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WORKING MEMORY AND MUSIC PERCEPTION AND PRODUCTION IN AN ADULT SAMPLE

by

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Abstract

This study examined the relationship between working memory and music perception and production in an adult population. Music perception and production was assessed using The Vocal Auditory Motor Development Assessment (VAMDA). Working memory was examined using both a forward and backward digit span test. A significant postivie correlaton was found between working memory and melody discrimination, while no significant relationship was found between working memory and pitch discrimination and production. Result implicatons and future research directions are discussed.

Acknowledgements

I am indebted to Dr. Tsang for her fast and acute comments that made this thesis anything worth reading. Also, to my parents for building me back up after said comments.

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Introduction

With the ability to convey emotions, share information, and encourage communication, music has great importance in our everyday lives. The relationship between music and intelligence has captivated the public with promises of quick fixes for intellectual improvement (Schellenberg, 2005). While phenomena like the “Mozart Effect” have shown to be limited to short-term cognitive benefits, could music perception and production be linked to other cognitive functions in a meaningful way? The complexity of music and the nature of auditory perception suggest that music may be strongly related to other cognitive functions, particularly short-term and working memory.

Music is organised into sequences of perceptually discrete elements organised in a structural manner according to syntactic regularities. An analysis of musical structures requires the computation of structural relations between these elements. Many studies have shown that even individuals who lack formal musical training are able to exhibit highly sophisticated implicit knowledge about musical syntax (Koelsch & Seibel, 2005). This musical syntax processing has been termed *phase-structure grammar*. Processing this level of grammatical complexity appears to be an innate human skill (Koelsch & Seibel, 2005). This supports past research which suggests being able to engage in music is a fundamentally human characteristic (Wise & Sloboda, 2008). Infancy research has shown that infants possess a number of musical processing predispositions and perceive music in similar ways to adults (Wise & Sloboda, 2008). As well, the identification of neural pathways specific to music suggests that some degree of musical processing is “hard-wired”. This helps to explain the sophisticated implicit knowledge present in untrained adults (Wise & Sloboda, 2008).

Not only does music perception appear to be an innately human characteristic, but the production of music seems to be as well. Singing is the most prevalent form of music production and is universally used (Peretz, Gagnon, Herbert & Macooir, 2004). Infants spontaneously learn to sing around one year. Even infant singing contains discrete pitches, rhythm, and melodic contours. By the age of five, children possess singing capabilities that remain largely unchanged into adulthood. Even without musical training, adults and children process the basic skills necessary to sing and display impressive memory for pitch level and tempo (Peretz et al,, 2004))

Singing and the Sensorimotor-loop

The vocal sensorimotor-loop model of singing describes the act of singing as a three stage process. In this model, auditory information is the input and singing as the output. The singer must continuously compare the output to the internal representation of the input from memory. This starts with the retrieval of pitch and tempo information from memory, which are then sent to motor control areas that enable the singing output. Then auditory feedback has to be monitored so that "real time" corrections can be made. Memory, motor skills, perception, and feedback are all skills vital to the success of the sensorimotor loop (Tsang, Friendly, & Trainor, 2011). This model proposes that working memory is vital to accurate reproduction and perception of music.

Reproduction of music or singing is a more complicated process than music perception due to the added production component. Despite the fact that singing is a natural part of human nature, people tend to think of only a select few possessing the skill of singing. In fact, occasional singers have an accurate memory for initial pitch and tempo of songs (Dalla Bella & Peretz, 2006). Singing proficiency is normally distributed with the majority of singers being able to reproduce songs with few pitch deviations. These deviations are also usually smaller then a semitone. Singing a single tone is harder for occasional singers, since a melody is highly structured on both pitch and time dimension, which provides more cues to monitor and aid performance.

Accuracy in pitch matching requires skills in both the auditory perception and vocal-motor production (Tsang et al., 2011). Pitch matching has become the predominant indicator to assess singing proficiency in both adults and children and generally an improvement is seen with age. The skill seems to develop without any formal training in the majority of the adult population. An increase in singing competency is related to two major factors. First: maturation of both the vocal cord and brain must occur. This maturation is important as accurate pitch matching requires skills in both vocal motor production and auditory processing. As well, accurate pitch matching requires the coordination of these skills. There is a significant positive relationship between pitch-matching accuracy and melodic perceptual abilities (Tsang, Friendly, Trainor, 2011). This suggests that good pitch perception will lead to accurate pitch singing.

