The Music Department of the Hofstra University
College of Liberal Arts and Sciences
and
Hofstra University Honors College

The Differences in Average Working Memory Capacity for Auditory Pitch and Rhythm Stimuli

An Honors Thesis Project

submitted by

Anthony DiTaranto

In partial fulfillment of the
Bachelor of Science in Music Education degree
with an Honors College Graduate Designation
at Hofstra University

Submitted 5/10/2015
Revised 6/17/2015

TABLE OF CONTENTS

I – Abstract

This paper addresses connections between aural skills pedagogy and current brain research, with an emphasis on rhythmic dictation. Musical dictation is an application of audiation and music literacy and therefore is taught to increase overall musicianship. An often debated aspect of rhythmic dictation is whether examples should be pitched or unpitched. Because of the connection between working memory and musical dictation, the best method for teaching dictation is that which students can hold best in their working memories. A study was conducted to investigate whether musicians have a higher working memory capacity for pitches, unpitched rhythms, or pitched rhythms. Subjects had the highest capacity for unpitched rhythms, followed by pitched rhythms, and finally the lowest capacity for pitches. This gives further validity to the argument in favor of using unpitched rhythms for rhythmic dictation.

II – Problem – Aural Skills Pedagogy

What is the most effective way to teach aural skills? This problem remains essential to music educators as the ability to not just hear, but understand sound is critical to overall music literacy. Music teachers at all levels strive to teach aural skills, but there is no standard method for achieving this goal. This essay will examine past and present theories of music education, memory, and audiation and put forth new conclusions about best practices for teaching aural skills.

Educators teach aural skills to teach musicianship. The ultimate goal of this research is not only an investigation into brain function (although that research plays a major role) but also research into music pedagogy, or how teachers evoke musicality from their students. The author is neither a neuroscientist nor a psychologist but rather a teacher, always searching, as teachers always do, for better ways to teach their students.

To exhibit increased musicality is to use more musicianship skills with greater faculty. To help students to do this, educators work to develop these musicianship skills. One such skill is the ability to perform dictation– to notate what one hears. This is thought to increase musicality because it necessitates an increased understanding of sound. It also requires extensive training and practice for the average[1] person to learn. Monophonic musical dictation can be divided into two types, melodic and rhythmic. Melodic exercises feature a simple melody and rhythmic exercises a simple rhythm. Rhythmic dictation is typically taught before melodic because an understanding of rhythm is required to locate pitches on the continuum of time and thereby understand the melody one is hearing. To illustrate this, consider the following concept from mathematics. In math education students learn to conceptualize and create number lines years before they learn about coordinate planes. This is essential to understanding the abstract concepts of measurement and location. The knowledge is sequenced this way so teachers can start by establishing a one-dimensional understanding of

---

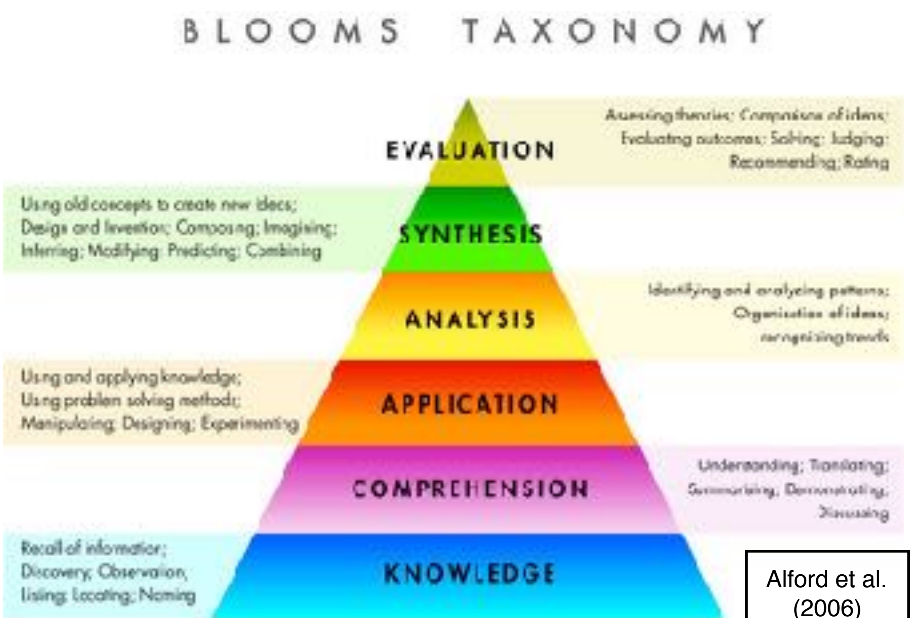
[1]This is even true for the exceptional person, as exceptional aural perception does not necessarily mean exceptional faculty with our musical notation system.

these concepts and then later build upon it to establish a two-dimensional understanding. Similarly in music, educators seek to establish a one-dimensional understanding at first (the ability to measure rhythm) and then build upon it to create a two-dimensional understanding. This is a long standing position in aural skills pedagogy, reaching back to Allan McHose's writing in the 1948 Eastman Series' *Teacher Dictation Manual:* "Although rhythmic dictation is concerned only with the recognition of meter and time values, the instructor should realize that he is establishing the foundation for melodic and harmonic dictation." However, before a student understands rhythm he or she must grasp the concept of meter, and before meter, pulse. This progression, from pulse to meter to rhythm, guides students from the most basic foundational unit of organized sound to fully measured groupings. Rhythmic dictation is the culmination of these prerequisite understandings. (Karpinski 2000)

It is here, in rhythmic dictation, that there is a notable division in teaching methods. Some pedagogues believe teaching rhythmic dictation should be accomplished by playing melodies and having students notate only the rhythm of the melodies they hear. Teachers who use this method believe this is the best way to contextualize early dictation for their students. They are also concerned with the potential utility of unpitched rhythmic dictation, or lack thereof, arguing that they teach a student to understand unpitched rhythms and nothing more. Other teachers believe students should hear and dictate rhythms played from non-pitched instruments. Advocates of this method argue it begins to train their students' memories for music by first training them to remember rhythms, without confusing the students with extraneous auditory stimulus. Therefore, they are opposed to the rhythm-from-melody method and argue that having the students only notate the rhythm of a melody trains them to regularly dispose of half the perceived auditory stimulus in the process. This is thought to cause more confusion later when the students progress to notating the melody with pitch and rhythm. (Karpinski 2000)

Memory is essential to dictation. Consider my above definition of dictation: "to notate what one hears." This definition is deceptively simple because in the process of notating what one hears, one is really notating a *translation of the memory of sound*. In other words, when musicians notate music they listen to using Western standard notation they are actually first listening, then recalling what they heard, and finally notating their memory of what they heard. This essential element of dictation (the translation of what one hears) is central to this research.

Considered in the context of Bloom's Taxonomy, the process of dictation is synthesis.



Alford et al. (2006)

The musician first must possess knowledge of the elements of music and comprehend their function. Then while performing the dictation the musician must apply this knowledge to analyze what he or she remembers hearing and synthesize a written representation. This translation process (from auditory information to written information) requires working memory (also known as short-term memory) to accomplish.

Western standard notation proves to be a particular barrier in this translation process, and thus other modified systems are used until students develop their memories enough to remember all the elements of a melody and notate it accurately using traditional notation. One popular example is the "protonotation" proposed by Karpinski (1990) which is used by students to dictate rhythm independent of pitch. This system greatly resembles the "stick notation" widely used by elementary teachers in early rhythm lessons. These alternate methods of notation save time in the translation process. However, they still take a non-zero amount of time to accomplish and thus still require the same fundamental memory process.

Furthermore, students will have to transition back to Western standard notation eventually as it is the universal standard they will be required to use as musicians.

Teachers cannot change the realities of our notation, but they can change how the musical examples are presented to their students. Additionally, because dictation is so fundamentally intertwined with memory, it follows that *the method with which people can best capture and hold music in their working memories will prove to be the most effective method for teaching musical dictation.* Thus the essential question of this research arises: what is the better method for teaching rhythmic dictation: providing auditory stimulus with pitch or without pitch? The examination of this deceptively simple question incorporates research into brain function, memory, and audiation. It also includes a new study to examine these factors further.

