Examining the Relationship between Skilled Musical Training and Attention

by

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Abstract

Recent interest in the research community has sparked the study of the impact of skilled musical training on specific cognitive abilities. While many aspects of cognition have been investigated, including extensive study of working memory capacity, very little work has been done examining the relationship between musical training and attentional abilities. The present study investigated the performance of skilled musicians on cognitively demanding sustained attention tasks, measuring both timing and visual discrimination over time. Participants with extensive formal musical training were found to have superior performance on a timing-based attention task, but not a visual-based attention task, compared to participants with no musical training. In addition, no differences between groups were found on the impact of fatigue over time on either type of task. These results highlight a basic cognitive ability that may be strengthened from extensive skilled musical training, and may help explain the advantages that musicians show in other cognitive measures.

Keywords: attention, sustained attention, musical training, oddball detection task, timing discrimination, visual discrimination

Examining the Relationship between Skilled Musical Training and Attention

Music, in its various forms, is an integral part of human culture. It is difficult to go through a day without hearing music in some form: a radio broadcast, an advertisement jingle, a stranger humming, or even a bell tower tolling. The ability to produce and appreciate music has been referred to as one of humankind's most complex abilities (Moreno, 2009), one that has been around for millennia.

In the last several decades, researchers have become increasingly interested in the influence of music on the mind and brain. Specifically, they have explored the link between music and cognitive abilities. This interest was first catalyzed by the study of "The Mozart Effect," tested by Rauscher, Shaw and Ky (1993). The researchers found a brief positive impact of music listening on spatial abilities, translating to a 9-point increase in IQ. The popular interpretation of this finding was that listening to music could make people "smarter."

However, attempts to replicate of this effect have been inconsistent (see Schellenberg, 2005 for a review). For example, no effect of musical listening was found on attentional abilities in either normal or cognitively impaired older adults (Lake & Goldstein, 2011). Generally, it is believed that the improvements in task performance resulting from listening to music are mediated by arousal effects, as there have been documented cases of a "Schubert effect," a "rock music effect," and a "Stephen King" effect – all instances of improvements on task performance following exposure to interesting stimuli (Chabris, 1999; Schellenberg, 2005). In other words, listening to music does not directly result in increased scores on intelligence tests; rather, participants who listen to music show temporarily heightened awareness and arousal, which leads to stronger performance on certain cognitive measures. These effects are neither long-lasting nor specific to music in particular.

Musical Training and Cognitive abilities

More recently, researchers have examined the effects of music training, as opposed to music listening, with a focus on the relationship between learning how to play music and development of cognitive abilities. Musical training has been linked with enhancements in many different measures, which have been shown to be long lasting and widespread (Hannon & Trainor, 2007; Moreno, 2009; Schellenberg, 2005). For example, musicians display improved divergent thinking and creativity (Gibson, Folley & Park, 2009), vocabulary and nonverbal reasoning (Forgeard, Winner, Norton & Schlaug, 2008), and general intelligence (Schellenberg, 2004; 2006) compared to controls with no musical training. Schellenberg (2005) outlines several possible explanations of how musical training may relate to these effects. Most notably, the author purports that music lessons train multiple skills simultaneously, including attention, fine-motor skills, emotional expression, and abstract reasoning, and this extensive training can cause widespread improvements in all of these cognitive domains.

These findings have contributed to a growing set of literature supporting the benefits of musical training not only for abilities directly related to music, but also for general cognitive abilities – a "transfer effect." However, many of these studies have not used random assignment to balance external factors; they have instead used purely correlational designs and recruited subjects who have already independently sought musical training. Consequently, these results could be interpreted in several different ways. It is possible, for example, that any cognitive differences that were measured were present prior to exposure to music, perhaps allowing the musicians to successfully seek out and complete their musical training. Alternatively, these benefits could have been caused by confounding factors, such as socioeconomic status or parental influence, as children in households with higher wealth or education may have increased opportunities to stimulate their cognitive development, as well as a higher likelihood to participate in musical training. As such, these findings do not definitively show that cognitive benefits are a direct result of the musical training itself (see commentary by Schellenberg & Peretz, 2007).

To test whether there is a causal link between musical training and cognitive performance, several researchers have used random assignment of music-naïve participants to music training conditions to see if musical training itself directly causes these cognitive benefits. For example, François, Chobert, Besson, and Schön (2012) provided a group of young children with music lessons to test their skills in speech segmentation. When compared to another group of children who were provided painting lessons, the music group displayed improvements over several months when asked to extract meaningless words from a flow of nonsense syllables, while the painting group did not. Using a similar manipulation, Moreno, Bialystok, Barac, Cepada, and Chau (2011) showed that children who received musical training for 20 days developed greater verbal intelligence compared to children who received visual artistic training, as measured by an increase in vocabulary skills during the testing period.

