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Electrophysiological and Behavioral Working Memory Differences Between Musicians and Non-Musicians

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ELECTROPHYSIOLOGICAL AND BEHAVIORAL WORKING MEMORY DIFFERENCES BETWEEN MUSICIANS AND NON-MUSICIANS

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by

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ABSTRACT

ELECTROPHYSIOLOGICAL AND BEHAVIORAL WORKING MEMORY DIFFERENCES BETWEEN MUSICIANS AND NON-MUSICIANS

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The current study examines the P300 brainwave and working memory differences between musicians and non-musicians. Differences in aspects of recorded electrical brain activity have been used to quantify differences in updating processes of working memory possibly related to differences in amount of music experience. The current study is designed to partially replicate and enhance a method previously implemented in research describing how music experience may be associated with differences in visual processing as well auditory working memory and executive function. Behavioral data were collected using six standardized subtest measures of the TOMAL – II, followed by ERP recordings during a visual oddball task. The results from the current study confirmed hypotheses that musicians score higher on working memory task especially related to executive functioning and record differences in P300 mean amplitude and peak latencies. Overall, these findings suggest that greater amounts of music experience lead to stimulus processing differences related to working memory.

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CHAPTER I

INTRODUCTION

Practicing music using an instrument entails coordinating a variety of tasks that tend to rely on both auditory and visual domains of sensory integration and working memory. While most studies evaluating abilities of musically experienced and naïve individuals focus on auditory processing, few studies describe the role of visual processing differences related to greater amounts of music experience. Research has demonstrated that musical training may be related to differences in a variety of cognitive abilities, including non-verbal reasoning (Forgeard, Winner, Norton, & Schlaug, 2008), verbal memory (Ho, Cheung, & Chan, 2003; Jakobson, Cuddy, & Kilgour, 2003), speech processing (Moreno & Besson, 2006), and vocabulary (Forgeard et al., 2008). In contrast, there is a lack of research describing visual processing differences between "musician" and "non-musician" groups related to working memory (Schellenberg, 2006; Zafranas, 2004; Moreno, Marques, Santos, Santos, Castro, & Besson, 2009). Mixed findings exist in the music cognition literature as to whether music experience may be related to differences in visual processing or if musicianship can only be associated with faster processing in the auditory modality. Research evaluating both visual and auditory working memory processing has suggested that electrophysiological differences in visual working memory processing may be more subtle than auditory processing differences when comparing "musicians" and "non-musicians" (George & Coch, 2011). The following sections will outline some of the key aspects involving the connection between musical training and cognition. Specifically, music's impact on cognition, working memory and Evoked Response Potential (ERP) data will be highlighted demonstrating a gap in the research related to visual processing and music experience.

Music Impacting Cognition

Longitudinal designs examining the effects of music training demonstrate improvements in a variety of cognitive domains. For example, Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, (2007) demonstrated participants recorded higher scores on cognitive tests of attention and working memory after individualized piano instruction courses. After six months of repeated practice of individualized music training sessions and a three-month delay period, participants in the music training courses continued to score higher on cognitive tests of attention and working memory. However, since Bugos et al. (2007) only tested elderly participants with memory deficits, the cognitive gains discontinued once the participants were no longer engaged in musical training. Another line of research has demonstrated longitudinal differences in electrical activity associated with music experience.

For instance, Besson, Schön, Moreno, Santos, & Magne, (2007) created 8-week training sessions composed of either engaging participants in painting activities or practicing with a music instrument. Results from the training sessions and a 6-month follow-up indicated significantly higher brain electrical activity (Late Positive Potential waveform) associated with an improved ability to determine pitch variations in music and speech. Similarly, differences in evoked brain wave response activity associated with music training were also recorded in brain areas identified as being structurally different between “musicians” and “non-musicians” (Gaser & Schlaug, 2003). Müller, Höfel, Brattico, & Jacobsen additionally reported that “musicians” register greater late positive brain waveforms over posterior parietal brain areas and Early Right Anterior Negativity (ERAN) brain wave activity when “musicians” make an aesthetic judgment of a series of chords varying in dissonance (Müller, Höfel, Brattico, & Jacobsen, 2010). These findings further demonstrate differences in ongoing processing and maintenance of information related to cognition in “musicians”. Alterations in electrical brain activity related to music experience therefore suggest that music has an effect on the mental processing ability of an individual. In addition to mental processing difference related to musical training, aesthetic judgments of sound sequences also appear to be different between “musicians” and “non-musicians”.

For example, when describing dynamics within music pieces, participants with no musician experience tend to use descriptions related to mood and emotional regulation at higher rates than participants with musician experience. Conversely, experienced “musicians” tend to focus more on structure and pattern identification suggesting the existence of a common conceptual space underlying aesthetic responses to music (Istók, Brattico, Jacobsen, Krohn, Müller, & Tervaniemi, 2009). Further research has posited “expert musicians” have a higher tendency to be considered “Music Systemizers,” in that “expert musicians” tend to focus more on overall structure and patterns within pieces. “Non-musician” judgment patterns tend to report dynamics in music as being on a spectrum of emotional fluctuations related to the changes in sound (Kreutz, Schubert, & Mitchell, 2008). Cognitive structuring of information by “musicians” suggests a greater reliance on working memory resources involving the creative manipulation of auditory and visual information as it is maintained in thought.

Further studies have documented parallel processing of auditory and visual information. For example, Vogt, Buccino, Wolschläger, Canessa, Shah, Zilles, Eickhoff, Freund, Rizzolatti, & Fink, (2007) demonstrated "musicians" imitating guitar chords actively allocate attentional resources integrating multiple networks by repeated practice (bimanual coordination) triggering parallel processing in visuospatial and auditory domains. Likewise, a functional brain mapping study suggested that repeated practice of coordinated music activity create coactivation of neuron communication pathways related to auditory and visual information processing (Hadjidimitriou, Zakarakis, Doulgeris, Panoulas, Hadjileontiadis, & Panas, 2011). Parallel auditory and visual pathway activity associated with music experience would suggest the existence of visual differences (i.e., visual working memory) in cognitive processing in addition to documented auditory differences (Besson et al., 2007; Müller et al., 2010). Overall, research examining both visual and auditory processing of music suggests that working memory mechanisms play a key role in music proficiency.

Working Memory

The term working memory refers to a multi-component system of cognitive mechanisms that are able to maintain and manipulate stimuli while orienting attention that is distinctly different from long-term memory encoding and storage. Baddeley and Hitch (1974) describe working memory as being composed of the "phonological loop", "visual-spatial sketchpad", and the "central executive" processing system. Respectively, these short term stores allow for maintenance and manipulation of small amounts of auditory information and an ability to rehearse inner mental speech, visual information and pattern recognition of visual stimuli, and a moderating governor mechanism which focuses attention of the phonological loop and visuo-spatial sketchpad. An update of the model by Baddeley (2003) additionally includes an episodic buffer that works in parallel to the phonological loop and visuo-spatial sketchpad to maintain organized orders of information, and the three subsystems operate under the umbrella of the attention allocating central executive. Several lines of research have demonstrated specific brain waveforms (components) that have been reliably linked to specific processes within working memory (Polich, 2007; Polich, Howard, & Starr, 1983; Duncan, Barry, Connolly, Fischer, Michie, Näätänen, & Van Petten, 2009; Townsend, LaPallo, Boulay, Krusienski, Frye, Hauser, & Sellers, 2010). The following section will focus on research dealing with a specific brain waveform (i.e., P300) and its relation to working memory.

Evoked Response Potential Data

In contrast to the poor temporal resolution associated with functional brain imaging, researchers can record electrical activity averages in real time using ERPs, demonstrating peaks in activity time locked to a specific stimuli. The ERP specifically refers to reliably occurring electrical differences recorded from the scalp that can be directly related to the presentation of a particular stimulus. A task involving presentation of visual and/or auditory stimuli referred to as the oddball has most commonly been used to elicit a positive waveform 300 milliseconds after the onset of a novel stimulus near areas of the prefrontal and parietal cortex. Reliably documented waveforms that appear in relation to particular stimuli are labeled as individual *components*, which have been examined in the literature in terms of specific behavior that may be related differences between the oddball and control conditions. Stimulus presentation/reaction markers are also recorded within the EEG recording representing reaction time compared to time of presentation.

Differences in how “musicians” use a subdivision of working memory that Baddeley (2003) described as the visuospatial sketchpad involving ERP and behavioral measures have suggested that musicians do not differ from “non-musicians” when performing tasks involving visual stimuli. Ho, Cheung, & Chan (2003) tested children and adults to investigate influences on working memory related to music experience. Data indicated children with music training tended to score higher on measures of verbal but not visual memory compared to their counterparts with no music training. These results were consistent with previous findings by Chan et al. (1998) who showed greater amounts of music training in adults as well as child participants were related to significantly higher scores on tasks of verbal but not visual memory compared to participants without music training. However both studies indicating lack of visual memory difference measured experience in children, and/or older adults who reported never playing music, excluding groups of young adults at or near a peak in neural development as a result of having practiced music for years. Studies demonstrating no difference in visual memory are additionally limited in the amount of music experience participants recorded, with the longest follow-up duration recorded after five years.