III – Research – Audiation, memory, and music

On Music (Briefly)

There is no all-encompassing definition of music. Most agree music is sound[2]; however, beyond this definitions differ greatly, particularly on what distinguishes music from noise. Delineations diverge regarding the structural qualities as well as the aesthetic qualities of the sound. For the purposes of this discussion I've chosen to consider Edgard Varèse's definition of music as "organized sound," as the purpose of this research is to explore a pedagogical issue (dictation methods) that applies to music which fits that definition.

To consider "organized sound," one must break it into essential components that can be classified. Daniel J. Levitin does this exceptionally in his book "This Is Your Brain On Music" (2006) with his "basic elements of any sound." They are loudness, pitch, contour, duration (or rhythm), tempo, timbre, spatial location, and reverberation. These components of sound create music when one's brain organizes them into "higher level concepts," which Levitin identifies as meter, harmony, and melody. The study associated with this research controlled for all these elements except for pitch and duration, the elements being investigated. This is explored in depth in the "study" portion of this paper.

On Pitch and Steady Pulse (Rhythm)

Levitin (2006) defines pitch as "the mental representation an organism has of the fundamental frequency of a sound." Humans can identify pitches because the cochlea (a part of the inner ear) is lined with hair cells that respond to particular sound frequencies. Because these cells are spread out topographically across the cochlea, they form what is called a tonotopic map. When sound activates these hair cells they send signals into the auditory cortex of the brain. The auditory cortex also has a tonotopic map, spread out across the cortical surface, in order of pitch. The implication of this structure is that the brain actually

---

[2] Some also include sounds not perceivable by human ears in their definition of music. For a discussion of "music" on an astronomical scale, see Levin's (2011) TED Talk: "The Sound the Universe Makes" (especially 8:46 to 12:19).

directly responds to the absolute pitch frequencies a person hears, a response entirely unique to pitch stimulus. To illustrate this important distinction consider the following example from Levitin (2006):

> *If I put electrodes in your visual cortex (the part of the brain at the back of the head, concerned with seeing,) and I then showed you a red tomato, there is no group of neurons that will cause my electrodes to turn red. But if I put electrodes in your auditory cortex and play a pure tone in your ears at 440 Hz, there are neurons in your auditory cortex that will fire at precisely that frequency, causing that electrode to emit electrical energy activity at 440 Hz – for pitch, what goes into the ear comes out of the brain!*

The physiological reasons behind human perception of audible pulse (as distinguished from heart rate) are less clear than that of pitch. This is because our sense of pulse and rhythm is more entangled with neuroscience than the physical structures of our hearing are, and therefore is currently less understood than our pitch perception. As Levitin (2006) writes, our rhythmic perception is so accurate because it is "probably in the cerebellum," because our essential timekeeping structures are thought to reside there. Scientists have found music making and heart rate to be intertwined. One such example is a study by Vickhoff et al. (2013) of choirs and individual singers which found that "Unison singing of regular song structures makes the hearts of the singers accelerate and decelerate simultaneously." Large and Snyder (2009) discuss that although there are a myriad of approaches to explain rhythm, one of the best "relies upon neural oscillations that resonate with rhythmic stimuli." This means that it is possible that neurons in the brain are literally firing at the same tempo as music we make or listen to. Therefore, meter, an interpretive organization of pulse, would be a higher level grouping of these rhythmic neural pulses, comparable to the physical relationship between overtones and fundamental pitch.

> *The theory holds that listeners experience dynamic temporal patterns (i.e., pulse and meter), and that they hear musical events in relation to these patterns because they are intrinsic to the physics of the neural systems involved in perceiving, attending, and responding to auditory stimuli. – Large and Snyder (2009)*

But what is the actual difference between pitch and pulse? From a physics standpoint, pitch and pulse are fundamentally the same. They are both auditory stimuli happening at even time intervals. The difference is merely a perceptual boundary humans draw in their minds based on the *speed*[3]. When people listen to a pulse of sound played at a steadily accelerating tempo, there will come a point where the pulse crosses a perceptual threshold and begins sounding like a pitch, increasing in frequency as the tempo continually accelerates. To listen to an audio example of this phenomenon, as well as an additional discussion on the relationship between composite rhythms and intervals, see Tepfer, 2012.

Now consider the facts of how humans perceive pitch in the context of the relationship between pitch and pulse. The difference between pitch and rhythm is speed as it applies to our physical ability to perceive sound. When the auditory pulses are fast enough to activate a particular subset of hair cells that correspond to a certain frequency, and therefore a particular location on the tonotopic maps of the cochlea and auditory cortex, the person perceives the sound as pitch. When the auditory pulses are too slow to activate a particular frequency grouping of hair cells, the person perceives the sound as a pulse. Pulse is then conceptually organized into meter and then rhythm based on patterns and emphasis. Therefore, when we listen to a melody we are simultaneously listening to the patterns of sound pulses over time on many levels. At one frequency range we perceive rhythm, at the next faster frequency range we perceive pitch[4].

The discussion of these perceptual groupings applies to how people construct meter and hypermeter. Radocy and Boyle (1997) surveyed studies on pitch and rhythm perception and found people gravitate toward tempos in the range of 60 to 120 beats per minute. This means when listening to a piece of music, people will half or double their reproduction of the tempo so it falls within that range. This observed behavior shows the commonalities we have in how we perceive the meter and hypermeter of a piece of music, and where we draw the perceptual boundary between the two.

---

[3] Speed here means the time interval between points of auditory stimulus.

[4] Additionally, when we subdivide the frequency range of pitches we perceive overtones (the perceived pitches that result from regular multiples of pitch frequencies).

Before the following discussion on audiation and memory, an important distinction must be made between the learned skills of musicianship and the normally innate skills of musicality. Performance skills, music literacy, and analysis usually require moderate to intensive study of music, but the foundations of musicality (tunefulness, perception of steady pulse, musical comparison, and evaluation, for example) are seemingly inherent in most people from birth. It is upon these foundations that those who choose to study music build their understandings.

Therefore, the reader of this paper is most likely at least somewhat inherently musical. Even without training the vast majority of people can distinguish between pitches, differentiate between melodies, and perceive dissonance. However, about 4% of people do not develop a normal pitch processing system (Hyde & Peretz 2004). This group of people have congenital amusia, defined as "a developmental disorder that arises from failures to encode pitch with sufficient resolution to allow acquisition of core knowledge regarding the pitch structure of music" (Hyde & Peretz 2004) and therefore cannot discern pitches less than two semitones apart (the average human sensitivity is at least four times more defined). This deficit in perception causes great difficulty in identification and comparison of music[5]. However, Hyde and Peretz (2004) found that these people who were unable to discern differences in pitches with normal resolution were able to discern differences in *rhythm* with normal resolution ("with 75% correct detection for an asynchrony of about 40 ms"). The physiological causes of congenital amusia are not well understood, but this research is a strong indication that pitch and steady pulse perception are discrete neurological processes.

On Audiation & Memory

Because pitch and pulse (and therefore rhythm) are likely processed differently in the brain, it follows that our minds and memories most likely interact with them in different ways. It

---

[5]However, people with congenital amusia often do not have issues understanding spoken language because the pitch fluctuations in spoken language are usually much larger. For example, the rise in pitch that signals a question is typically over seven semitones in English and French (Fitzsimons, Sheahan, & Staunton, 2001).

is the aim of this research to illuminate this crucial difference and discuss its relation to aural skills pedagogy.

Essentially, to audiate is to imagine sound. The word audiation was coined by Edwin Gordon as an auditory alternative to imagination, which focuses on visual images. To teach aural skills is to teach audiation. It is the ultimate goal of any musician to be able to audiate (or imagine sound) before creating sound. This is the key to many facets of higher level musicianship.