Schellenberg (2004) gave groups of six-year-old children keyboard, singing, and drama lessons, and compared their changes in IQ's to a control group. Following a 36-week training period, all four groups showed increases in IQ, as would be expected from normal development. However, both the keyboard and singing groups displayed greater increases in IQ compared to the drama group, which had no greater increase than the control group. This is a notable finding for many reasons. First, this study provides compelling evidence that music training, in the form of both keyboard and vocal lessons, causes significantly greater increases in IQ compared to what is expected during normal development. Second, the researcher controlled for multiple factors such as prior IQ, family income, and age, which further supports a causal link by accounting for several potential confounding variables. Third, the finding that the drama group had no difference from controls supports the specificity of musical training in providing these increases; the increases in IQ were likely not due to just any pedagogical extracurricular activity in this type of format. These findings support the idea of a transfer effect from musical training directly to general intelligence through a causal relationship.

Neural Evidence

The documented improvements in cognitive abilities resulting from musical training have been accompanied by neural evidence of both structural and functional differences between musicians and non-musicians. In a review by Münte, Altenmüller and Jäncke (2002), the authors propose that musicians are ideal models of neuroplasticity, due to their extensive exposure to complex stimuli and high cognitive demands. The authors discuss differences found in several brain structures between musicians and non-musicians, and show that these anatomical differences correlate strongly with the age at which a participant's musical training started. The authors argue that this is compelling evidence against the documented neurocognitive effects being attributable to pre-existing differences between musicians and non-musicians; rather, these differences are likely the direct effects of the training itself.

It has also been found that musicians have stronger communication between the two hemispheres of the brain, as evidenced by reduced interhemispheric transfer time (Patston, Kirk, Rolfe, Corballis & Tippett, 2007) and increased bilateral activation during musical feature detection (Ono et al., 2011). In addition, Schmithorst and Wilke (2002) found that, compared to the corpus callosa of non-musicians, the corpus callosa of musicians had a higher degree of white matter organization, as measured by the extent to which fibers were oriented in a parallel fashion.

In fact, Schlaug and colleagues (2009) found that, when given music lessons for 29 months, children who practiced music more than 2 hours per week developed larger corpus callosa than both those who practiced fewer than 2 hours per week and those who received no musical training. These findings support the idea that musical training can directly result in neuroanatomical changes, and taken together with the cognitive findings described above, further suggests the possibility of functional differences as well.

Executive Function

While these relationships are interesting, the underlying cognitive processes that mediate these increases in general cognitive measures are still not well understood. It is thought that these benefits may result from improvements in executive function (Moreno et al., 2011). Executive function refers to a set of cognitive abilities that control and coordinate other cognitive processes in a goal-directed and flexible manner; examples include attention, planning, decision-making, task-switching and working memory (Elliott, 2003). Improvements in executive processes would benefit performance on almost all cognitive tasks, and could thus explain the improvements in other measures in musicians (see Hannon & Trainor, 2007 for a review of executive function effects in musicians).

Much work has investigated the relationship between musical training and working memory, a system is intimately related to executive functions (Smith & Jonides, 1999). Both children (Lee, Lu & Ko, 2007) and young adults (Chan, Ho & Cheung, 1998) with musical training have been shown to recall more items on memory tasks than non-musicians. Musicians have increased brain activation in neuronal networks that govern executive function during demanding working memory tasks, supporting the notion that musicians have improved control of their cognitive processes (Pallesen et al., 2010). Similarly, George and Coch (2011) found that musicians show superior phonological and visual working memory capacity when compared to non-musicians. These findings implicate improvements in working memory as one potential explanation for why musically trained children and young adults outperform their peers on many cognitive measures.

Along with working memory, George and Coch (2011) also discuss attention as a system that may be affected by musical training. The attentional system works intricately with executive functions (Smith & Jonides, 1999), involved in orienting to stimuli, detecting relevant targets, and alerting to important information (Posner & Petersen, 1990). There has been extensive work examining the relationship between working memory and attention; processing and manipulating information using working memory begins with attending to and receiving stimuli using attentional processes (e.g., Cowan, 2011; Engle, 2002; Oberauer, 2002). Cowan (2000) puts forth a model of working memory that is limited by the capacity of attention, and Kane and colleagues (2007) reported that lower working memory capacity correlated with increased mind-wandering in challenging and effortful daily tasks. Patients suffering from ADHD, a pathological inability to maintain attention, often display impaired working memory capacity (see Barkley, 1997 for a review). Taken together, these findings illustrate the intimate connection between working memory and attention. In addition, attentional control was found to be an effective predictor of differences in intelligence in both children and adults (Cowan, Fristoe, Elliot, Brunner & Saults, 2006). Given the strong link of attentional processes to working memory, as well as to general intelligence, it is logical to investigate attention as a possible mediator between musical training and cognitive improvements.