Research describing working memory has associated the mean of a positive inflection in the ERP wave (P300) recorded at 250 – 550ms for auditory stimulus and 300 – 750ms for visual stimulus with an updating of working memory processes for the respective modalities (Brumback, Low, Gratton & Farbiani, 2004). Higher mean amplitudes and earlier P300 onset latencies during working memory related tasks in "musicians" compared to "non-musicians" have been recorded in frontal and parietal brain areas allowing differences to be discussed in terms of electrophysiological response and working memory ability related to differing amounts of music experience (George & Coch, 2011). The visually elicited P300 has been documented in studies as an illustration of visuospatial working memory updating (Bledowski et al., 2004), a division of working memory, which allows active rehearsal of fluid visual representations of objects and experiences (Baddeley, 2003).

Mean amplitude of the P300 has been utilized to demonstrate the difficulty in performing an identification task. For instance, P300 amplitude tends to decreases as it becomes more difficult for the participant to identify a difference between the rare and non-rare stimulus (Polich, 2007). Consistent with this finding, greater working memory capacity as indexed by a reading span task has been correlated with a higher P300 mean amplitudes during a five choice reaction time task (Nittono, Nageishi, Nakajima, & Ullsperger, 1999). Mean amplitude has also been described by Luck (2014) as less sensitive to high frequency noise compared to peak amplitude and will therefore be utilized in the current study. Additionally, P300 latency has been referred to as a representation of reaction time to the stimulus and a measure of the duration of the period between identification and cognitive interpretation (Polich, 2007). A negative correlation has been reported in the research between P300 peak latency and working memory capacity as measured by digits spans (Polich, Howard, & Starr, 1983). In addition, research related to expertise has shown individuals with greater amounts of experience tend to record earlier latencies, demonstrating faster processing while performing tasks related to their experience (Wong et al., 2005).

Studies using subtle variations of pitch and rhythm have demonstrated faster cognitive reactions in "musicians" P300 latency onset as well as greater mean amplitudes compared to "non-musicians" indicating a more sensitive system in recognizing subtle changes in an auditory stimulus (Müller, Höfel, Brattico, & Jacobsen, 2010; Gagnon, & Peretz, 2000; Ungan, Berki, Erbil, Yagcioglu, Yüksel, & Utkucal, 2013). In addition, Ungan et al. (2013) have shown that "musicians" tend to be more accurate at identifying subtle changes in rhythmic units, suggesting a more sensitive auditory working memory circuit. Moreover, amount of music experience tended to be more related to differences in EPR latency compared to mean amplitude. However, "musicians" have been reported to record higher mean amplitudes, which Jongsma, Meeuwissen, Vos, & Maes, (2007) have shown to be associated with greater amounts of expectation violation. Other groups have also demonstrated higher mean amplitudes and shorter latencies when identifying differences in vowel encoding within speech (Kühnis, Elmer, Meyer, & Jäncke, 2013), and music note semitone judgments between "musicians" and "non-musicians" (Zarate, Ritson, & Poeppel, 2012). Previous research implementing brain waveform measures have demonstrated a variety of differences using auditory stimulus designs (Besson, Schön, Moreno, Santos, & Magne, 2007; Moreno & Besson, 2006; Ungan et al., 2013). In contrast, the current body of research examining "musician" groups performing a visually oriented task demonstrates conflicting evidence with some groups that suggest no evoked differences using a visual stimulus (Lee, Lu, & Ko, 2007), and others that suggest more efficient visuospatial working memory in “musicians” (Bugos et al., 2007; Jakobson et al., 2008).

The aim of the current study is to partially replicate and enhance previous research on music cognition, which has shown differences in brain wave activity using a visual oddball design (George & Coch, 2011). Based on previous studies showing improvements in performance of “musicians” on mental imagery (Aleman, Nieuwenstein, Böcker & Haan, 2000) and executive functioning tasks, it is hypothesized that “musicians” will show enhanced performance on all six subtests of the TOMAL – II (Test of Working Memory and Learning) measuring auditory and visual working memory processes as well as executive function (Reynolds & Voress, 2008). Additionally, it is hypothesized that “musicians” will show a shorter latency of mean amplitude in the ERP in areas of the parietal cortex and frontal areas previously associated with visual working memory, executive function, and attention (George & Coch, 2011; Schulze, Mueller, & Koelsch, 2011). Previous research has also observed that the P300 ERP wave is positively correlated with higher degrees of expectancy violation in the stimulus, in that the greater the violation of what is expected in the stimulus, the higher the peak, or mean peak of the P300 wave (Jongsma et al., 2007). Therefore, it is also hypothesized that the visual difference in rare compared to non-rare stimulus in the oddball design will illicit a more pronounced P300 amplitude in “musician” participants when compared to “non-musicians”.

CHAPTER II

METHOD

Participants

A total of 19 participants were recruited for the study consisting of 11 “musician” participants (8 males, 3 females), and 8 “non-musicians” (4 males, 4 females). In order to be labeled as a “musician”, participants met the following set of criteria: 1) they have studied music for at least 7 years, 2) the participant has studied on the same instrument the majority of the time up to the time of the experiment, and 3) the participant still actively participates in some kind of focused music study group (e.g., are involved in a curricular or extracurricular music group on a regular basis, or have taken lessons and/or self-report practicing at least 3 hours per week). “Non-musicians” did not meet criteria of practicing for at least 7 years, did not report having any experience with any instrument, and did not report currently studying music. These criteria are based on previous studies of working memory and musicianship (George & Coch, 2011; Strait et al., 2010). Further research is required in order to build a widely accepted definition of musician criteria, which could improve between study comparison validity.

Recruitment of participants was achieved through the Central Washington University Department of Psychology’s SONA system website. Research participation credit was granted to students based on their attendance to the date and time submitted by the participant on the SONA website. The study was open to anyone willing to participate over the age of 18 who were free of any persistent medication, drug use, and/or neurological disorders.

Consistency of Criteria

A major issue involving research of “musician” compared to “non-musician” groups is the consistency in criteria used to define the amount of experience an individual is required to have to be considered a “musician”. One shortfall of studying a particular group of expertise is how to define the qualifying criteria that classifies a participant in one group or another. The proposed study implements criteria utilized in previous studies comparing “musician” and “non-musician” groups (George & Coch, 2011; Strait et al., 2007) in order to also evaluate the effectiveness of previously established criteria in a different geographic area with a relatively similar participant sample size. Further research is required to provide input and support for a more descriptive and widely accepted definition of valid and reliable criteria, which accurately delineates an expert “musician” from a “non-musician”.

Design

The study consisted of three between-subjects measures associated with working memory, and compared data from groups who met criteria qualifying them as a “musician”, to groups who met criteria for the “non-musician” group. After participants provided consent to participate in the study (Appendix A), demographic data was collected by way of the participant completing a packet (Appendix B) documenting the participants handedness as measured by the Central Washington University Brain Dynamics and Cognitive Neuroscience Lab Handedness Questionnaire as well as two additional questions inquiring specifically about music instrument handedness. Also included in the demographic data packet were questions asking for participants' primary instrument, additional instruments played, how long (in years) the participant has been playing a music instrument, how many hours per week the participant practices their instrument, and general additional demographic data of age, gender, university standing, and university focus subject. "Musicians" were defined by meeting the criteria in the above section. "Non-musicians" were identified as those who did not have experience playing an instrument and reported less than seven years experience and 0 hours practiced per week.

Following completion of the demographic data, measures of "visuospatial", "phonological", and "executive function" working memory were recorded using six subtests of the TOMAL – II (Reynolds and Voress, 2007). These subtests make up a battery of measures that previously has been associated with "visuospatial" processing and working memory (Baddeley, 2003; Gaser & Schlaug, 2003). Specifically, subtests used in the current study targeted phonological working memory using Digits and Letters Span Forward (DF, and LF respectively). "Visuospatial" working memory was recorded using the Abstract Visual Memory task (AVM) as well as the Memory for Location task (MfL), and "executive function" working memory was recorded using the Digit and Letter Span Backward tasks (DB, and LB respectively).

Upon conclusion of subtests from the TOMAL – II which made up the behavioral measure of the study, participants were led into another room where the EEG was recorded while responding to the visual oddball paradigm. The oddball paradigm presents participants with a randomly arranged mixture of frequently occurring stimuli (control/non-rare), with a target stimuli (target/rare) that occurs at a lower frequency. The participants objective during the oddball task of the current study was to respond only when the target/rare stimuli was presented. The specific oddball procedure administered in the current study involved presenting participants with a small circle in 80% of the trials, and a large circle during the remaining 20% of the trials. This creates a “non-rare” stimulus presented to the participant in 80% of the trials, and a “rare” stimulus occurring for the remaining 20% of the total trials. While recording continuous EEG data, participants were asked to respond only when the rare stimulus is presented. Responding only to the rare stimulus consistently elicits a positive spike in the EEG near 300 milliseconds (P300 brain wave) and the response to this rare stimulus will allow for both identification of the ERP as well as allow for a measure of reaction time speed recorded from the moment of stimulus onset to the participant’s click of a computer mouse. Following the recording of EEG during the four blocks of trial presentations, reaction times to the rare stimulus, as well as ERPs time locked to the response to the stimulus were summed and averaged in order to compare across groups of “musicians” and “non-musicians”.