Audiation can be broadly categorized in two ways: recollection of sound and synthesis of original sound. This is similar to how a person can use his or her imagination to either remember something from his or her past or to synthesize something completely original. This research is concerned with the functions of the former over the latter because of its application to dictation. Synthesis of original music often is in fact an obstacle for musicians attempting to perform accurate dictation because it tends to cause consonant mistakes in the finished product (wrong notes that are members of the same harmony, or subdivisions of given rhythms, for example). As part of this research a survey style study was designed and conducted to investigate this musical working memory further.

Although philosophical and psychological study of brain function is not new, most physiological research concerning the brain is. Most of what scientists know about the brain is the result of the veritable explosion of brain research following the introduction of Functional Magnetic Resonance Imaging (fMRI) in the 1990s. For the first time, scientists could have a look at blood flow patterns in the active living brain and start drawing directly observable conclusions about function. Prior to this, all scientists knew about brain localization was learned from studying the behaviors of people with brain injuries. Ultimately, while our knowledge of the brain is becoming more detailed, it is in its very basic stages of development. It is for this reason this research will focus primarily on the current psychological understandings of memory, as opposed to the recently blossoming neurological understandings.

Broadly, current scientific understanding of memory divides the phenomenon into two groups, short term and long term memory. Short term memory (also known as working memory) is engaged with that which is recalled soon after exposure. Long term memory is engaged when something is recalled after some time has lapsed. This research is involved with the greatly debated functions and limitations of working memory.

George Miller's article "The magical number seven plus or minus two: some limits on our capacity for processing information" is widely considered to be the seminal article that sparked interest in working memory research. In his 1956 article published in *The Psychological Review*, Miller discussed a particular limitation on the number of items a person could store in their working memory (which he referred to as "channel capacity") based on current research. According to the research of the time, universally that number was about seven, with some people remembering as few as five and some as many as nine items.

> *There seems to be some limitation built into us either by learning or by the design of our nervous systems, a limit that keeps our channel capacities in this general range.* – Miller 1956

Miller was particular in his specification that this applied exclusively to one-dimensional stimuli. That is, input information with only one discernible characteristic (a collection of colors, of pitches, of rhythms, etc.). When the stimuli was multi-dimensional (more identifying characteristics per unit of information) working memory capacity increased greatly. This observation encouraged a body of research extending all the way to today[6] involving the nature of the limits on working memory.

Chunking also plays a significant role in retention and reproduction of musical examples. Generally speaking, chunking[7] is the natural function of human minds to group relevant pieces of information together, the intention being to fit more information into the approximately seven working memory slots people have. This is how people can keep track of

[6]"Despite decades of research, the source(s) of the severe capacity limits of WM [working memory] storage are still under intense debate." (Fougnie et al. 2015)

[7] A term Miller coined in his 1956 article.

and engage in conversations, for example. A typical conversation will contain more than seven words or sentences but it is in the chunking of ideas that people can engage in advanced dialogue.

Just as chunking happens with spoken language it happens with music. A person who knows more musical patterns will identify those patterns immediately[8] and store the entire pattern in memory as opposed to its individual components. This is the process that enables skills such as sight reading or listening to a piece of music and tracking the occurrence of multiple motives throughout.

> *As musical understanding increases, so does musical memory. Listeners who can hear and immediately understand such features as scalar passages, triads, repetitions, sequences, modulations, and rhythmic patterns have a leg up on those listeners still listening without immediate comprehension. Such immediate comprehension affords listeners the opportunity to encode music in meaningful chunks, thereby dramatically reducing the number of memorable "bits" [of information] in a passage. – Karpinski 2000*

Some studies argue that limitations on working memory are domain specific (such as Baddeley & Loggie 1999), meaning that working memory limits are specific to the type of information being recalled. Consider the following simplistic example: if a person could store seven items in her working memory then she would be able to store and recall seven colors as well as seven tones simultaneously. Other studies argue the limits are not domain specific (such as Cowan 2006), meaning there is a hard limit on the number of items a person can store in their working memory regardless of content. For the person in the previous example, she would be able to recall seven items of color or tone total. The question proves difficult to answer because causes of working memory interference are hard to isolate and study experimentally.

> *Thus, the debate centers on the degree to which limits arise from interference in content-specific stores or from a capacity-limited process that operates over items regardless of content.* – Fougnie et al. 2015

[8]Here, again, we see the influence of the time it takes someone to identify something on overall understanding. Those who identify patterns more quickly are able to chunk information more effectively.

Therefore I designed a study which investigates the average working memory capacity for pitch examples, rhythm examples, and examples with pitch and rhythm. The nature and degree of interference between these sets of stimuli is unknown, but also not necessarily relevant to the purposes of this research. The debate of the dimensionality of working memory capacity is an ongoing and fascinating one and cannot be answered here. As stated above, the researcher is not a psychologist or neuroscientist, but a teacher searching for what is most effective for students. Ideally this research has the potential to spark further investigation of a psychological or neurological nature by those with the body of knowledge and resources to do so.

IV – Study

Method

To investigate working memory capacity for pitch, rhythm, and pitched rhythm a short term memory capacity test was designed. The test was in three major sections: a pitch test, a rhythm test, and a pitched rhythm test. Each of the three tests had 16 examples (for a total of 48 original examples across the three tests). The pitch examples confined to the equal tempered standard pitch system but did not conform to any key or any other patterns of organization. Each pitch example was four seconds of a single note played with a neutral synthesized timbre. Each rhythm example was four seconds long and contained a rhythm played on an unpitched snare drum sample at 60 bpm. The pitched rhythm examples were combinations of the pitch and rhythm examples. Each one played a 4 second rhythm (at 60 bpm) on a single pitch. Each example contained only one pitch, but the pitched changed from one example to another.

The procedure for each test subject is as follows: the subject enters the room, hands in the filled in survey, and takes a seat at a controlled distance from the sound source. The examiner, sitting across from them explains that the test is in three parts (pitch, rhythm, and pitched rhythm). The examiner begins the pitch test by playing the first pitch sample and asking the test subject to refer to that pitch as “pitch 1.” The examiner plays "pitch 1" and asks the subject to identify it as "pitch 1". Then the examiner plays pitch 2 and identifies it as “pitch 2.” The examiner plays "pitch 1" and "pitch 2" in a random order (determined by a random number generator and controlled across all examinations) and asks the subject to identify each pitch as it is played. If the subject is successful, the examiner adds "pitch 3", first playing and naming it, and then playing pitches 1 through 3 in a random sequence, again asking the subject to name each pitch as it is played. The pitch test continues in this manner until the subject begins to confuse the number names of pitches (defined as a majority of pitches incorrectly named) or the subject finishes all 16 levels. Upon completion of the pitch test the examiner moves on to the rhythm test, which functions in exactly the same way, except the examples are the unpitched rhythms. Upon completion of this test the examiner moves on to the pitched rhythm test, which functions the same as the previous two tests, only with the pitched rhythm examples.