Researchers have found that children with musical training show patterns of brain activity consistent with stronger attentional abilities during stimulus detection tasks (Hannon & Trainor, 2007). Behaviorally, Scott (1992) found that students undergoing musical training were able to respond to unpredictably changing stimuli more effectively than their non-musically trained counterparts, displaying an advantage in attending to these random targets. These findings support the idea that musical training may enhance attentional abilities and can help explain why musicians show advantages in other cognitive measures. While these results point to a potential link between music and attention, previous work has examined the ability to detect or attend to stimuli specifically in the short term. No previous studies have examined the ability of musicians to perform on attentionally demanding tasks over extended periods of time. This ability is perhaps another cognitive faculty in which musicians may be advantaged compared to non-musician controls. If musical training leads to superiority in sustained attention, this may be a mechanism through which musical training aids other aspects of cognitive performance, including complex, high-level cognitive skills measured in previous studies of IQ, vocabulary, and nonverbal reasoning.

The Present Study

The present experiments investigate whether musicians demonstrate superior sustained attentional abilities. Both participants with extensive past formal musical training and participants actively pursuing a degree in music performance were tested on these abilities, compared to participants with no reported formal musical training. By examining the ability of musicians and non-musicians to maintain performance on an attentionally demanding task over extended periods of time, it is possible to see whether there is a relationship between musical training and attention. The studies compare the performance of musicians and non-musician controls on sustained attention tasks, which measure declines in the ability to detect rare stimuli over long periods of time. A shallower decline is indicative of a stronger ability to sustain attention.

Furthermore, the present studies examine whether the advantage in attention, if any, is specific to a specialized domain targeted by musical training or transfers to more general attentional abilities. To test this, two different perceptual domains are examined using different sustained attention tasks: timing discrimination and visual discrimination. Timing perception is an important skill that is specifically addressed in musical training, while visual perception is a more distantly related domain that is not specifically trained by music lessons or practice. By using these two different paradigms, it is possible to examine the effects of domain on differences in attentional abilities between musicians and non-musicians. Stronger performance by musicians in attention in timing only would indicate that these advantages are specific to domains that musicians specialize in, while stronger performance in attention in both tasks would indicate a more general advantage, one that is transferred to or expressed in other domains. Given the evidence that musical training leads to stronger executive processes, it is logical to hypothesize that musicians will display a general advantage in attention overall. This would manifest in stronger performance, both in absolute terms and in declines over time, in both the visual and timing tasks when compared to non-musician controls, reflecting a domain-general benefit of musical training.

Experiment 1

Method

Participants. Participants were recruited from a subject pool where students receive course credit in exchange for their participation. Participating students completed several questions as part of an online questionnaire at the beginning of the semester to assess their formal musical training. Using this information, two groups of subjects were recruited: to be eligible as a musician, students were required to have received a minimum of seven years of formal musical training, while to be eligible as a non-musician, students were required to have received no formal musical training past required study as part of primary education. All participants were healthy University of Michigan undergraduate students with no history of psychiatric or neurological problems and no use of medications known to affect cognition. All learned English prior to age 5, and all were between the ages of 18 and 20. Demographic information of both groups, including formal musical experience, is displayed in Table 1.

Tasks. The tasks in the present study were adapted from the Continuous Temporal Expectancy Task (CTET; Berry, Li, Lin, & Lustig, in press; O'Connell et al., 2009), an oddball detection task used to measure sustained attention. This task is relatively simple in isolation, but becomes demanding when completed over an extended period of time. In the first version used in the present study, subjects observed a visual stimulus — a pattern of alternating light and dark triangles — that changed directional orientation at a set pace (820 ms per orientation). The subjects were asked to respond to the rare "oddball" stimuli, when the orientation change happened at a longer interval (1090 ms); targets occurred 6 times per minute and were pseudo-randomly placed with 7 to 14 intervening standard trials (M = 11) between targets. Subjects responded by pressing the space bar when they detected a target; there was no response required on non-target trials.