Measures

Behavioral Data

TOMAL – II

Created by Reynolds and Voress (2007), the TOMAL – II, is a test that contains a variety measures that can be used to evaluate memory and attention. The TOMAL – II allows measurements to be made recording auditory, visual as well as cognitive multitasking within the domain of working memory. It has been shown to be an accurate measure in quantifying working memory capacity in children and adults, and additionally is useful in identifying specific learning disabilities, traumatic brain injury, neurological diseases, serious emotional disturbances, as well as ADHD. The subtests of the TOMAL – II chosen for the study were used due to previous administration during the only other known measure of visual odd-ball research involving "musicians" (George & Coch, 2011). Specifically, the study presented the subtests of the TOMAL – II in the following order: Abstract Visual Memory, Memory for Location, Letters and Digits Forward (phonological memory), and Letters and Digits Backward (executive function). Administration of all six subtests took approximately an hour. Total scores on each subtest were transformed to standardized scores for each participants age range based on the standardized score transformations listed for each test in the appendix of the TOMAL – II. Means for each standardized subtest score for "musicians" and "non-musicians" were then compared using a multivariate analysis of variance (MANOVA) and regression was run on each subtest in relation to years experience with a music instrument and score on each TOMAL – II task.

EEG Acquisition

Following the six subtests of the TOMAL – II, participants were guided into the EEG stimulus viewing room and fitted with the Neuroscan 32 channel quick cap. Electrical impedance of each electrode was minimized to under 15mΩs, and the system was referenced on the nasion of the participant. Eye blinks were monitored via an electrode positioned at the outer canthus of the left eye. Electrodes are aligned in a 10-20 system, meaning the distances between adjacent electrodes are either 10 or 20% of the total front-back, left-right distance of the skull. Actual electrophysiological data were recorded from 28 electrode sites distributed evenly across the scalp using silver/silver-chloride (Ag/AgCl) electrodes attached to an elastic cap (Neuromedical Supplies Inc.) and a Neuroscan amplifier/stimulator with the Neuroscan recording software. Data was recorded continually and dissected into epochs time locked to the onset of the rare or non-rare stimulus. A trigger indicating the onset of the visual stimulus marked the beginning of each epoch. The stored epoch encompassed 1200 msec (including a 200 msec prestimulus baseline) relative to stimulus onset.

Amplification of the continuous EEG recording was from .15 to 70 Hz (1 to 100 Hz for the VEOG channel), and digitized through the Neuroscan acquisition interface system. Neuroscan acquisition interface system was used to conduct continuous analog-to-digital conversion of the EEG, and stimulus trigger codes were performed on the online data. Offline artifact rejection and baseline correction was performed followed by EEG signal averaging.

Individual epochs were examined and rejected whenever electrical activity in either VEOG (Blink) channel or the frontal channels (FP1, FP2) exceeds ±50μV. Successfully averaged ERP waveforms were then digitally lowpass-filtered with zero phase-shift at 20Hz with a filter slope of -48 dB per octave in order to remove ambient electrical noise and muscle artifact.

Coding Procedures

To ensure participant anonymity, everyone who participates in the study was labeled with a code made of a series of numbers and letters. This code was also used in the storage of the participants EEG data. Participants data from the TOMAL – II, averaged waveforms from the EEG, and demographic data was analyzed and compared between “musician” and “non-musician” groups.

Hypothesis

H (1): Participants who meet criteria categorizing them as “musicians” will record higher standardized scores on all six subtests of the TOMAL – II (letters/digits forward subtests targeting “phonological” memory, Abstract Visual Memory and Memory for Location subtests targeting “visuospatial” memory, and letters/digits backward targeting “central executive” control) in comparison to participants who meet criteria for “non-musicians”.

H (2): Participants in the “musician” group will record an averaged positive waveform in the EEG occurring between 300 to 750 milliseconds after the onset of the stimulus with a shorter P300 latency, as well as a higher mean amplitude compared to “non-musician” participants.

H (3): “Musician” participants will record shorter reaction times to the stimulus.

H (4): Correlations will exist between years experience practicing music and performance on each TOMAL-II task.

CHAPTER III

RESULTS

TOMAL – II Analysis

Mean scores for TOMAL – II subtests for "musicians" and "non-musicians" are presented in Table 1. A one-way between-subjects multivariate analysis of variance (MANOVA) was performed on six dependent variables: Abstract Visual Memory, Memory for Location, Digits Forward, Letters Forward, Digits Backward, and Letters Backward. The independent variable (IV) was musician status ("musician" or "non-musician").

A MANOVA was used for the analysis with sequential adjustment for non-orthogonality. Box's test of equality of covariance matrices indicated non-significance allowing assumption of equal covariance to be met. Results of evaluation of assumptions of normality, homogeneity of variance – covariance matrices, linearity, and multicolilinearity were satisfactory allowing the assumptions to be met in order to perform a MANOVA.

With the use of Wilks' criterion, the combined DVs were significantly affected by "musician" status ($\Lambda = .016$, $F(6, 12) = 3.414$, $p < .05$). The results reflected a strong association between Musician Status ("musician" or "non-musician") and the combined DVs, partial $\eta^2 = .631$ with 95% confidence limits. Results from the affect of Musician Status on each individual DV indicated statistically significant results for Digits Forward

Table 1

Means and Standard Deviations for TOMAL-II

	Musicians		Non-Musicians		$F(1,17)$	p
Measure	*M*	*SD*	*M*	*SD*		
AVM	12.091	1.14	10.875	2.70	1.825	.194
MfL	12.182	2.68	10.375	2.92	1.955	.180
LF	12.273	2.53	9.000	2.33	8.253	.011
DF	12.182	1.78	8.375	3.02	11.947	.003
LB	11.181	2.93	9.125	2.17	4.819	.042
DB	11.545	3.01	8.125	1.64	8.405	.01

Note. The TOMAL-II is from Reynolds and Voress (2007) *Test of memory and language* (2nd ed.). AVM refers to Abstract Visual Memory, MfL refers to Memory for Location, LF refers to Letter span Forward, DF refers to Digit span Forward, LB refers to Letter span Backward, and DB refers to Digit span Backward. Raw scores were collected and transferred to standard scores adjusted for age of the participant.

($F(1, 17) = 11.947$, $p < .01$, $\eta^2 = .413$), Letters Forward ($F(1,17) = 11.947$, $p < .05$, $\eta^2 = .327$), Digits Backward ($F(1,17) = 8.405$, $p < .05$, $\eta^2 = .331$), and Letters Backward ($F(1,17) = 4.819$, $p < .05$, $\eta^2 = .221$). These results demonstrate "musician" participants scored higher on tasks of auditory working memory as indexed by Digits Forward ($M = 12.182$, $SD = 1.7787$, $M = 8.375$, $SD = 3.0208$) and Letters Forward ($M = 12.273$, $SD = 2.5334$, $M = 9.00$, $SD = 2.3299$), as well as tasks related to executive function as indexed by Digits Backward ($M = 11.545$, $SD = 3.0121$, $M = 8.125$, $SD = 1.6421$), and Letters Backward ($M = 11.818$, $SD = 2.9264$, $M = 9.125$, $SD = 2.1671$). Significant correlations were found between the independent variables Years Music Experience and Digits Forward ($R = .587$, $F(1,17) = 8.940$, $p < .01$, $R^2 = .345$), Letters Forward ($R = .615$, $F(1,17) = 10.364$, $p < .01$, $R^2 = .379$), and Letters Backward ($R = .515$, $F(1,17) = 6.141$, $p < .05$, $R^2 = .265$). A trend toward significant correlation was also found between Years of Music Experience and Digits Backward ($R = .450$, $F(1,17) = 4.326$, $p < .06$, $R^2 = .203$).

ERPs: Comparison of "Musicians" and "Non-Musicians"

Omnibus ANOVAs were used to compare differences between groups of "musicians" and "non-musicians" for P300 mean amplitude and latency. Overall comparisons for mean amplitude between groups were non-significant; however, overall P300 peak latency was statistically significant ($F(1, 54) = 10.832$, $p < .01$) with "musicians" registering a longer peak latency ($M = 402.79$, $SD = 10.408$) than non-"musicians" ($M = 394.82$, $SD = 7.459$). Anterior and posterior (anterior electrode sites included: FP1, FP2, F7, F3, Fz, F4, F8, FT7, FC3, FC4, CZ and FT8; posterior electrode sites included: TP7, CP3, CP4, TP8, P7, P3, PZ, P4, P8, O1, O2, and Oz) mean amplitude did differ but only when not taking into account musician status ($F(1,22) = 11.689 = p < .01$, $\eta^2 = .347$). Overall, participants registered higher mean amplitude at posterior sites ($M = 14.82$, $SD = .63$) compared to anterior electrode sites ($M = 9.705$, $SD = .656$) (See figure 1). Evaluation of peak latency for anterior compared to posterior sites revealed main effects of musician status ($F(1,42) = 15.24$, $p < .001$, $\eta^2 = .266$), as well as electrode location ($F(1,42) = 22.81$, $p < .001$, $\eta^2 = .352$), demonstrating "musicians" recorded later peak latencies ($M = 402.55$, $SD = 1.47$) compared to "non-musicians" ($M = 394.45$, $SD = 1.47$), and peak latencies were shorter at anterior sites ($M = 393.55$, $SD = 1.50$) compared to posterior sites ($M = 403.46$, $SD = 1.44$).