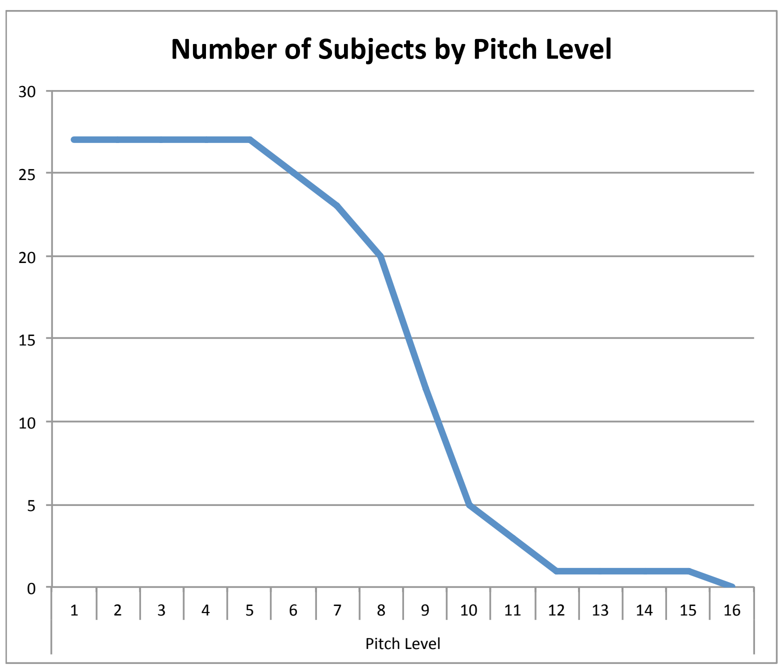
Hypothesis

The subjects will likely reach the furthest level on the pitched rhythm test, followed by rhythm, and perform lowest on the pitch test. They will chunk the pitched rhythms the best because they provide the most information. These examples provide the most information because unlike the unpitched rhythms which only have one discernible characteristic relative to the examples around them (their rhythm) the pitched rhythms have two (their pitch and their rhythm). They will perform differently on the pitch and rhythm tests because of research that implies we may process pitch and rhythm differently in the brain, which may affect memory. They will likely perform higher on the rhythm test in light of research by Dowling (1973) who found rhythmic groupings aid chunking. Finally they’ll perform worst on the pitch examples because those examples lack the benefits of the first two. The average differences in performance for these three tests are likely to be very close, as they are all single dimensional auditory stimuli, but there is reason to expect the subtle differences between the three described above.

It is proposed that those who have had the most private study on their instruments will be able to store the most information across the categories because their musical practice should increase their chunking ability. Age will likely correlate with performance because additional experience will increase chunking skill and therefore overall performance. Subjects who play piano as their primary instrument will likely perform highest because of the focus on musical structure typically required of taking lesson on the instrument. Percussionists will likely have the highest scores on the rhythm section. People with perfect pitch will likely have the highest scores on the pitch test.

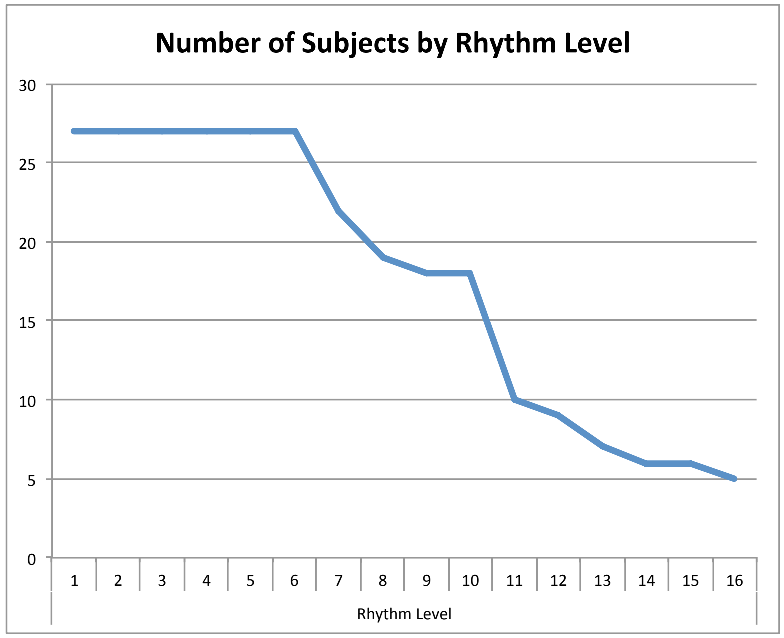
Data Summary

Participants: In total, data from 27 people was collected for the study[9]. The subjects were all undergraduate university musicians aged 17 to 24, 12 female and 15 male. The most represented major instrument by far was voice (48.1% of total subjects). Many had studied their primary instrument for 5 to 8 years (44.4%), followed by those who studied for 9 or more years (25.9%). Many secondary instruments were listed (15 different types) but the most predominant was the piano (37.0%). Most subjects either studied their predominant secondary instrument for 8 or

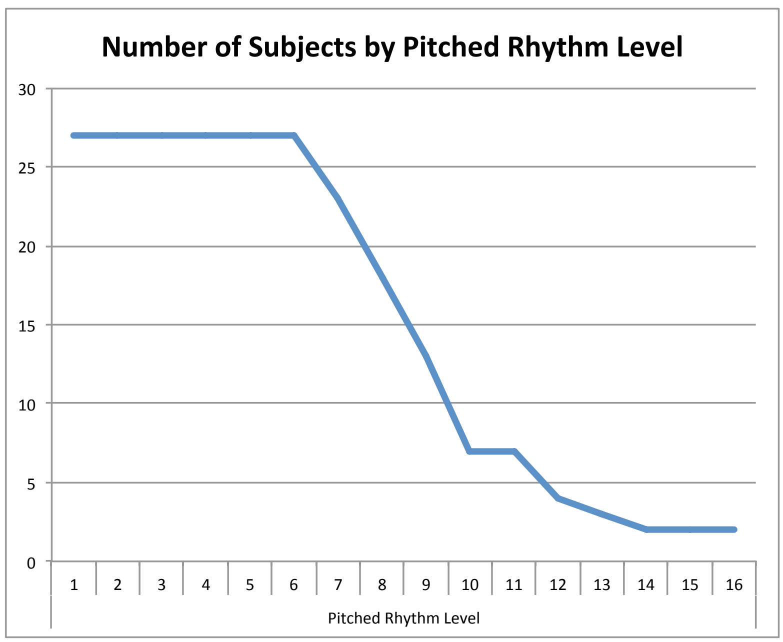


[9] The number of participants was 28, but one subject's data had to be discarded due to a recording error.

more years (40.7%) followed by those who studied for 2 to 4 years (22.2%). Almost half (48.1%) of the participants were able to accurately define "audiation," the rest did not provide a definition, including one who provided an incorrect one. Three subjects (11.1%) had perfect pitch.



The average number of pitch examples these undergraduate musicians could hold in their working memories is 8.4. The average number of rhythm examples is 10.4. The average number of pitched rhythm examples is 9.0. This represents a deviation from my stated hypothesis that the highest average performance would be on the pitched rhythm, followed by the rhythm, and finally the pitch.



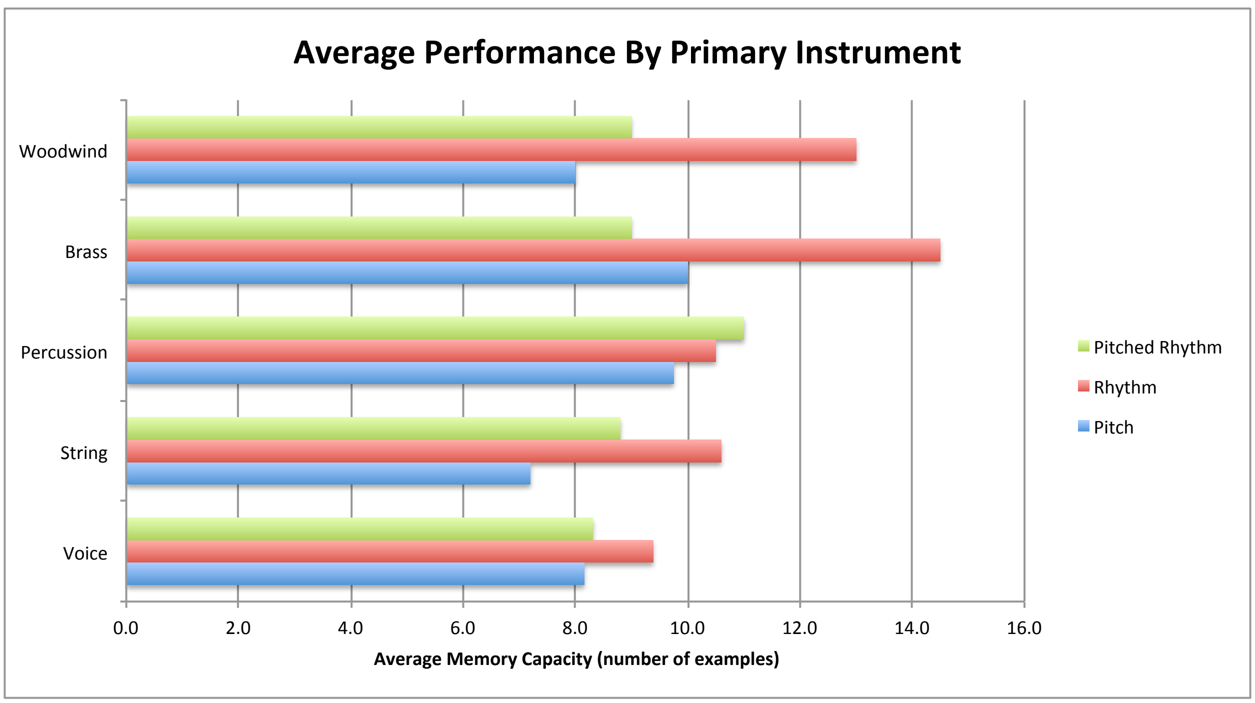
Pitch test: All subjects were able to reach the 5th level of the pitch test. As a reminder, each level number corresponds to the number of examples the subject could keep track of in his/her working memory. So to reach the 5th level demonstrates the example to keep track of