For the present experiment, an additional variation of the CTET was used that relied on detection of physically distinct targets, rather than temporally distinct targets. This version was based on a paradigm described by MacLean and colleagues (2010), and was also used to measure sustained attention and perceptual discrimination. Alternating horizontal and vertical lines – each

400 pixels in length – appeared individually on the screen for 200 ms at a time, each followed by a noise mask for 620 ms. These figures were the standard stimuli, and the duration of the line display and mask together was equal to the duration of the standard stimuli in the timing task. The rare "oddball" targets were lines that were at 80% (320 pixels) of the standard line length. The duration of these target trials was identical to the non-target trials; thus, this task used only the length of the lines (a visual property) to characterize target events. Again, the targets were pseudo-randomly placed to ensure 7 to 14 intervening standard stimuli ($M = 11$) between them. See Figure 1 for a schematic of both tasks.

Procedure. For each task, five pseudorandom trial orders with unique target spacing were generated, and these five runs were arranged into four unique orders, which were counterbalanced across subjects. Participants were required to complete five runs of each task, each run lasting six minutes, with a one-minute break in between runs. The order in which the tasks were administered (e.g., timing or visual task first) was counterbalanced across subjects. Prior to beginning each task, participants completed a brief practice task, consisting of six 30-second long runs, each with three targets. The first practice run for the visual task contained targets that were easier to detect than the target events in the main task – a longer target duration (1620 ms) – to ensure understanding of directions, while the final five runs were identical to the actual experimental task. All subjects were required to achieve 100% accuracy in at least one practice run for each type of task and received feedback about their performance after each run.

For each participant, the percentage of correctly identified targets (hits) and the percentage of incorrectly identified non-targets (false positives) were calculated for each minute and averaged across runs. Thus, an average minute-by-minute hit rate and false positive rate was determined for each subject. Next, for each minute, a d′ value was calculated. d′ is a sensitivity index that determines a subject's ability to correctly identify and respond to targets, taking into account both hits and false positives (Stanislaw & Todorov, 1999). It is calculated as follows: d′ = norminv(hit %) – norminv (false positive %), where norminv represents the inverse function of the normal Gaussian distribution. A higher d′ value indicates that the subject is more capable of detecting correct targets, while a d′ value of zero indicates the subject was unable to detect targets at a rate above chance. Using these sensitivity values, a decline in performance over time was interpreted as an indicator of waning attention, as subjects who have more difficulty concentrating as the task progresses should have a larger drop in performance. A shallower decline is reflective of stronger attentional abilities.

Results

A repeated-measures ANOVA was performed with task and time as within-subjects variables and group as a between-subjects variable, using d′ data as the outcome measurement. This revealed a significant main effect of task, $F(1, 26) = 11.732$, $p < .01$, driven by better performance on the line task than the timing task, $t(27) = 3.521$, $p < 0.01$. There was also a significant task × group interaction, $F(1, 26) = 8.828$, $p < .01$. This was driven by a dissociation in performance across the tasks between the two groups (Table 2). The musicians tended to perform better on the timing task, $t(26) = 1.564$, $p = .130$, while there was no difference on the visual task $t(26) = .800$, $p = .431$.

While d′ is a statistic incorporating both hits and false alarms, we examined each component of task performance separately to parse out the difference in performance between the two groups on the timing task. There was no difference in hit rate in the timing task, $t(26) = .085$, $p = .646$, but the non-musicians tended to have a higher hit rate in the visual task, though this difference did not reach statistical significance $t(26) = 1.647$, $p = .111$. A Levene's test for equality of variances indicated that the distributions for false positive rate were not of equal variance between the two groups, and this was confirmed using a visual inspection of the data. Thus, using the Welch-Satterthwaite equation to correct for inequality of variances, it was found that the musicians had a lower false positive rate for the timing task that approached significance, $t(14.464) = 2.102$, $p = .054$, but not the visual task, $t(13.372) = 1.256$, $p = .230$. Thus, the difference in performance on the timing task seems to be driven by a reduced false positive rate for musicians.

In addition, for d′ data, there was a significant main effect of time, $F(5, 130) = 15.736$, $p < .001$, but no significant time × group interaction, $F(5, 130) = 1.205$, $p = .310$. As expected, participants performed worse over time as indicated by a decline in d′ values over the course of the task (Figure 2). This is reflective of a decline in performance, likely resulting from fatigue. In both tasks, there were significant differences in performance between minutes 1 and 6: $t(27) = 4.070$, $p < .001$ for the timing task, $t(27) = 4.474$, $p < .001$ for the visual task. There was no significant task × time interaction, $F(5, 130) = .912$, $p = .475$, nor a significant task × time × group interaction, $F(5, 130) = .412$, $p = .840$. Finally, the linear slopes of each subject were calculated for each task, using the change in d′ from minute to minute. There was no difference between groups in the slopes of either task: $t(26) = .496$, $p = .624$ for timing; $t(26) = .526$, $p = .604$ for visual. Thus, even though time had an effect on each task, there was no difference in the impact of time between the tasks or between the groups. The minute-by-minute data is displayed in Table 3.