A series of mixed design ANOVAs using Musician Status as the between subjects variable and hemisphere amplitude and latency as within subjects factors indicated no hemispheric differences between participant groups on measures of mean P300 amplitude and latency. Measures of anterior compared to posterior mean amplitude indicated a significant overall ($F(1,22) = 15.93$, $p < .01$, $\eta^2 = .453$) difference of participants registering higher mean amplitudes at posterior electrode sites ($M = 13.93$, $SD = 2.73$), compared to anterior sites ($M = 9.75$, $SD = 3.73$), and there were no differences when evaluating peak latency for anterior compared to posterior sites.

Midline data was computed using the rare stimulus averages from each individual participant (Midline electrodes included: Fz, Cz, Pz, and Oz). Missing data due to non-functioning electrodes were replaced using linear regression of that electrode position from that participants group. Smoothing procedures were performed on all rare stimuli averages in order to reduce the amount of noise to the oddball stimulus. Area reports were then created for each individual participant as well as for each groups grand averages which were then transferred to an Excel spreadsheet and imported to IBM SPSS.

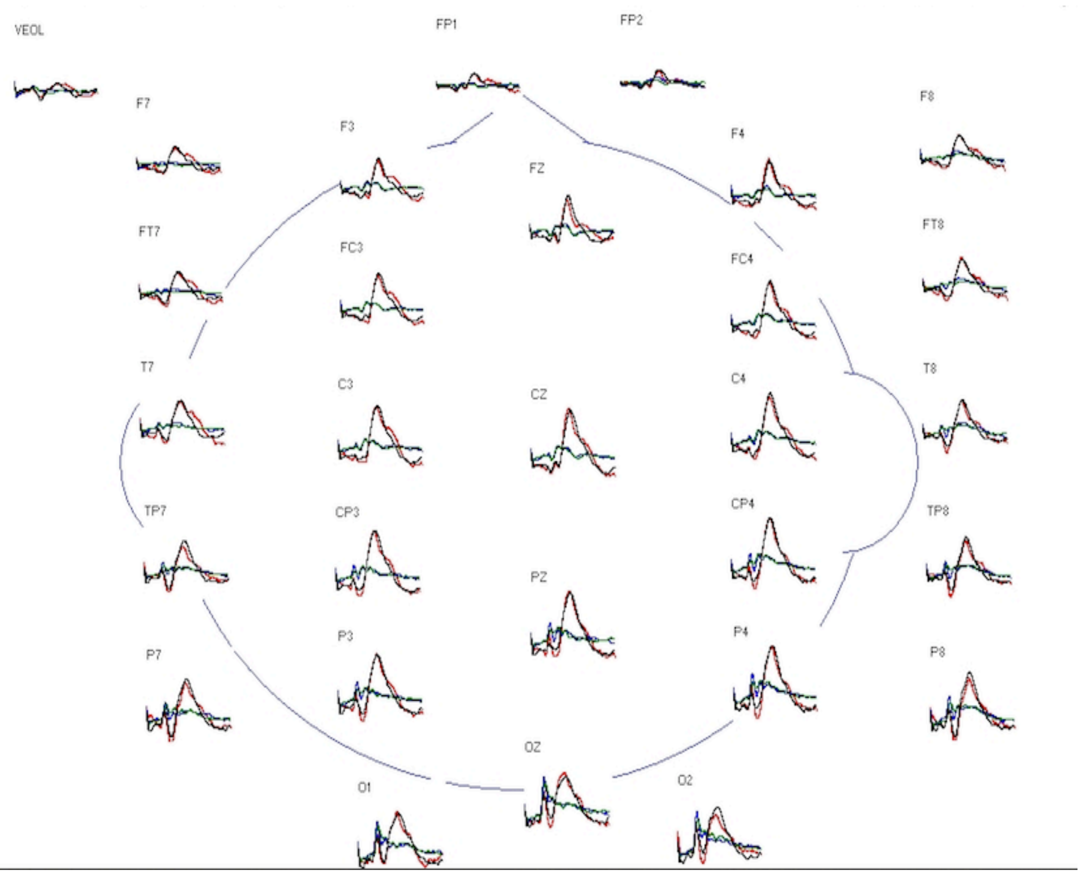

Figure 1. Total ERP scalp map of the oddball task recorded from -100ms to 1000ms. Black line represents "musicians" in the rare condition, red line represents "non-musicians" in the rare condition, blue line represents "musicians" in the non-rare condition, and the green line represents "non-musicians" in the non-rare condition.

Analysis of the midline electrode sites between groups indicated no significant differences in amplitude between "musician" and "non-musician" groups. However, there was a significant main effect of overall electrode site using the Greenhouse-Geisser correction ($F(1.59,27.01) = 6.470$, $p < .01$, $\eta^2 = .276$) indicating overall, participants recorded lowest amplitude measures at frontal sites ($M = 11.83$, $SD = 4.60$), and the highest amplitudes at the Pz electrode site ($M = 19.75$, $SD = 8.37$) (See figures 2, 3 and 4). For midline electrodes there was also a main effect of electrode site found ($F(3,51) = 14.08$, $p < .01$, $\eta^2 = .43$), indicating that the lowest mean was recorded at site Fz ($M = 11.83$, $SD = 4.60$), and the highest mean amplitude was recorded at site Pz ($M = 19.75$, $SD = 8.37$). At midlines sites a trend existed toward statistical significance with "musicians" showing higher mean amplitude at site Fz compared to "non-musicians" while also recording a lower mean amplitude at site Pz compared to "non-musicians" but comparisons between groups were non-significant. Figures 5 and 6 represent amplitude fluctuations through the time window of -100ms to 1000ms after the onset of the stimulus for "musicians" (figure 5) and "non-musicians" (figure 6).

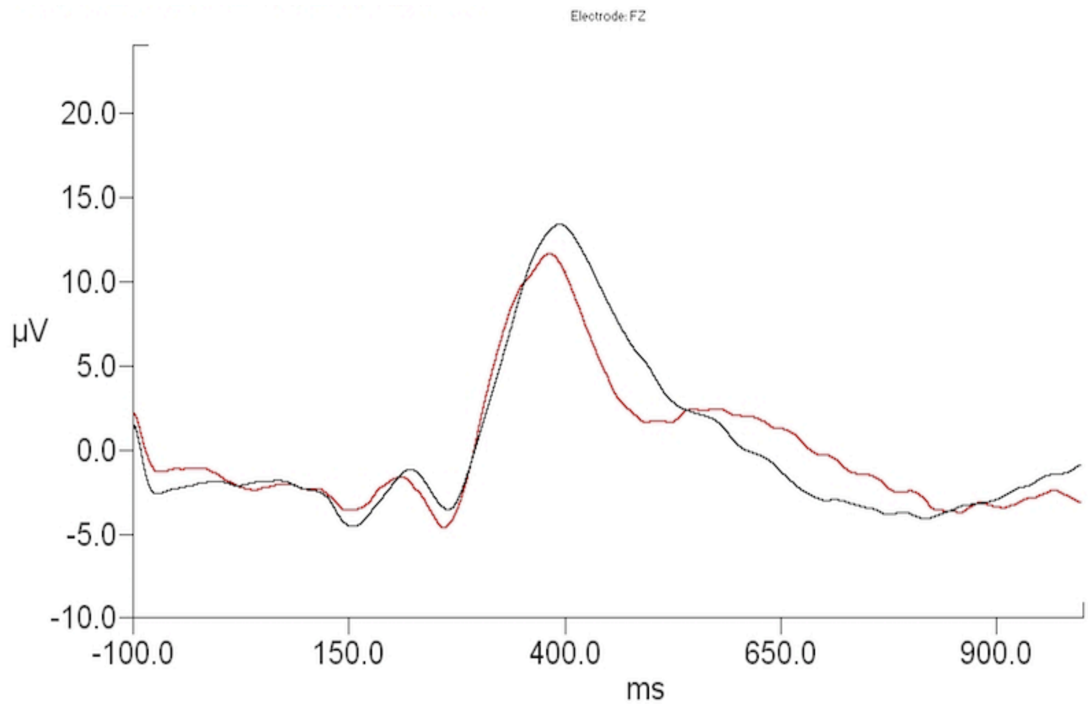

Figure 2. ERP waveform recorded during the rare oddball condition at site Fz. The black line represents "musicians'" response to the oddball stimulus. The red line represents "non-musicians'" response to the oddball stimulus.