5 pitches in working memory before becoming very confused. The number of subjects then drastically declined from level 5 to 11, with no subjects able to reach level 16.

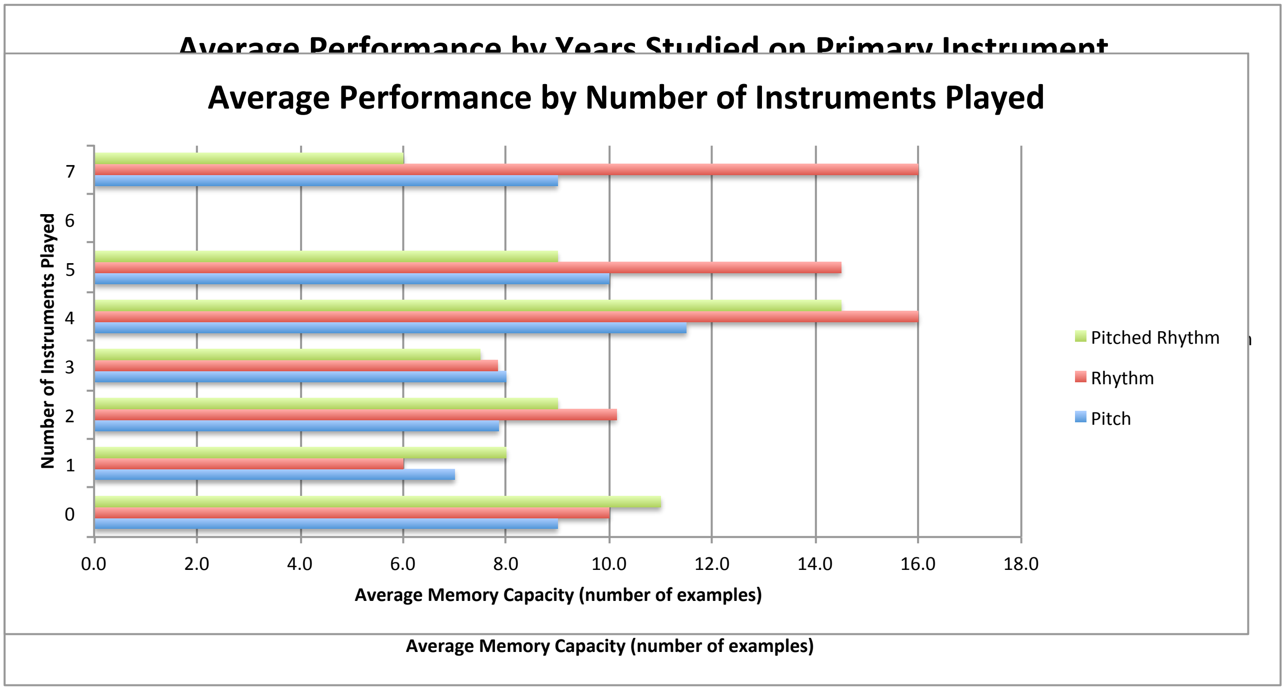
Rhythm test: All subjects were able to reach the 6th level of the rhythm test. The number of subjects then declined, although more steadily than the pitch test. Five subjects were able to reach level 16.

Pitched rhythm test: All subjects were able to reach the 6th level of the pitched rhythm test. The number of subjects then steadily declined to level 14. Only two subjects were able to reach level 16.

Primary instrument and average capacity: Average performance was not drastically effected by the primary instrument of the participant. There was a spike in rhythm performance for woodwind and brass players but this is most likely an anomaly resulting from the small sample size.



Number of years of study on primary instrument and average capacity: The number of years of study did not seem to have a noteworthy effect on average performance.



Number of instruments studied and average capacity: Despite the number of years studied not having a great effect, the highest performing participants tended to be those who studied a greater number of instruments.

Average capacity by gender: Gender did not have great effect on performance, with males performing only slightly better than females.

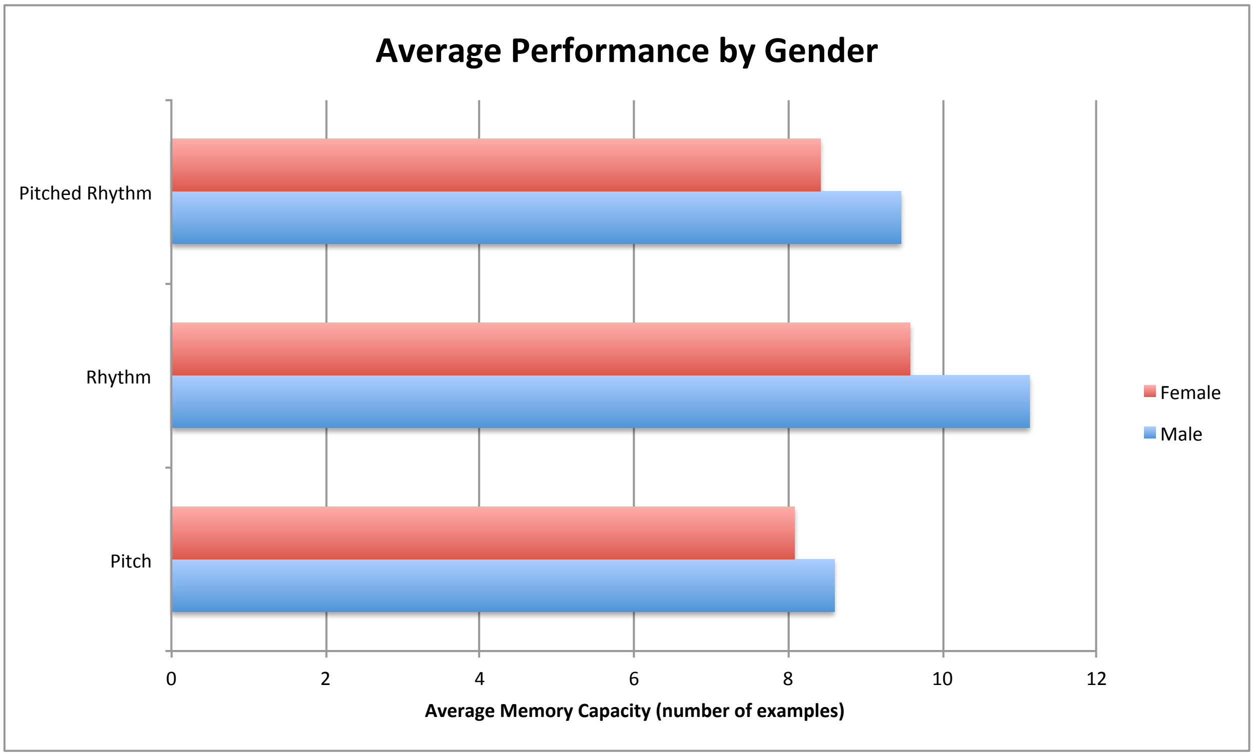
Performance by age: Age had an effect opposite of what was expected. More experienced participants did not perform as well as those who were less experienced.