Adults who cannot produce pitch accurately may have difficulties monitoring their internalized representation to the actual singing output produced and do not appear to have perceptual deficits. This internalized "voice" that allows individuals to compare singing input and output as outlined in the sensorimotor-loop may be underdeveloped in individuals who define themselves as "tone deaf". When given a battery of pitches and asked to reproduce pitches, tone deaf individuals can sing as accurately as controls on shorter stimuli, especially when accompanied (Wise & Sloboda, 2008). They were also able to accurately reproduce the contour of "Happy Birthday". If the deficit is not perceptual, then what creates the variations seen in music perception and production? It is possible that these individuals are not encoding the auditory information effectively. This hypothesis is supported by the improvement seen when tone deaf individuals hear auditory information a second time or sing with accompaniment which provides a prompt (Wise & Sloboda, 2008). This performance of self-defined "tone-deaf" individuals supports that perceptual deficits are not responsible for poor reproduction capabilities, but instead an inability to accurately encode the auditory information and compare it to a motor output. Working would be a vital component of these skills, and it is possible that it can help to explain variations seen in the general population.

Memory and Music

Singing accurately seems to require precise memory as well as the ability to compare outputs. Music, like all auditory information, has a temporal component, meaning it unfolds over time. Auditory cognitive systems must depend on mechanisms that allow a stimulus to be maintained in short term memory while being able to relate one element in a sequence to another that occurs later in time(Peretz & Zatorre, 2005). Baddeley (1990) created a model for working memory that consists of a central executive controller working alongside two "slave systems". These two systems are the phonological loop and the visuospatial sketchpad, both of which allow for storage and manipulation of information. The phonological loop is the phonological store and the articulation control process (inner speech). It is responsible for coding speech and other sound information. The sketch pad is responsible for storing and manipulating visual information. Many music researchers have accepted this dual memory system that separates short and long term storage components of information for music perception. The short term memory component is responsible for both storage of and processing of auditory information, making it a working memory model (Berz, 1995). It is this working memory that would allow for the continuous auditory feedback monitoring by the perceptual process so that "real time" corrections can be made

Auditory information held in this short term memory store is easily lost if not rehearsed (Berz, 1995). Interruption between a given tone and a comparison tone has been shown to decrease performance accuracy, meaning that individuals are not as proficient in keeping the original tone in mind when presented with an increased mental load. A very similar phenomena is experienced with verbal information. This means that participants had a more difficult time keeping verbal auditory information in mind when their memory task was interrupted with a tone (Berz, 1995). While untrained participants do not have difficulty with melody contours, training is important for interval perception. This suggests that pitch information in melodies might be stored in a schema consisting of the contour and tonal scale giving individuals more information to rely on. Intervals and tones are more precise as the tonal framework becomes context dependent (Berz, 1995). Individuals are not able to rely on other contextual cues like contour and tempo with the more precise interval and tones.

Research involving musical production tasks and memory would support the idea that while there is variability, there is an innate ability to utilise working memory and sensory motor codes for singing production. Over 25% of participants who were asked to recreated pop songs from memory were able to reproduce pitch without an error on any given trial (Levitin, 1994). As well, 40% were able to perform without error for at least one trial. This demonstrates some degree of absolute pitch memory exists in the general population. This task required participants to encode pitch information, store information, and recall without shifting pitch. This requires participants to continuously evaluate their singing output and compare it to their internal auditory representation.

Working memory is likely not only involved in singing but also music discrimination as well. Studies assessing verbal recall suggest that even if no auditory reproduction is necessary, auditory information stays in the phonological loop where it is processed using its working memory mechanisms. Verbal auditory information has several limitations for recall (Wilson, 2001). When recalling verbal information the *phonological similarity effect* (difficulty recalling similar sounds), *word length effect* (difficulty recalling longer sounds), and *irrelevant speech effect* (difficult recalling when competing sounds are present) are all factors that make recall of verbal information more difficult. These effects are not seen when auditory responses (articulation) are suppressed only if the information is presented in a non-auditory fashion, like pictures or print. However, even when auditory responses are suppressed but the information is presented verbally, these recall limitations are still present (Wilson, 2001). It would appear that once information has entered the phonological loop, it continues the be processed here even if recall does not require auditory production. That auditory information is held in the phonological loop regardless of whether production is required leads us to believe that even though music perception does not require an auditory reproduction of sounds through singing (and the sensorimotor-loop), perception still requires the same working memory mechanisms.

Past research has provided clear evidence that music and singing perception are related to the working memory. The sensorimotor-loop proposes that singing requires auditory information to be held in memory as an internal representation which must be continuously compared to the auditory output produced. This comparison between input and output must then be used to make “real time” corrections to minimise discrepancies between the internal representation and output. Similarly, music perception requires that auditory information be held in the phonological loop where it can be stored and processed.