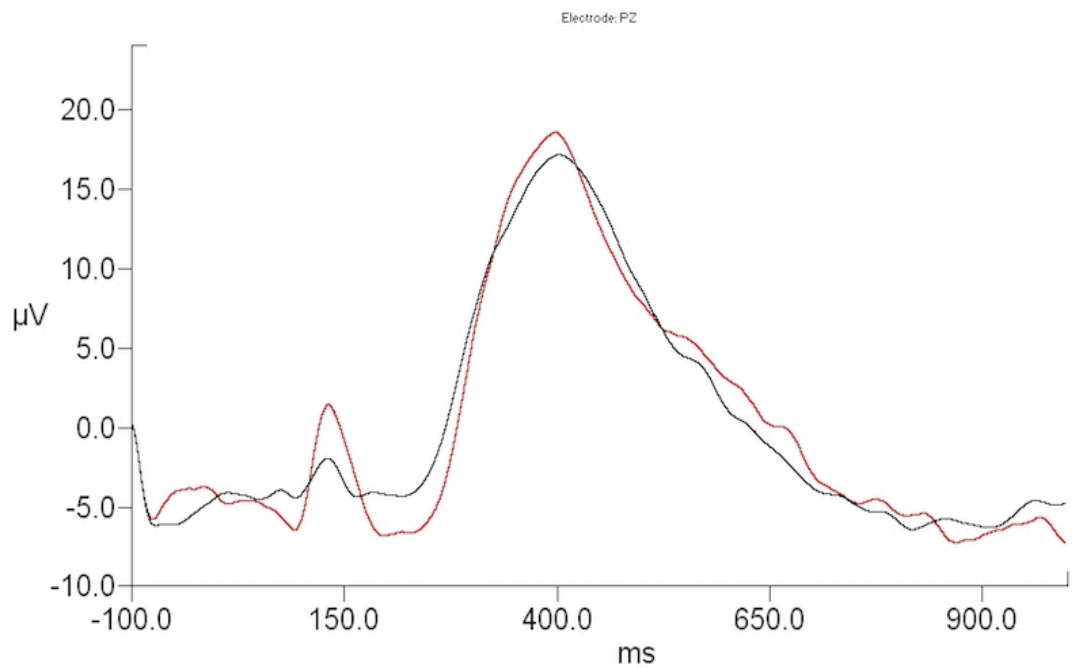

Figure 3. ERP waveform recorded during the rare oddball condition at site Pz. The black line represents "musicians'" response to the oddball stimulus. The red line represents "non-musicians'" response to the oddball stimulus.

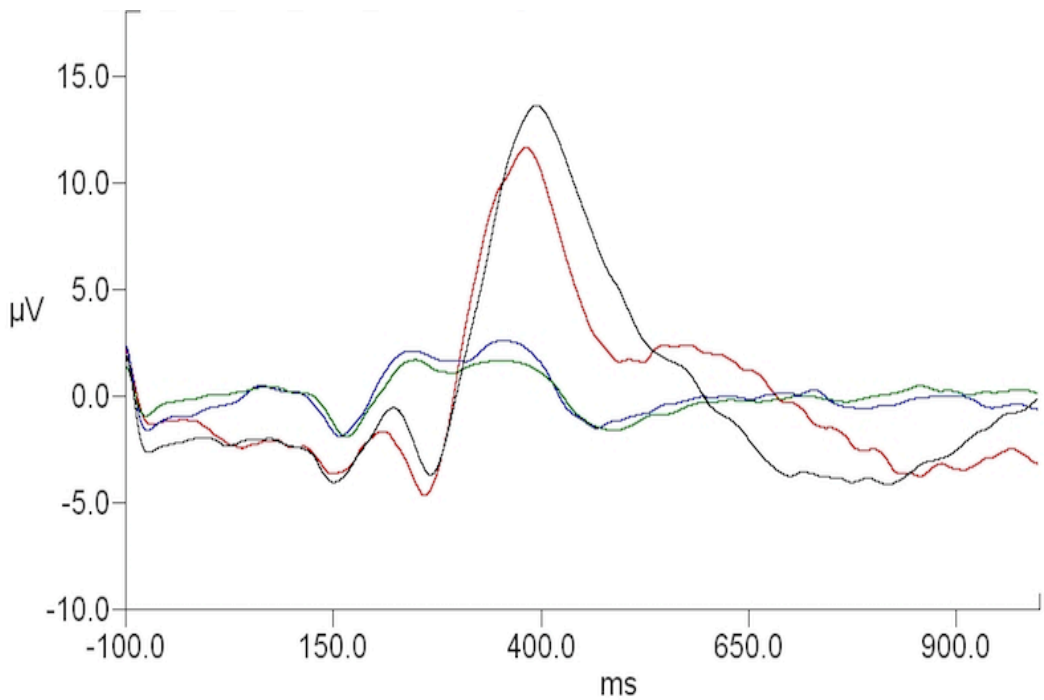

Figure 4. ERP plot at site Fz. Black line represents “musicians’” response to the rare condition, red line represents “non-musicians” in the rare condition, blue represents “musicians’” response to the non-rare condition, and green represents “non-musicians” in the non-rare condition.

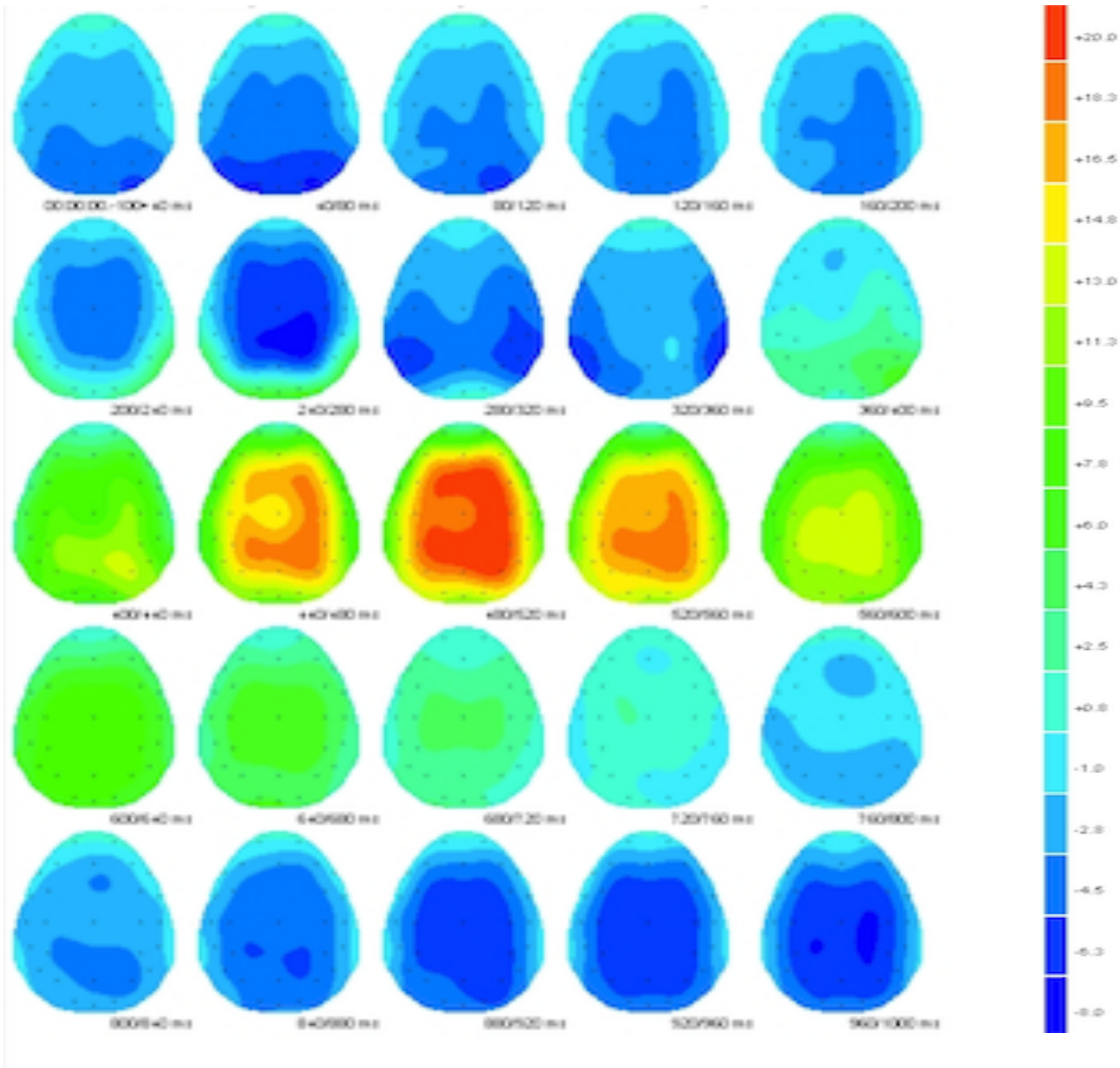

Figure 5. Amplitude maps of "musician" participants beginning at -100ms and recording an image every 40ms to 1000ms.