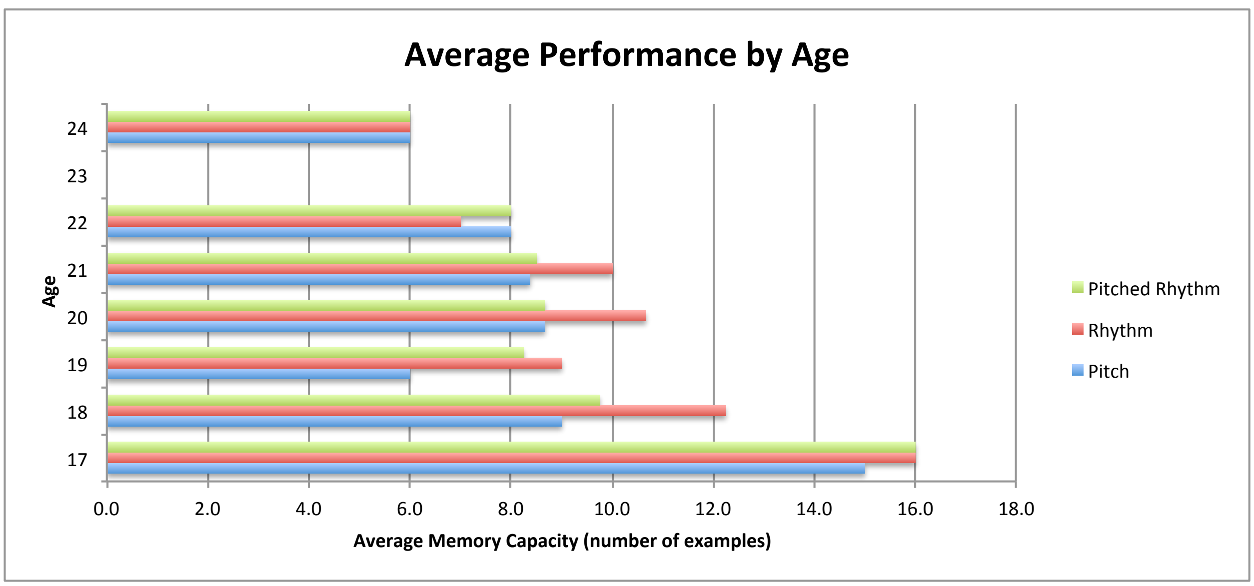
Understanding of audiation and average capacity: An understanding of audiation did not give subjects a distinct performance advantage.

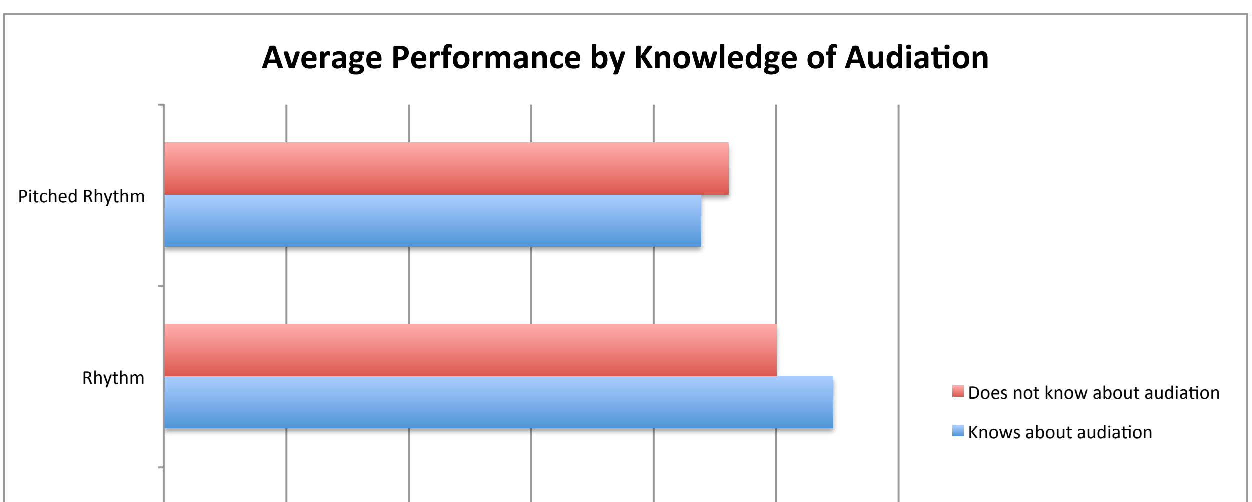
Perfect pitch and average capacity: Perfect pitch ability did not give participants an advantage, and in fact may have put them at a slight disadvantage.

V – Conclusion

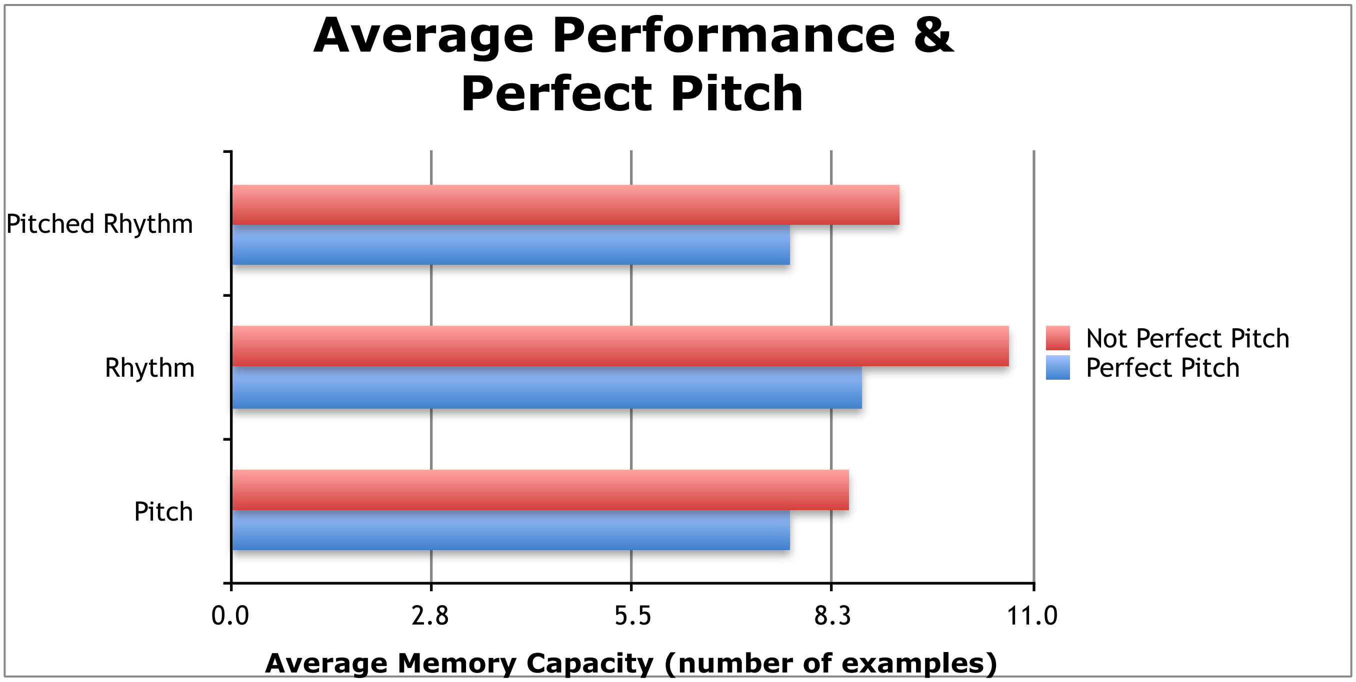
The students were able to store and make use of the unpitched rhythmic examples in their short term memories better than the pitch and pitched rhythm examples. This evidence


Average Performance by Gender
Pitched Rhythm
Rhythm
Pitch
0
2
4
6
8
10
12
Average Memory Capacity (number of examples)
Female
Male


Average Performance by Age
24
23
22
21
20
19
18
17
Age
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Average Memory Capacity (number of examples)
Pitched Rhythm
Rhythm
Pitch


Average Performance by Knowledge of Audiation
Pitched Rhythm
Rhythm
Does not know about audiation
Knows about audiation

makes an argument for performing rhythmic dictation without pitch, particularly because the introduction of pitch to the rhythm was shown to decrease overall performance. The fact that



the pitch score and the rhythm score were the most different with the pitched rhythm in the middle suggests that introducing a single pitch to a rhythm makes the rhythm harder to remember and introducing rhythm to a single pitch makes the pitch easier to remember. This is likely due to the differences in physiological structures for pitch and rhythm perception. Despite the fact that both pitch and rhythm are both stimulus over time they are likely encoded differently in memory because of the differences in the structures humans use for listening, with more people having inclinations toward rhythmic memory than pitch memory. Further research is needed to investigate this conclusion.