To understand and confirm the interactions identified above, an ANOVA of each task was performed separately. An ANOVA on the timing task, using time as a within-subjects variable and group as a between-subjects variable, revealed a significant main effect of time, F(5,

130) = 10.362, $p < .001$, but no significant time × group interaction, $F(5, 130) = .513$, $p = .766$. Similarly, an ANOVA of the visual task, using time as a within-subjects variable and group as a between-subjects variable, also revealed a significant main effect of time, $F(5, 130) = 8.584$, $p < .001$, but again no significant time × group interaction, $F(5, 130) = 1.211$, $p = .308$. These results confirm that there were no differences in the effects of time between the two groups on either task. Thus, while there was a difference in overall performance between the two groups, this was not mediated by an impact of fatigue over time. Rather, the musicians performed better overall on the timing task, but showed similar declines in task performance over time compared to non-musicians.

Discussion

Musicians outperformed non-musicians on a timing-based attentionally demanding task. This is consistent with past research that showed that musicians have improved temporal discrimination (Guclu, Sevinc & Canbeyli, 2011; Rammsayer & Altenmüller, 2006), irrespective of sensory modality (Rammsayer, Buttkus & Altenmüller, 2012). Since musicians are regularly trained in keeping time as they play music, it is logical to find that they have heightened performance on a type of task that directly assesses this trained ability.

Contrary to our hypothesis, there did not seem to be a difference in the slope of performance between the two groups on either task, using both linear slope comparisons and time × group interactions. While there seemed to be a difference in attention itself, with the musicians demonstrating superior performance in the timing discrimination task, there did not seem to be any change in *sustained* attention, per se, because the impact of time was not different between the two groups. Therefore, the data from Experiment 1 do not support the conclusion that musical training is related to improvement in sustained attention.

Thus, in Experiment 1 we show preliminary evidence that musicians may have some advantage in a timing-based attention task, while showing no such advantage in a task of visual discrimination. Furthermore, there were no differences between the groups in the declines over time on either task, as indications of the ability to sustain attention. However, it must be noted that the participants in Experiment 1 were not students actively engaged in studying music. In fact, only two participants reported active and regular participation in musical rehearsal or performance; both performed better than the average musician in terms of overall d′ measurement on both tasks. The rest of the participants only reported *past* musical training, some as distantly removed from formal musical training as eight years. These participants may not display the benefits of music training because of their lack of continued musical involvement. Therefore, the hypothesized effects of musical training on sustained attention may only appear with more specialized musicians, a possibility that is addressed in Experiment 2.

Experiment 2

Method

Participants. Musicians were recruited from the University of Michigan School of Music, Theater and Dance; all participants were studying music in instrumental or vocal performance, with extensive private instruction and regular rehearsal. Control non-music subjects were recruited from the general student population, and were screened to ensure no formal musical training except basic music instruction as part of primary education. Subjects were recruited via email solicitation and flyers, and were offered $10 per hour as compensation for their participation. Again, participants were also screened to ensure normal psychological and physical health, with no history of psychiatric or neurological problems and no use of medications known to affect cognition. All learned English prior to age 6, and all were between the ages of 18 and 25. Unexpectedly, there was a significant difference in age, with the Music group being significantly younger than the Non-Music group, $t(29) = 3.453$, $p < .01$. Demographic information of both groups, including formal musical experience, is displayed in Table 4.

Tasks. The tasks were identical to those in Experiment 1, with a few minor modifications. First, the visual task was adjusted slightly to increase the difficulty: targets were changed from 320 pixels (80% of standard target) to 330 pixels (82.5% of standard target). In addition, the first run of the practice visual task contained a shorter target line (292 pixels or 73% for the standard target), analogous to the easier first practice run in the practice timing task. Finally, subjects were now explicitly instructed to maintain a stable position as much as possible during the experiment. All participants were seated approximately 18 inches from the computer screen. These measures were implemented to help control the visual angle and distance at which participants viewed the tasks.