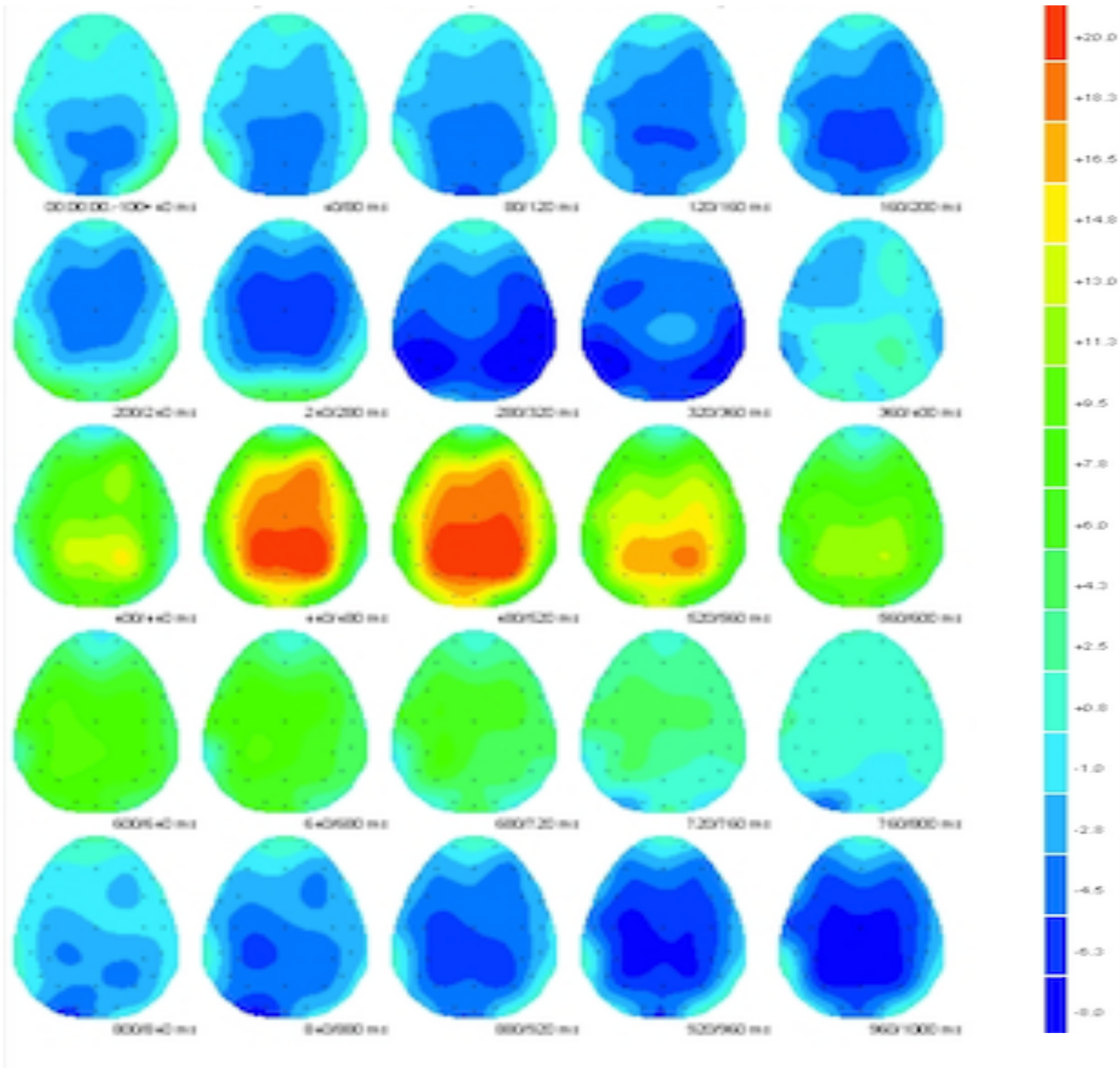

Figure 6. Amplitude maps of “non-musician” participants beginning at -100ms and recording an image every 40ms to 1000ms.

CHAPTER IV

DISCUSSION

Current Study

The purpose of the current study was to evaluate and add to the understanding of how music experience may play a role in changing cognitive abilities related to working memory. Six subtests of the TOMAL-II were used to measure various aspects of working memory and a visual oddball task was incorporated in order to specifically examine electrophysiological visual working memory differences between groups of experienced "musicians" and "non-musicians". Specifically, it was predicted that "musicians" would record higher scores on all measures of the TOMAL-II and correlations will exist between years of music experience and performance on each measure of the TOMAL-II. Additionally, it was hypothesized that "musicians" would record higher P300 mean amplitudes specifically at frontal and parietal electrode sites, and "musicians" would record shorter P300 peak latencies compared to "non-musicians".

Evaluation of both ERP data and performance on behavioral tasks indicated differences, suggesting that long-term music practice may be related to processing differences in working memory. Behavioral measures of working memory using the TOMAL-II indicated "musicians" scored statistically better than "non-musicians" on all subtests, specifically on tasks related to auditory working memory and executive functioning. "Musicians"' better performance on tasks related to auditory and executive function working memory was also supported by significant correlations that were found between years of music experience and performance on auditory and executive functioning tasks (Digits Forward, Letters Forward, Digits Backward, and Letters Backward). The current studies findings of enhanced performance on auditory working memory tasks supports similar results found in previous studies (Lee, Lu, & Ko, 2007; George & Coch, 2011; Ho, Cheung, & Chan, 2003; Schulze, Müller & Koelsch, 2011) demonstrating improved performance on working memory tasks by participants with greater amounts of music experience. Moreover, the current data also supports recent research that suggests music training may lead to enhanced executive function ability (Moreno, Bialystok, Barac, Schellenberg, Cepeda, & Chau, 2011; Bugos et al., 2007; Degé, Kubicek & Schwarzer, 2011). Although there were no differences found between “musician” and “non-musician” groups on behavioral tasks of visual working memory, trends toward statistical significance did exist and, therefore, these findings may be explained by small sample sizes and ceiling effects related to the simple nature of the visual memory tasks. In addition, significant correlations of years of music experience and auditory as well as executive function measures of working memory provide further evidence for improved auditory rehearsal and focus of attention in participants with greater amounts of musical expertise. Finally, the behavioral findings of the TOMAL-II also manifested in electrophysiological changes detected in the ERP waveforms.

Electrophysiological data measuring differences in P300 amplitude and latency mainly revealed “musicians” registered longer latencies of overall mean amplitudes compared to “non-musicians” on the visual oddball task. This finding is in contrast to previous research (George & Coch, 2011), which used a similar paradigm to measure P300 differences between “musicians” and “non-musicians”. One reason for the contrasting findings of the current study may be the unequal and low sample sizes, which could lead to a lack of generalizable group variance, resulting in longer ERP latency times. Longer peak latencies in "musician" groups could also be related to the hypothetical construct of what defines a participant as a "musician" in the current study, suggesting defining features of what categorizes a participant as a "musician" or a "non-musician" should be continually evaluated in order to produce more reliable and generalizable findings.

Part of the goal of the current research was to test criteria used in previous studies (George & Coch, 2011; Strait, Kraus, Parbery-Clark, & Ashley, 2010) while additionally measuring correlations that exist between years of music experience and performance on working memory measures of the TOMAL-II in order to further examine behavioral items that may be useful in defining a participant as a "musician" or "non-musician". For example, the current research utilized definition criteria of "musician" based on two previous studies (George & Coch, 2011; Strait, Kraus, Parbery-Clark, & Ashley, 2010). However, in order to provide a more precise definition of "musician", the current study included an adjustment for seven years of music experience. Consequently, differences found in the current data highlight the importance of creating a more precise operational definition of what defines a "musician" or "non-musician".

Another interesting finding related to later P300 latencies in "musicians" was a statistical trend toward higher mean amplitudes at frontal midline sites (FP1, FP2, Fz), and a lower mean amplitude compared to "non-musicians" at parietal midline sites (P3, P4, and Pz). Previous research has demonstrated specific areas such as the dorsal lateral prefrontal cortex that may be related to executive function and attention (Kane & Engle, 2002). Higher mean amplitude at frontal sites in "musician" participants may reflect greater activation of the dorsal lateral prefrontal cortex which would additionally be supported by better performance on TOMAL-II tasks related to executive function as well as significant correlations between executive function tasks and years of music experience. Moreover, faster peak latency in "non-musician" groups may additionally suggest that individuals with no music experience rely less on abstract evaluation of a visual stimulus change and, therefore, recognize the visual oddball with less stimulus processing time.

