop bad habits that may then spread to other areas of a student's musical life. This research suggests the urgency of making the aural-skills environment as low in stress as possible.

Conclusion

The current state of research on working memory clearly complicates the ways we understand the process of taking dictation. In light of the unified nature of the working memory system, we must sacrifice the simplicity of understanding this process as a series of separable components. This is not to say that Karpinski's framework is no longer useful: rather, we must now understand the four components as different windows into an essentially unified system. We can still treat them separately, but they all ultimately interconnect and rely on each other. This unified framework can help explain why many students' deficiencies seem to fall into at least two of Karpinski's categories.

Understanding this framework should also have an effect on the way we understand the purpose of aural skills classes. Well-established learning goals such as internalizing musical schemata and gaining fluency with notation should not be replaced, but we must understand that at the root of nearly every task we do—and particularly tasks that must be done in a time-sensitive manner, like sight singing and dictation—is the system of working memory. To better reach these traditional goals, we should pay attention to our students' working memory skills—and, of course, these skills are valuable in and of themselves. While we may not be able to increase the capacity of working memory, we might add to our traditional goals something like,

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32 The extensive literature on this negative effect includes Qin et al. (2009); Luethi, Meier, and Sandi (2009); and Schoofs, Preuß, and Wolf (2008).

33 Qin et al. (2009, 30).

"This class will increase the speed, efficiency, flexibility, and accuracy of students' working memory."

A more detailed model of exactly how dictation (or sight singing, or improvisation, or many other musical tasks) uses the various components of working memory will need to await further studies, both of working memory generally and of applications to music. But in the meantime, we can use exercises based on the working-memory literature and develop a sensitivity especially to the role of students' attentional control. Making these changes at the very least gives us new ways to exercise traditional skills, and may even improve students' performance—both within music and in their broader lives.

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