Procedure. As in Experiment 1, participants completed five runs of each task, with randomized run and task order, as well as a practice set before tasks. Again, all participants were required to receive 100% accuracy in a single practice run of each task before beginning the experiment. In addition, after completion of both tasks, participants completed a series of neuropsychological tests: WAIS-III Digit Span Forward and Backward (Wechsler, 1997) to assess working memory capacity; the Extended Range Vocabulary Test (Educational Testing Services, 1976) to assess crystallized intelligence; Raven’s Advanced Progressive Matrices (Raven, 1990) to assess fluid intelligence; the Need for Cognition Scale (Cacioppo & Petty, 1982) to assess self-reported tendency to engage in and enjoy thinking; and various portions of the Imaginal Processes Inventory (Singer & Antrobus, 1970) to assess self-reported distractability, mind-wandering, and boredom. Participants also completed a Post-Experimental Questionnaire to assess their reactions to the experimental tasks.

Results

As in Experiment 1, a repeated-measures ANOVA was performed with task and time as within-subjects variables and group as a between-subjects variable, using d′ data. This again revealed a significant main effect of task, $F(1, 31) = 18.609$, $p < .001$, driven by better performance on the line task than the timing task, $t(32) = 4.425$, $p < 0.001$, even with the increased difficulty compared to Experiment 1. There was also a significant task × group interaction, $F(1, 31) = 8.506$, $p < .01$. This was driven by a dissociation in performance across the tasks between the two groups (see Table 5). The musicians performed better on the timing task, $t(31) = 3.083$, $p < .01$, while there was no difference on the visual task $t(31) = 1.580$, $p = .124$. This is similar to the trending group difference reported in Experiment 1; however, the musicians now showed a statistically significant advantage in timing task performance relative to the non-musician group.

Again, hit and false alarm rates were examined independently for each task. Unlike Experiment 1, there was a significant difference in hit rate in the timing task, $t(21.129) = 3.164$, $p < .01$, with musicians achieving a higher percentage of hits, but again no difference in the visual task, $t(31) = 1.306$, $p = .201$. The musicians also had a lower false positive rate for the timing task, $t(21.031) = 2.298$, $p < .05$, but not the visual task, $t(31) = 1.116$, $p = .273$. Equal variances were not assumed when Levene’s Test failed to verify this assumption for both the hit and false positive rate for the timing task, and the Welch-Satterthwaite equation was used, which corrects for the inequality of variances. Now, unlike in Experiment 1, when musicians only tended to have a lower false positive rate, the difference in performance on the timing task is driven by both a significantly reduced false positive rate and a significantly improved hit rate for musicians, producing a more robust advantage compared to non-musicians.

In addition, again consistent with Experiment 1, there was a significant main effect of time for d′, $F(5, 155) = 12.140$, $p < .001$, but no significant time × group interaction, $F(5, 155) = .463$, $p = .803$. Data are displayed in Figure 3. In both tasks, there was a significant difference in performance between minutes 1 and 6: $t(32) = 4.119$, $p < .001$ for the timing task, $t(32) = 3.861$, $p < .01$ for the visual task. As in Experiment 1, there was no significant task × time interaction, $F(5, 155) = .970$, $p = .438$, nor a significant task × time × group interaction, $F(5, 155) = .208$, $p = .959$. Finally, there was no difference between groups in the linear slopes of either task: $t(31) = .338$, $p = .738$ for timing; $t(31) = .039$, $p = .969$ for visual. Thus, the findings from Experiment 1 were replicated: the declines over time for both tasks did not differ between groups. Performance on both tasks, as measured by d′ values or linear slopes, did not correlate with age (all $p < .34$), making the difference in age between the two groups likely inconsequential.

An ANOVA was performed on each task separately. An ANOVA on the timing task, using time as a within-subjects variable and group as a between-subjects variable, revealed a significant main effect of time, $F(5, 155) = 5.557$, $p < .001$, but no significant time × group interaction, $F(5, 155) = .204$, $p = .960$. Similarly, an ANOVA of the visual task, using time as a within-subjects variable and group as a between-subjects variable, also revealed a significant main effect of time, $F(5, 155) = 8.321$, $p < .001$, but again no significant time × group interaction, $F(5, 155) = .501$, $p = .775$. As with Experiment 1, these results show no evidence of differences between the groups when examining fatigue due to time.

The Post-Experimental Questionnaire assessed self-reported mind-wandering, concentration, and boredom in each task. Musicians self-reported less boredom than non-musicians during the timing task only, $t(31) = 2.275$, $p < .05$, consistent with their stronger performance on the task. Similarly, musicians also self-reported to have found the visual task harder compared to the timing task more frequently than non-musicians (50% vs. 24%), although this difference did not reach significance, $\chi^2(1) = 1.588$, $p = .21$.