Previous research measuring differences in visual and auditory imagery between "musicians" and "non-musician" groups (Aleman, Nieuwenstein, Böcker, & Haan, 2000) demonstrated "musicians" performed statistically better on measures of musical auditory memory compared to non-musicians. The researchers found no differences between "musicians" and "non-musicians" on measures of visual imagery. This suggests "musicians" may utilize executive function working memory, as well as auditory rehearsal, to a greater extent than "non-musicians", which is supported by data collected in the current study. Additional research using masking tasks to measure top-down processing has suggested greater amounts of music experience are related to more complex processing systems of auditory and executive function working memory systems (Strait, Kraus, Parbery-Clark, & Ashley, 2010) and extraction of higher-order, semantic information during encoding (Jakobson, Lewycky, Kilgour, & Stoesz, 2008). Top-down processing refers to processing patterns of information that is influenced by the individual's personal experiences, biases, and training, which can shape the way participants experience stimuli and lead to later or shorter electrophysiological latencies in the ERP response. More complex processing systems related to greater amounts of music experience may explain a longer P300 latency in “musicians” as well as improved performance on auditory and executive function tasks.

Overall, the current study demonstrated higher scores on measures of auditory and executive function in “musician” participants using the TOMAL-II. Measures of visual working memory demonstrated some statistical trends but did not reveal significant differences between groups, which may suggest music training improves processing of information mainly in the auditory domain. Hypotheses that “musicians” will register overall higher P300 mean amplitude could not be statistically confirmed, however the lack of statistical significance could have been related to the low sample size as well as the standard simple design of the circle stimuli used in the oddball task.

Future Research

Further research evaluating differences related to music experience should pursue larger participant groups as well as more powerful stimuli to evaluate more subtle differences related to music experience and visual working memory. Criteria that are found to be useful at maximizing differences between “musician” and “non-musician” groups should be further investigated and repeatedly implemented in order to build generalizability of findings and participant categorization validity. One of the main difficulties in generalizing research performed on individuals that have different types and levels of proficiency such as “musicians” is that not all participants in the general population have identical music experience. Due to these individual differences that exist within samples of “musicians”, findings from one study may be difficult to generalize to larger populations due to a lack of consistency and standardization of what the defining criteria of a "musician" should incorporate. Therefore, further research involving "musician" groups should work toward building a more confident set of criteria with high reliability that participants who meet criteria to be categorized as "musicians" accurately reflect the broader group to which the data is being generalized. Also, further research should work toward identifying specific aspects of cognition (such as executive functioning processes found in the current study and attention) that may be related to amounts of music experience, and continue to evaluate differences in those specific areas of cognition in order to build a better understanding of how music can affect thought processes and stimulus evaluation. In addition, findings of the current study demonstrating "musicians'" enhanced performance on measures of auditory and executive function working memory also support theories of more complex executive functioning activation patterns (Strait, Kraus, Parbery-Clark, & Ashley, 2010; Jakobson, Lewycky, Kilgour, & Stoesz, 2008) in participants with more music training. As mentioned previously, executive function include other cognitive processes like attention; therefore, future studies should pursue research investigating potential differences in "musicians" vs. "non-musicians" in relation to attention or other cognitive processes that make up executive function.

In conclusion, the current study provides further evidence that music training is related to differences in cognitive capabilities. Specifically, findings from the current study add support to the notion that music experience can have a positive impact on a person's cognitive performance (Brumback, Low, Gratton, & Fabiani, 2004; Forgeard, Winner, Norton, & Schlaug, 2008; Jakobson, Lewycky, Kilgour, & Stoesz, 2008). Further studies should work toward better understanding what an accurate definition of a “musician” should consist of and isolate specific components of auditory working memory, executive function and attention that can be statistically attributed to greater amounts of music experience. Findings of the current study provide evidence that greater amounts of music experience can lead to more complex stimulus evaluation patterns and additionally illustrate differences that exist in working memory and attention processes related to long term focused music practice.

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Table 2

Means and Standard Deviations for ERP Overall Between Groups μV Amplitude and Latency Analysis

	Musicians		Non-Musicians		$F(1, 56)$	p
Measure	*M*	*SD*	*M*	*SD*		
Overall Mean Amplitude	12.78	3.74	12.63	3.94	.022	.882
Overall Latency	402.79	10.41	394.82	7.46	10.832	.002

Note. Table 2 displays the overall mean amplitude and peak latencies across the entire scalp electrode sites for "musician" and "non-musician" groups.

Table 3

Means and Standard Deviations for ERP µV Amplitude by Hemisphere Analysis

	Musicians		Non-Musicians		$F(1, 22)$	p
Measure	*M*	*SD*	*M*	*SD*		
Right Hemisphere Ampl	12.66	3.89	12.02	3.77	.03	.959
Left Hemisphere Ampl	11.35	3.56	10.83	3.75	.03	.959
Right Hemisphere Total	12.34	3.76	11.09	3.58	1.23	.280
Left Hemisphere Total	11.52	3.66	11.52	3.66	1.23	.280
Anterior Amplitude	10.11	3.75	9.40	3.85	.008	.931
Posterior Amplitude	14.76	2.44	14.96	2.91	.008	.931
Anterior Total	9.75	3.73	9.75	3.73	15.931	.001
Posterior Total	13.93	2.73	13.93	2.73	15.931	.001

Note. Table 3 displays left and right as well as anterior and posterior hemispheric differences in mean amplitude using all electrode sites except midline electrodes (Fz, Cz, Pz, and Oz) to compare left to right hemisphere overall and between groups as well as anterior compared to posterior overall and between groups (lateral midline electrodesT7, C3, Cz, C4, T8).

Table 4

Means and Standard Deviations for ERP Latency by Hemisphere Analysis

	Musicians		Non-Musicians		$F(1, 22)$	p
Measure	*M*	*SD*	*M*	*SD*		
Right Hemisphere Latency	400.25	5.21	394.08	4.74	12.248	.002
Left Hemisphere Latency	404.17	12.83	395.83	8.0	12.248	.002
Right Hemisphere Total	397.17	5.80	397.17	5.80	1.01	.306
Left Hemisphere Total	400.00	11.29	400.00	11.29	1.01	.306
Anterior Latency	396.67	4.92	390.33	5.19	.558	.463
Posterior Latency	393.83	46.84	398.08	4.60	.558	.463
Anterior Total	393.50	5.91	393.50	5.91	.120	.732
Posterior Total	395.96	32.62	395.96	32.62	.120	.732

Note. Table 3 displays left and right as well as anterior and posterior hemispheric differences in peak latency using all electrode sites except midline electrodes (Fz, Cz, Pz, and Oz) to compare left to right hemisphere overall and between groups as well as anterior compared to posterior overall and between groups (lateral midline electrodes T7, C3, Cz, C4, T8).

Table 5

Means and Standard Deviations for Midline ERP µV Amplitude Analysis

	Musicians		Non-Musicians		$F(3, 51)$	*p*
Electodes	*M*	*SD*	*M*	*SD*		
Fz Amplitude	13.26	4.75	10.04	3.97	1.319	.277
Cz Amplitude	18.27	4.25	16.52	7.76	1.319	.277
Pz Amplitude	19.34	6.86	20.26	10.42	1.319	.277
Oz Amplitude	11.82	6.42	13.19	10.18	1.319	.277

Note. Table 5 displays mean amplitude differences for midline electrode sites between groups.

Table 6

Means and Standard Deviations for Midline ERP Latency Analysis

	Musicians		Non-Musicians		$F(3, 51)$	p
Electodes	*M*	*SD*	*M*	*SD*		
Fz Latency	389.364	25.33	379.38	27.23	.647	.507
Cz Latency	387.06	32.27	379.88	25.74	.647	.507
Pz Latency	347.72	112.88	383.01	30.38	.647	.507
Oz Latency	411.09	76.52	412.63	76.73	.647	.507

Note. Table 5 displays peak latency differences for midline electrode sites between groups.

Table 7

Means and Standard Deviations for Main Effect of Midline ERP µV Amplitude Analysis

Electodes	*M*	*SD*	*F*(3,51)	*p*
Fz Amplitude	11.83	4.60	16.75	.000
Cz Amplitude	17.49	5.93	16.75	.000
Pz Amplitude	19.75	8.37	16.75	.000
Oz Amplitude	12.43	8.06	16.75	.000

Note. Table 7 displays the mean differences for amplitude recorded from midline electrode sites.

Table 8

Means and Standard Deviations for Main Effect of Midline ERP Latency Analysis

Electodes	*M*	*SD*	*F*(3,51)	*p*
Fz Latency	385.16	25.89	2.194	.136
Cz Latency	384.03	29.15	2.194	.136
Pz Latency	362.576	88.08	2.194	.136
Oz Latency	411.737	74.45	2.194	.136

Note. Table 7 displays the mean differences for amplitude recorded from midline electrode sites.

APPENDIX A

Central Washington University

Research Participant Consent Form

Study Title: Electrophysiological and Behavioral Working Memory Differences Between Musicians and Non-Musicians

Principal Investigator: Benjamin Richardson, Graduate Student,
Central Washington University,
richardsob@cwu.edu.

Faculty Sponsor: R. Greenwald, Ph.D., Associate Professor. Central Washington University Department of Psychology, (509) 963-3630, greenwar@cwu.edu

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1.) What you should know about this study:

- You are being asked to join a research study.
- This consent form explains the research study and your part in the study
- Please read this carefully and take as much time as you need.
- Ask questions about anything you do not understand at any time.
- You are a volunteer. If you do join the study and change you mind later, you may quit at any time without fear of penalty or loss of benefits.