It is not possible to discern the reasoning for the observed limits on working memory from this study. These observations are the result of an unknown combination of physiological, psychological, and educational factors. As earlier discussed, there is evidence to suggest that rhythm and pitch are physically processed differently in the brain. These observations give reason to investigate that difference as it relates to working memory in further research. Also, all participants came from a variety of educational backgrounds. The particulars of the subjects' music education helped each participant to a different degree, because previous experiences could influence strategy and improve performance.

As Karpinski (2000) described, the more musical patterns a person knows the more immediately they can chunk information. Therefore it would be logical for the musicians with the most experience to have the best chunking strategies and perform better on the working memory test. This is supported by other research, which has found "A relatively small number of persons are capable of chunking melodic materials at first hearing in order to exceed Miller's 7 ± 2 limits" (Marple n.d.), and that the most proficient dictation takers use chunking (Potter 1990). The average performance on all three tests was higher than the standard limit of 7 proposed by Miller, most likely because the participant population was musically educated to some extent, and all had some strategies they used to chunk the examples.

Post-study, a concern was raised regarding the control over the level of difficulty of the three tests relative to each other. It has been argued that a memory test which involves remembering random sequences of pitches is not comparable in difficulty to a test which involves remembering rhythmic examples. This is because in the subjects' musical experience, they are trained to recognize and chunk patterns of rhythmic subdivision, but they are not trained to do the same for random atonal sequences of pitches. The researcher acknowledges this potential experimental flaw and how it could possibly have skewed the results of the pitch test to be lower than the other two.

Surprisingly, the correlation between age and performance was opposite of what was expected. The youngest participants demonstrated the highest overall working memory capacities and average capacity steadily decreased as age increased. This would suggest that experience is inversely correlated to musical working memory capacity. However this could be more a simple consequence of the small sample size than a true correlation, especially considered with the fact that number of years of musical study did not correlate with performance. If both musical experience as well as life experience correlated with performance, the evidence for connection between experience and working memory capacity would be much stronger.

It is possible that the inverse correlation between age and performance could be a consequence of the structure of the shared music education experience of the participants. The vast majority of participants were undergraduate students of the Hofstra University music department, which, at the time of this study, structured its curriculum to have students take all their aural skills classes in the first four semesters of its eight semester programs. The latter half of the degree programs then, in general[10], shifted to a greater emphasis on pedagogy, performance, or business (depending on whether a student was a music education, music performance, or music business major, respectively). Chunking is a learned skill, and like all learned skills it atrophies over time if left unused. If the students further along in the program are performing more poorly on this memory test, it implies that they may not be exercising the skills they learned in aural skills classes after they complete the courses. This is possibly due to students relying on resources to learn their music that only require a lower level of thinking (regularly learning new pieces from recordings instead of sight reading, for example). Further institutional research is needed to evaluate the implications of this connection.

Having a basic understanding of what audiation is did not give participants a significant advantage, nor was it expected to. People audiate, with varying degrees of proficiency, regardless of whether they have put a name to the process or not. This question appeared on the experimental survey primarily to illustrate the population's pre-existing understandings in relation to the research.

Another unexpected observation pertained to the participants with perfect pitch. Contrary to the hypothesis, they did not perform any better on the pitch test than the other participants, and slightly below average across all three experiments. The difference was not great enough to imply perfect pitch was a hinderance, but it certainly did not give them an

---

[10] Of course, exceptions to this trend apply. Students design their own schedules with their advisers and in some cases courses may be taken in different orders or over different periods of time. However the majority of students follow a curriculum similar to the one outlined above.

advantage. The implication here is that *although perfect pitch helps people identify and synthesize pitches, it does not give them a working memory advantage for random sequences of those pitches*. Meaning also that pitch perception and pitch memory are most likely separate neurological processes. When their preexisting perceptual associations are taken away (the standardized naming of pitches by letter), the person with perfect pitch no longer has a greater short term memory capacity for a sequence of pitches than the person without.

The study associated with this research is by no means perfect and its primary function is to support the greater body of research compiled for this paper. One primary issue with the design of the study is the incorporation of too may variables to draw substantial conclusions. The multiplicity of aspects being investigated here provides a wealth of data but makes it difficult to discern with absolute clarity which causes are influencing which effects. The correlations suggested here could be used as starting points for many pieces of more focused research.

Recently it has been observed that repetition changes memory, making it less accurate (Peterson & Mulligan 2012). This seems counterintuitive when considered in context of the traditional understanding that repetition only helps strengthen memory. What Peterson & Mulligan found, however, is that the more a memory is recalled the more malleable it becomes and the less accurate it is. This newly discovered phenomenon, called “The Negative Repetition Effect” can provide an alternate reason for the rate of the decline in memory performance observed in the study. By this principle, the more the subjects listen to the examples the less accurate their memory of them will be. This could possibly effect the rate of decline in memory performance across the examination.

This research also raises further questions about the nature and process of audiation. Can we audiate rhythm without pitch? How would that work and what would it “sound” like? This would necessitate addressing the question of how similar audiation is to a kind of sampling as well as the psychological processes behind it.

The findings of this research suggest the optimal way for students to remember a rhythmic pattern in their working memory is for the rhythm to be unpitched. This gives further support to the pedagogical viewpoint that rhythmic dictation should be performed with unpitched musical examples. In addition, teachers should continue to have their students practice dictation as it improves their musical working memory and overall musicianship.

> *Dictation and the many concomitant activities that can improve and increase short term musical memory also go a long way toward improving musicianship in general.*
> *– Karpinski 2000*

VI – References

Alford, G., Herbert, P., & Frangenheim, E. (2006). Bloom's taxonomy overview. In *Innovative teacher's companion* (pp. 176-224). ITC Publications.

Baddeley, A. D., & Logie, R. (1999). Working memory: The multiple component model. *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control*, 28-61. doi: 10.1017/CBO9781139174909.005

Beebe-Center, J. G., Rogers, M. S., & O'connell, D. N. (1955). Transmission of Information About Sucrose and Saline Solutions Through the Sense of Taste. *The Journal of Psychology*, 39(1), 157-160. doi:10.1080/00223980.1955.9916166

Cowan, N. (2006). *Working memory capacity*. New York: Psychology Press.

Fitzsimons, M., Sheahan, N., & Staunton, H. (2001). Gender and the Integration of Acoustic Dimensions of Prosody: Implications for Clinical Studies. *Brain and Language*, 78(1), 94-108. doi:10.1006/brln.2000.2448

Fougnie, D., Zughni, S., Godwin, D., & Marois, R. (2015). Working Memory Storage Is Intrinsically Domain Specific. *Journal of Experimental Psychology: General*, 144(1), 30-47. doi: 10.1037/a0038211

Hyde, K. L., & Peretz, I. (2004). Brains That Are out of Tune but in Time. *Psychological Science*, 15(5), 356-360. doi:10.1111/j.0956-7976.2004.00683.x

Karpinski, G. S. (1990). A model for music perception and its implications in melodic dictation. *Journal of Music Theory Pedagogy*, 4, 191-229.