Current Study

The current study evaluates the relationship between working memory and adult music perception and production through pitch and melody discrimination as well as pitch matching. The importance of holding and manipulating auditory information for music perception suggests that working memory will be positively correlated with performance on the discrimination tasks, particularly melody as participants must keep track of unfolding auditory information. It is predicted that working memory will also have a positive relationship to the pitch matching task, as the sensorimotor-loop proposes that singing relies on working memory. However, the perception tasks should not be related to the pitch matching task, since research suggests that difficulties in pitch matching may be due to a weak internal representation or inability to reproduce as opposed to perception deficits.

Method

Participants

The sample was composed of 24 undergraduate students from Huron University College. Ages of participants ranged from 18-22 and there were 17 females and 7 males. These students were recruited via an on-line research participation system (Sona) maintained by the Department of Psychology at Huron. Participants were compensated in the form of course credit. An additional six participants were reomoved from the study, either from having pressure-equalizing tubes inserted during childhood, or from having incomplete data sets.

Materials

Each participant completed: a music experience questionnaire (see Appendix I), Peabody Picture Vocabulary Test (PPVT), Digit Span Test, and the Vocal Auditory Motor Development Assessment (VAMDA).

The Peabody Vocabulary Test consists of picture stimuli and vocabulary words. Participants are presented with picture stimuli, and required to point out the corresponding picture from the vocabulary word given. This test was given to assess general intelligence, as past studies have shown strong correlations between vocabularly and scores on the Wechsler Intelligence Scale (Billy, Smith, Taylor & Hobby, 2005).

To assess working memory a digit span test was administered. In the first part of the task, the participant was asked to repeat back strings of digits that got progressively longer until the participant is unable to do the task. This is a measure of short-term memory capacity. In the second part of the task, the particpant was asked to repeat back strings of digits in reverse order, which also assesses the participants's working memory.

Musical production and perception skill was assessed using the VAMDA. Perception taks were split into pitch and melody discrimination. During the pitch discrimination tasks, particpants were told that animals are trying to sing two notes exactly the same. On each trial, a picture of one animal appears on the computer screen and sings two notes. Then a second animal appears and also sings two notes. The pitch perception tests uses a method of contsant stimuli that enables researchers to assess percent of correct trials. There was also a melody discrimination task, which follows the same outline as the pitch discrimination task but with the animals singing a four note melody.

The production tasks were split into single pitch (one note), interval (two note), and melody (four note) production trials.

Procedures

Before testing particpants signed a consent form and filled out a brief questionnaire regarding their past musical experiences. Each participant was tested individually in a quiet laboratory room. The testing room was set up with a computer and microphone system that was used for the administration of the Vocal Auditory Motor Development Assessment (VAMDA). The musical stimuli was presented through a custom computer program, and a microphone hooked up to a separate computer recorded the participant's singing.

A trained experimenter administered tests to each participant, in a quiet, private room. Each session began with the administration of the Peabody Vocabulary Test, in an effort to create a rapport with the participant, and to keep the testing consistent with previous testing with children. This was always followed by the digit span tests. The VAMDA was administered through the computer program. Before testing, particiapants were asked to warm up by making a siren sounds from high to low, as demonstrated by the experimenter. The participants's most comfortable singing range was also determined prior to testing by have the computer sing pitches and having the participant imitate them until they are no longer able to do so. The middle of their range was chosen as their most comfortable singing range. For testing, perception and production tasks were seperated into two seperare blcoks. For perception tasks, the block was divided into two pitch discriminatio tasks and melody discrimination. The singing production block was split into pitch matching, interval matching, and melody matching. Each of the tasks within the block was randomized, but each block was always administered in order.

Results

As shown in Table 1, a Pearson *r* Correlation was conducted to examined the relationship between: digit span forwards and backwards (working memory task), PPVT, pitch and melody discrimination (perception task), single pitch matching (production task), and years of music training. Scores from the PPVT were obtained by calculating each particpants raw score, or the level achieved minus number of errors. Digit span scores were calculated based on number of sequences the partcipant correctly recalled. For the VAMDA discrimination tasks (tests 1,2,3) the score was calculated using the percentage of correct selections. For this study, only the single pitch matching score was analysed for time and resource purposes. The pitch matching was analyzed by comparing the presented note to the note produced. The differences between these were calcualted for each of the 5 pitch trials.

It was predicted that there would be a positive correlation between working memory and the pitch perception tasks as well as the pitch matching task. As well, it was predicted that there would be no relationship between the pitch perception and pitch matching task. There should be no relationship between the PPVT and music experience and the music perception and production taks, as it is believed that working memory is responsible for any variations of scores between partcipants as opposed to general intelligence of musical experience.