Neuropsychological test data appear in Table 6. Although there were no definitively significant differences between groups on any test, comparisons of performance on the Extended Range Vocabulary Test, $t(31) = 2.042$, $p = .050$, and the Need for Cognition Scale, $t(31) = 1.925$, $p < .063$, trended toward significance. None of the Imaginal Processes Inventory subscales, assessing boredom, mind wandering, and distractibility, correlated significantly with overall performance or linear slope on either task. When using an alternate calculation for these subscales (the Short Imaginal Processes Inventory [SIPI] subscales; Huba, Singer, Aneshensel & Antrobus, 1982) these correlations still did not reach significance. However, Raven’s Advanced Progressive Matrices (APM) did significantly correlate with overall performance on both tasks ($r(30) = .555$, $p = .001$, for timing task; $r(30) = .400$, $p = .023$, for visual task). Note that while these correlations meet the traditional definition of significance, the visual task correlation does not survive the Bonferroni correction for the large number of correlations tested and should thus be interpreted with caution. Future studies can assess these relationships in more detail. All correlations with neuropsychological test data are displayed in Table 7.

In summary, overall, the findings in Experiment 2 closely mirror the results of Experiment 1, with a key difference being the statistically significant performance differences in d′ as well as hits and false alarms between the two groups in the timing task, indicating an advantage of musicians in the temporal domain.

Discussion

As before, musicians outperformed non-musicians in the timing task, even more robustly than in Experiment 1. This difference was more pronounced than previously found in Experiment 1, so it further supports the finding that musicians outperform non-musicians on timing discrimination in an attentionally demanding context. Thus, it seems reasonable to conclude that extensive, formal musical training offers musicians an advantage on a timing-based attention task. Consistent with this conclusion, musicians generally found the timing task to be easier than the visual task, while the opposite was true for non-musicians. Furthermore, non-musicians reported less structured, complex strategy use on the timing task: most reported keeping a simple beat (76%), while others did not report a notable strategy (24%). On the other hand, almost all musicians reported keeping a beat (94%), with 31% of participants reporting mental subdivision of the beat and 38% reporting thinking of a song to keep time. Both of these complex sub-techniques are closely related to musical training.

Furthermore, this relationship between musical training and strategy use may also explain the lower false positive rate in musicians. Generally, when performing in a group, it is very common for musicians to have to wait their turn to play, requiring them to count silently in time before their entrance. This is very similar to the situation during the timing task. When counting in between entrances, it is much more obvious and embarrassing to accidentally play out of turn, rather than to miss an entrance, especially when many musicians share the same part. This trained tendency to remain cautious may translate to the apparent increase in conservatism when performing this type of task, leading to a lower false positive rate.

Surprisingly, the IPI and SIPI scales of mind wandering, boredom, and distractibility did not correlate with the overall performance on either task, considering these traits seem related to attentional abilities. However, performance on Raven’s Advanced Progressive Matrices, a test of fluid intelligence, did correlate with performance on both tasks. This finding is consistent with Engle, Tuholski, Laughlin and Conway (1999), who reported that performance on fluid intelligence tasks is related to attentional abilities.

General Discussion

The findings in the present studies do not support the hypothesis that musical training can improve the ability to sustain attention over time. This is surprising given the previous research on improvements in working memory, since attention is a related process. There could be many explanations for why musicians did not show better sustained attention in this set of experiments. It is possible that the attentional advantages are slight and cannot be measured with such a small sample size. Also, the advantages could manifest with more complex tasks – the tests used in the present experiments were designed to be simple to maximize experimental control, but such simplicity is rarely present in everyday tasks that could benefit from such improvements.

Furthermore, it is reasonable to propose that the benefits in attention would appear in primary-school-age populations. Since the populations studied here were college-age participants attending a competitive institution of higher education, a high degree of academic success throughout primary and secondary education can be assumed, likely meaning a relatively homogenous, high level of attentional abilities in our sample. It is possible that any improvements in attention that were evident at a young age are no longer apparent because the continuous development of these attentional abilities has reached a peak, making these differences indiscernible at this point in their lives. While musical training may have hastened the development of these abilities, the difference may now be negligible.

However, it was found that musicians showed better abilities to detect deviations in timing, translating to stronger performance on a timing-based attention task. This advantage is likely related to their extensive training with rhythm and keeping time. This result is consistent with previous research, as described above. Although timing may appear to be an arbitrary skill compared to visual discrimination, it is an important component of many everyday actions, such as motor control in speech and ambulation (for a review, see Buhusi & Meck, 2005). An advantage in the ability to detect small changes in speech prosody could lead to improved performance on vocabulary and other language skills (for a review, see Moreno, 2009) in children with musical training.