Karpinski, G. S. (2000). *Aural skills acquisition: The development of listening, reading, and performing skills in college-level musicians.* New York: Oxford University Press.

Klemmer, E. T., & Frick, F. C. (1953). Assimilation of information from dot and matrix patterns. *Journal of Experimental Psychology*, 45(1), 15-19. doi:10.1037/h0060868

Large, E. W., & Snyder, J. S. (2009). Pulse and Meter as Neural Resonance. *Annals of the New York Academy of Sciences*, 1169(1), 46-57. doi:10.1111/j.1749-6632.2009.04550.x

Levin, J. (Writer). (2011, February). The sound the universe makes [Video file]. Retrieved from http://www.ted.com/talks/janna_levin_the_sound_the_universe_makes

Levitin, D. J. (2006). This is your brain on music: The science of a human obsession. New York, NY: Dutton.

Marple, H. D. (n.d.). Short term memory and musical stimuli. In E. P. Asmus Jr. (Ed.), *Psychology and acoustics of music: A collection of papers* (pp. 74-93). Lawrence, Kan.: University of Kansas.

McHose, A. I. (1948). *Teachers dictation manual*. New York: F.S. Crofts.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 63(2), 81-97. doi:10.1037/h0043158

Peterson, D. J., & Mulligan, N. W. (2012). A negative effect of repetition in episodic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 38(6), 1786-1791. doi: 10.1037/a0028220

Pollack, I. (1952). The Information of Elementary Auditory Displays. *The Journal of the Acoustical Society of America*, 24(6), 745. doi:10.1121/1.1906969

Pollack, I. (1953). Assimilation of Sequentially Encoded Information. *The American Journal of Psychology*, 66(3), 421. doi:10.2307/1418237

Potter, G. (1990). Identifying successful dictation stretegies. *Journal of Music Theory Pedagogy*, 4, 63-71.

Radocy, R. E., & Boyle, D. J. (1997). *Psychological foundations of musical behavior*. Springfield, IL: Charles C. Thomas.

Tepfer, D. (2012, December 13). Rhythm / Pitch Duality: Hear rhythm become pitch before your ears. Retrieved from http://dantepfer.com/blog/?p=277

Vickhoff, B., Malmgren, H., Åström, R., Nyberg, G., Ekström, S., Engwall, M., . . . Jörnsten, R. (2013). Music structure determines heart rate variability of singers. *Front. Psychol.*, 4(334). doi: 10.3389/fpsyg.2013.00334

VII – Appendix – Experimental Data

Total Level Achievement by Subject

Subject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Pitch Score	9	X	8	8	8	8	8	9	7	8	9	11	7	10	9	9	8	8	7	9	15	10	6	8	5	11	5	6
Rthm Score	10	X	7	12	10	6	7	10	6	10	10	16	10	6	16	13	15	11	12	10	16	10	6	16	6	16	8	7
P/R Score	12	X	8	8	8	7	8	11	8	9	11	16	6	7	6	9	9	9	9	7	16	7	6	13	6	9	11	7

Average Pitch: 8.4 Average Rhythm: 10.4 Average Pitched Rhythm: 9.0

Number of Subjects by Pitch Level

Pitch Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Number of Subjects	27	27	27	27	27	25	23	20	12	5	3	1	1	1	1	0

Number of Subjects by Rhythm Level

Rhythm Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Number of Subjects	27	27	27	27	27	27	22	19	18	18	10	9	7	6	6	5

Number of Subjects by Pitched Rhythm Level

P/R Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Number of Subjects	27	27	27	27	27	27	23	18	13	7	7	4	3	2	2	2

Average Performance by Primary Instrument

	Pitch	Rhythm	Pitched Rhythm
Voice	8.2	9.4	8.3
String	7.2	10.6	8.8
Percussion	9.8	10.5	11.0
Brass	10.0	14.5	9.0
Woodwind	8.0	13.0	9.0

Average Performance by Years Studied on Primary Instrument

	Pitch	Rhythm	Pitched Rhythm
One	8.0	9.0	8.3
2 to 4	8.3	13.0	10.3
5 to 8	8.6	10.8	8.9
9 or More	8.1	9.1	8.4

Average Performance by Gender

	Pitch	Rhythm	Pitched Rhythm
Male	8.6	11.1	9.5
Female	8.1	9.6	8.4

Average Performance by Knowledge of Audiation

	Pitch	Rhythm	Pitched Rhythm
Knows about audiation	8.8	10.9	8.8
Does not know about audiation	7.9	10.0	9.2

Average Performance and Perfect Pitch

	Pitch	Rhythm	Pitched Rhythm
Perfect Pitch	7.7	8.7	7.7
Not Perfect Pitch	8.5	10.7	9.2

Average Performance by Age

	Pitch	Rhythm	Pitched Rhythm
17	15.0	16.0	16.0
18	9.0	12.3	9.8
19	6.0	9.0	8.3
20	8.7	10.7	8.7
21	8.4	10.0	8.5
22	8.0	7.0	8.0
23			
24	6.0	6.0	6.0

Average Performance by Number of Instruments Played

	Pitch	Rhythm	Pitched Rhythm
0	9.0	10.0	11.0
1	7.0	6.0	8.0
2	7.9	10.1	9.0
3	8.0	7.8	7.5
4	11.5	16.0	14.5
5	10.0	14.5	9.0
6			
7	9.0	16.0	6.0

Survey	Results						
Main Instument	Total	Subjects					
Saxophone	1	17					

Bassoon	1	18					
Horn	1	16					
Tuba	1	26					
Percussion	1	9					
Piano	3	1	5	21			
Viola	1	7					
Double Bass	1	15					
Guitar	2	24	27				
Bass Guitar	1	23					
Voice	13	3	4	6	10	11	12
		13	14	19	20	22	25
		28					
Nubmer of years studied	Total	Subjects					
One	3	3	5	10			
2 to 4	4	4	12	15	27		
5 to 8	12	1	6	9	11	13	14
		16	17	18	20	24	26
9 or more	7	7	19	21	22	23	25
		28					
Secondary Instruments	Total	Subjects					
Flute	3	6	10	12			
Clarinet	1	17					
Saxophone	2	15	18				
Alto Recorder	1	3					
Trumpet	1	16					
Trombone	2	15	26				
Euphonium	3	16	23	26			
Sousaphone	1	15					
Percussion	5	1	3	15	24	26	
Piano	10	6	13	14	15	16	20

		24	25	27	28		
Violin	3	14	21	22			
Viola	2	4	21				
Cello	1	11					
Guitar	3	15	19	23			
Voice	6	5	7	16	21	24	26
Most years studied a secondary	Total	Subjects					
1	2	3	27				
2 to 4	6	5	6	13	24	25	28
5 to 8	4	1	10	19	22		
8 or more	11	4	7	11	12	14	16
		17	18	20	21	23	
Female/ Male	Total	Subjects					
F	12	3	4	6	10	11	12
		13	18	20	22	25	28
M	15	1	5	7	8	9	14
		15	16	17	19	21	23
		24	26	27			
Age	Total	Subjects					
17	1	21					
18	8	1	9	10	12	15	16
		18	26				
19	4	17	25	27	28		
20	3	4	8	20			
21	8	5	6	11	13	14	19
		22	24				
22	1	7					
23	0						
24	1	23					

Audiation definition	Total	Subjects					
Yes & accurate definition	13	3	5	6	11	13	14
		15	19	20	21	24	26
		28					
Yes, but inaccurate definition	1	4					
No definition	13	1	7	8	9	10	12
		16	17	18	22	23	25
		27					
Perfect pitch	Total	Subjects					
Yes	3	7	16	23			
No	24	1	3	4	5	6	8
		9	10	11	12	13	14
		15	17	18	19	20	21
		22	24	25	26	27	28
Number of Instruments Studied	Total	Subjects					
0	1	8					
1	1	9					
2	14	1	4	5	10	11	12
		13	18	19	20	22	25
		27	28				
3	6	3	6	7	14	17	23
4	2	21	24				
5	2	16	26				
6	0						
7	1	15					