2.) Why is this research being done?

- This research is being done to examine the possible relationships between music experience and working memory processing. Specifically, I am studying correlations that have been proposed to exist between scores on behavioral measures of working memory and electrophysiological indices of cognitive processing.

3.) Who can take part in this study?

- If you are a healthy CWU student, between the ages of 18 and 40, you may qualify to take part in this study. You must be without neurological injury or condition, and not be taking medication(s) that might affect reaction time. In order to determine your eligibility for the study, further screening will be done using questionnaires detailed in item 4 below. The study procedures should take about 60 minutes. We hope to collect data from at least 40 participants.

4.) What will happen if you join this study?

If you agree to be in this study, you will be asked to do the following:
Complete two Questionnaires (approximately 20 minutes):

a. **Participant History Questionnaire**: On this form, you will be asked to provide basic information (age, gender, etc.) and answer questions concerning your neurological health and any medications that you are currently taking that may affect response time. If certain medical conditions exist, you may be excluded from participating in this study. In such cases, the principle investigator will notify you immediately. You will also be asked questions about your music ability and practice history.
b. **Hand Preference Questionnaire**: Since handedness has been shown to influence reaction time, the Hand Preference Questionnaire will be used to determine which is your dominant hand.

Experimental Tasks (approximately 30 minutes):

a.) **General Overview**: After completing the questionnaire, verbal instructions will be provided to you prior to beginning the experimental task. A practice session for the experimental task will also be conducted to familiarize you with the procedure and stimuli. The practice session will take about 10 minutes.
b.) **Experimental Visual Task**: After the practice session, you will begin the experimental task. You will be asked to focus on a series of circles that will be presented one at a time. You will have your hand resting on the response keypad. Immediately after seeing one of the circles you are asked to respond whenever you see the larger of the two circles. There are 6 blocks of the experimental trials. Each trial takes about 1.5 seconds. After each response you will have a one second delay period when you are able to blink or move. Blinking and moving creates noise in the EEG, which is why it is necessary moving and blinking is kept to a minimum during the experimental trials. The EEG portion of the experiment should take approximately 20 minutes.

Debriefing (approximately 10 minutes):

After the trial, I will ask you a few questions about your experience completing the experimental task.

Total Study Time: 120 minutes

5.) What are the risks or discomforts of the study?

There are no known risks to participating in this research. All procedures described in this proposal are considered non invasive. You may experience mild discomfort or fatigue as a result of sitting and staring at the screen; this risk is no more than what you would normally experience in daily. However, you control the amount of the rest periods between each trial.

6.) Are there benefits to being in the study?

There is no direct benefit to you from being in this study. If you take part in this study, you may however help others in the future. Results of this research may enhance our understanding of how music knowledge may influence attention, reaction time and decision-making.

7.) What are you options if you do not want to be in the study?

You do not have to join this study. If you do not join, it will not affect your grade in any class or any of your privileges as a CWU student.

8.) Can you leave the study early?

You can agree to be in the study now and change your mind later. If you wish to stop at any time, please let the principle investigator know as soon as possible. Leaving this study early will not affect your standing at CWU in any way. If you leave the study early, the investigator may use information already collected from you.

9.) Why might you be removed from this study?

You may be removed from the study if:

a.) You fail to follow instructions.

b.) There may be other reasons to remove you from the study that we are naïve to at this time.

10.) What information about you will be kept private and what information may be given out.

Only members of the research team will have access to the original research data I collect. The collected data will be locked in the research laboratory. Moreover, research data will be entered into the computer database by coding strategies. Only the principle investigator and the faculty sponsor have access to the code key, which will be kept separately on a password-protected thumb drive. No personal information will be gathered that could link you to your responses. When we have completed the study, I will destroy your contact information. I will not use your name in any written report.

Compiled data with all personal identifiers completely removed may be used in future studies, for secondary analysis, or audited by HSRC or other legally authorized body.

11.) What other information should you be aware of regarding this study?

This study has been reviewed and approved by the CWU Human Subjects Review Committee. You may contact the HSRC if you have questions about you rights as a participant, or if you think you have not been treated fairly. The HSRD office phone number is (509) 963-3115.

If you have any questions about this study, contact the principle investigator, Benjamin Richardson, at richardsob@cwu.edu, or you can call the faculty sponsor, Dr. Ralf Greenwald, at (509) 963-3630.

Will I receive extra credit?

While extra credit for participation may be offered if you sign up through SONA by some professors, this is discretionary on the part of the professor and is in no way offered or guaranteed by the study.

You have received a copy of this consent form.

Participant's s Name
(print) :____.

Participant's Signature :
Date__________________.

Phone Number :
Email_________________________.

Signature of Inverstigator :
Date__________________.

APPENDIX B

Participant History Questionnaire

What is your age? ___________

How do you identify yourself?

- ❑ Male
- ❑ Female

Have you had a concussion, stroke, seizure or any other traumatic brain injury?

____

Do you have any conditions, neurological or physiological that could affect reaction time? (Y/N only) ____________________

Have you taken any pharmaceutical or non-pharmaceutical drugs within the past two weeks?

- ❑ Yes
- ❑ No

If yes, please specify.

____

Are you currently on any medications that might affect reaction time (ask the researcher if you are uncertain whether or not what you are on might have an effect)? _________

Do you regularly play an instrument? If so, please list which instruments in order of time spent practicing, greatest to least?

____

Are you a currently a student?

- ❑ Yes
- ❑ No

If so, please specify your major course of study.

____

On average, how many years have you been practicing music with any instrument?

____

On average, how many hours per week do you dedicate to practicing a musical instrument?

- ❑ 0
- ❑ 1 – 4
- ❑ 5 – 10
- ❑ 11 – 15
- ❑ Other (specify below)

____

At what age did you start practicing music persistently?

____

Choose any of the following that categorize your instrument of most experience.

- ❑ Piano
- ❑ Brass
- ❑ String Instrument
- ❑ Woodwind
- ❑ Percussion
- ❑ Other (specify)

____

APPENDIX C

____

Data Code (**lab use only**)

Brain Dynamics & Cognitive Neuroscience Lab

Central Washington University

Hand Preference Questionnaire

Please indicate which hand you use for each of the following activities by circling:

R for right **L** for left or **E** for either

Which hand orientation would you use:

To write a letter clearly?	R	L	E
To throw a ball to hit a target?	R	L	E
To hold a racket in tennis, squash or badminton?	R	L	E
To hold a match while striking it?	R	L	E
To cut with scissors?	R	L	E
To guide the thread through the eye of a needle?	R	L	E
At the top of the broom while sweeping?	R	L	E
At the top of the shovel when moving sand?	R	L	E
To deal a deck of cards?	R	L	E
To hammer a nail into wood?	R	L	E
To hold a toothbrush while cleaning your teeth?	R	L	E
To unscrew the lid of a jar?	R	L	E
To play your most practiced instrument?	R	L	E
To hold a pick while playing guitar?	R	L	E

If you use the RIGHT HAND for all these actions, are there any one-handed actions for which you use the left hand? Please list:

If you use the LEFT HAND for all of these actions, are there any one-handed actions for which you use the right hand? Please list:

Were you born one of TWINS? _________ or TRIPLETS? _________

If yes, please indicate the hand preference of your twin or triplets. ___________

If you have children, please indicate the hand preference of your:

First Child __________ This child's other parent ____________

Second Child __________ This child's other parent ____________

Third Child __________ This child's other parent ____________

APPENDIX D

Central Washington University

Research Participant Debriefing Script

Study Title: Electrophysiological and Behavioral Working Memory Differences Between Musicians and Non-Musicians

Principal Investigator: Benjamin Richardson, Graduate Student, Central Washington University, richardsob@cwu.edu

Faculty Sponsor: Ralf Greenwald, Ph. D., Assistant Professor, Central Washington University Department of Psychology, greenwar@cwu.edu or (509) 963 – 3630

Thank you for taking the time to participate in our study investigating working memory processes in groups of musicians and non-musicians. Your data will be kept on a password protected hard drive and names will be coded to protect participant's identity. Your data will contribute to the Brain Dynamics and Cognitive Neuroscience Lab's research examining differences in working memory processing between groups with different amounts of music experience. Previous research has demonstrated relationships between music experience and differences in behavioral measures of working memory as well as electrophysiological components related to visual processing. The current study was conducted to demonstrate supportive evidence for differences in visual working memory related to varying levels of music experience.

The behavioral tests completed in the first section of the study were used to measure specifically abstract visual memory, memory for location, auditory working memory, and executive functioning measured by the number and digits span forward and backward. The visual oddball task allowed us to record speed of reaction to rarely occurring stimuli, as well as the latency and amplitude of specific electrical waveforms indexing measures of working memory updating. If you have any questions about the methodology, purpose, or research implications please feel free to email me at richardsob@cwu.edu.

Once again thank you very much for taking the time to participate in my research and being a part of scientific inquisition. Have a great day!