Results did not demonstrate a significant relationship between pitch discrimination and working memory. There was not a significant relationship between the forward digit span and the first pitch discrimination task, $r(22) = .33$, $p > .05$, nor the second pitch discrimination task

$r(22) = .07$, $p > .05$. For both pitch discrimination tasks there was also not a significant relationship with the backwards digit span, $r(22) = .18$, $p > .05$, $r(22) = .25$, $p > .05$.

Results did indicate a significant relationship between working memory and melody discrimination. There was a significant positive correlation between backwards digit span and melody perception $r(22) = .44$, $p <.05$.

Pitch matching was not shown to have a significant correlation with any of the measures analysed. There was no significant correlation with forwards digits span, $r(22) = .20$, $p > .05$ nor the backwards digit span, $r(22) = .12$, $p > .05$

Results also indicated that perception is not related to pitch matching abilities. The pitch discrimination task did not have a significant relationship with the first pitch matching, $r(22) = 17$, $p > .05$, nor the second, $r(22) = .13$, $p > .05$. There was also not a significant relationship between melody discrimination and pitch matching, $r(22) = .24$, $p > .05$.

Performance on the VAMDA tasks did not appear to be related to musical experience. Number of years of musical training was not found to have a significant relationship with the first pitch discrimination task $r(22) = .12$ $p > .05$. No significant relationship was found between years of musical training and melody discrimination $r(22) = .12$, $p > .05$ nor pitch matching $r(22) = -.12$, $p > .05$.

Discussion

The results of this study provides support for previous research and our hypothesis that working memory is related to music perception due to the positive relationship seen between the backwards digit span and melody perception. . Results indicate that PPVT scores and years of musical training do not correlate with either melody perception and pitch production, which

Table 1

Correlations for Key Study Variables

	Digit Span- Forward	Digit Span - Backwards	PPVT	Music Experience
Pitch Discrimination 1	.325	.175	.354	.123
Pitch Discrimination 2	.072	.253	-.028	-.522
Melody Discrimination	.188	.444**	.162	.124
Pitch Production	.201	.120	-.025	-.120

***p<.01

suggests that the results cannot be attributed to differences in musical experience and other general intelligence measures.

Melody perception was shown to have a positive correlation with the backwards digit span. This suggests that accurate perception of a melody is related to an individuals ability to hold and manipulate information held in their short term memory. This holds with past research that proposes auditory cognitive systems rely on mechanisms that allow a stimulus to be maintained in memory while also relating one element in a sequence to another that occurs later in time (Peretz & Zatorre, 2005). According to many cognitive and music psychologists, this involves individuals making use of the phonological loop which allows for storage and manipulation of auditory information (Baddeley, 1990). While perception does not require the same motor functions and self assessment as singing, components of the sensorimotor-loop are still relevant. The phonological loop is likely a component of the sensorimotor-loop, as this loop requires auditory information to be held memory and developed into an internal representation of the auditory information presented (Tsang, Friendly, & Trainor, 2011). This internal representation then has to be compared to new incoming auditory stimuli. While not making use of the motor component, melody discrimination likely utilises components of this sensorimotor-loop that rely heavily on working memory. Further research should be conducted to examine if the phonological loop are separate entities working within each other, or simply one single entity.

That pitch discrimination was not found to be positively related to working memory does not contradict the hypothesis that working memory is related to music perception. Rather it suggests that single pitches are not complicated enough to show the relationship between working memory and music perception. Discriminating between single pitches has a smaller working memory load. Participants are required to hold less ongoing auditory information in mind, while simultaneously comparing it to new incoming information compared to melody discrimination. While pitch discrimination does not require much working memory power, it may be a more complicated task for a musical standpoint. Pitch information in melodies can be stored in schemas consisting of the contour and tonal scale which provide more information and cues. Since single tones are more precise then melodies as the tonal framework depends on context.(Berz, 1995).

Working memory was also not found to have a significant relationship with the pitch matching task. It is likely that single pitch matching was not found to be related to working memory because it does not require enough use of working memory. The participant is not required to keep in memory a stream of auditory information while also using motor control areas that enable the singing while motoring output so that "real time" corrections can be made. Additionally, participants were not given the opportunity to assess their note production and make online adjustments. This means that individuals with better working memory might have been more aware of the differences between the pitch presented and pitch they produced, but were not given the opportunity to demonstrate this awareness. Reproduction of a melody is also a simpler task for occasional singer. Singing a single tone is a more difficult task since it lacks the structure of pitch and time dimension present in melodies which provide more cues to monitor and aid performance (Dalla Bella & Peretz, 2006). A melody task would have allowed the relationship between working memory and singing to be better demonstrated. Participants could have utilised these cues to compare their singing output to their internal representation in ways beyond pitch. If participants had been asked to reproduce a melody it is likely a significant positive relationship with working memory would be seen. The difficulty of reproducing a single pitch also may mean that the single pitch matching task did not allow participants to fully demonstrate their singing production abilities which undermines that ability to assess production capabilities with working memory. If participants had been required to reproduce a multi-note sequence they would have had more opportunity to correct themselves, given that they were able to accurately hold the auditory information in memory and compare their internal representation to their output. It is likely that interval and melody perception would have more definitive results regarding the relationship between working memory and singing.

The pitch matching was also shown to be unrelated to the perception tasks, which supports the hypothesis that singing proficiency has more to do with working memory than perception. Past research proposes that it is poor encoding and internal representation that creates difficulties in singing, not perceptual difficulties. Having difficulties producing accurate pitches may be due to difficulties monitoring internal representation to the singing output. This corresponds to the assertion that the sensorimotor-loop relies on an accurate internal representation, produced by memory, that can be compared to the singing output. This means that accurate singing and pitch reproduction would rely more on memory then perception.

There are several limitations of this study that may minimise the impact of its results. The VAMDA and digit span test used for this study may have caused limitations for this study. Since both these tasks were originally designed for children, it is possible that they did not provide accurate representations of abilities for adult participants. As previously discussed, it is possible that the tasks presented were too simple to allow participants to fully demonstrate their full musical perception and production capabilities, which diminished the ability for the connection between working memory and music to be shown. Additionally, the two pitch discrimination tasks did not correlate with one another This undermines the reliability of the task, since one would expect that scores would be related for the two tasks.

Future research should expand on the sensorimotor-loop model and connect it to phonetic awareness and language. Since both speech and music perception must convert a dynamic stream of sound into hierarchal structures, they both rely on rapidly processing signals of acoustic detail and structural organisation (Patel, Gibson, Ratner, Besson, Holcomb, 2008). This relationship between language and singing is supported by the effect of increased singing proficiency by reducing linguistic information. When two activities require resources from similar cognitive functions, performance tends to suffer (Saegent, 1973). Research looking at occasional singers without formal training saw that they displayed more accurate singing skills when language demands were decreased (Berkowski & Dalla Bella, 2009). Participants were asked to perform a familiar melody production task where they had to sing lyrics. Additionally, they were asked to sing a familiar melody repetition task that involved them repeating a syllable /la/. Pitch and time accuracy of the singing was then analysed based on both pitch dimension and time dimension variables. Participants sang more in tune and in time during the repetition production task. These results demonstrate an advantage to singing one syllable over singing with lyrics (Berkowski et al. 2009). This advantage could be the result of a reduced cognitive load, specifically reduced linguistic demands. A reduced linguistic load means that participants could focus on the retrieval of melodic information. This effect of reduced linguistic load could also mean that both the lyrics and physical singing production were making use of the same auditory processing skills. This would mean, that the effectiveness of the sensorimotor loop depends on the cognitive load. Therefore, both language and singing make use of the sensorimotor loop. This would also explain brain imaging results that show the brain behaving similarly when reading out loud or singing (Trollinger, 2010).

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Appendix I

Singing Experience Survey

The following questions are optional, and you may choose to skip any that you would prefer not to answer. Any information that you do provide will be kept confidential.

What is your native language? ________________________________

List any other languages that you can speak.

____

How many hours a day do you generally listen to music? ____________

What styles of music does you listen to? (circle all that apply):

Rock, Jazz, Classical, Top20/popular, Alternative, Other:________________

Do you sing? Yes/No (circle)

Have you ever been part of a singing group (e.g., choir, band, etc.)? Yes/No

If YES, are you still part of a singing group?

Have you ever taken any formal music lessons or music-related classes? **YES NO** (circle)

If YES, list the type(s) of instrument training (e.g., piano, voice, violin, etc.) and duration of lessons (e.g., 1 year, 2 years etc.)

Do you have any vision or hearing problems? **YES NO** (circle)
If yes, please specify: ____

Is there a history of vision or hearing impairment in your family? **YES NO** (circle)
If yes, please specify: ____

Have you ever had pressure-equalizing tubes in your ears as a child? **YES NO** (circle)

If yes, please indicate the ages at which they were inserted & removed_______________

Curriculum Vitae

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