Research investigating the relationship between musical training and cognitive abilities is important for several reasons. First, the neural networks that govern musical thought, expression, and memory have yet to be elucidated. For such a uniquely human ability as music, it is important to examine such systems and their cognitive outcomes. Second, research on the possible cognitive benefits of music is relevant to children, parents, and educators alike. With shrinking budgets, school districts around the country must evaluate the importance of each academic program, with the fine arts often targeted for reduction or removal. Evidence of benefits of musical training on cognitive development, especially in young children, can provide a counterargument for the furloughing of these programs.

In addition, research on music and cognition is relevant for the field of music therapy. Recently, music therapy has developed into a growing interest of the health care community. It has been used in treatment for Parkinson's disease (Hackney, Kantorovich, Levin & Earhart, 2007) and aphasia resulting from stroke (Schlaug, Marchina & Norton, 2008), among other disorders. Because music involves so many areas of the brain, it can often assist patients with small neurological defects or damage because these extensive neural networks can serve as compensatory mechanisms. Musicians have drawn interest as examples of positive aging with sustained cognitive, emotional, and physical abilities (Brodsky, 2011). These areas of research illustrate the connection between music and the brain in aging and pathological circumstances.

Further research is needed to provide more definitive evidence on the relationship between musical training and attention. As described above, the benefits to sustained attention may appear in a younger population, a larger sample, or a different type of task. Presently, however, these findings do provide evidence for the benefit of musical training on temporal discrimination in a demanding timing-based attention task.

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Table 1

Experiment 1 Demographics

Group	Age	Education	Musical Experience
Music (n = 14, 7 female)	18.64 ± 0.17	12.64 ± 0.20	7.36 ± 1.20***
Non-music (n = 14, 6 female)	19.00 ± 0.23	12.57 ± 0.17	0.21 ± 0.21

Note. All data are in years and presented as mean ± SEM. All participants were between 18 and 20 years of age, with between 12 and 14 years of education. There were no significant differences between groups for age ($p > .2$) or education ($p > .7$). ***$p < .001$

Table 2

Experiment 1 Results

Task	Music (n = 14)	Non-Music (n = 14)	TOTAL (*N* = 28)
Timing Task	d': 3.374 ± 0.23	d': 2.861 ± 0.26	d': 3.117 ± 0.17
	Hit: 70.79% ± 5.37%	Hit: 67.81% ± 3.48%	Hit: 69.30% ± 3.16%
	FP: 0.42% ± 0.14%	FP: 1.73% ± 0.61%*	FP: 1.08% ± 0.33%
Visual Task	d': 3.506 ± 0.14	d': 3.706 ± 0.21	d': 3.606 ± 0.12
	Hit: 70.47% ± 4.22%	Hit: 79.29% ± 3.30%	Hit: 74.88% ± 2.76%
	FP: 0.12% ± 0.04%	FP: 0.57% ± 0.35%	FP: 0.34% ± 0.18%

Note. All data are presented as mean ± SEM. "Hit" refers to percentage of correctly identified targets. False positive (FP) refers to percentage of non-target trials that elicited incorrect responses. *$p < .05$

Table 3

Experiment 1 Results, Minute-by-Minute

Minute	Timing Task			Visual Task		
	Music	Non-Music	TOTAL	Music	Non-Music	TOTAL
1	3.94 ± .28	3.26 ± .22	3.60 ± .18	3.93 ± .18	4.07 ± .30	4.00 ± .17
2	3.50 ± .26	3.18 ± .29	3.34 ± .19	3.62 ± .17	3.94 ± .22	3.78 ± .14
3	3.31 ± .27	2.88 ± .25	3.09 ± .19	3.64 ± .18	3.79 ± .26	3.71 ± .15
4	3.67 ± .31	2.94 ± .27	3.30 ± .21	3.58 ± .16	3.66 ± .21	3.62 ± .13
5	3.33 ± .27	2.68 ± .30	3.01 ± .21	3.39 ± .16	3.68 ± .18	3.54 ± .12
6	3.33 ± .22	2.75 ± .24	3.04 ± .17	3.29 ± .15	3.61 ± .23	3.44 ± .14

Note. All data are d′ and presented as mean ± SEM. No significant differences were found between the groups at any minute, although several minutes (Minutes 1, 4 & 5) in the Timing task approached significance ($p < .10$).

Table 4

Experiment 2 Demographics

Group	Age	Education	Musical Experience
Music (n = 16, 12 female)	19.13 ± 0.27**	13.38 ± 0.30*	12.63 ± 0.67***
Non-music (n = 15, 11 female)	20.94 ± 0.44	13.38 ± 0.30	1.41 ± 0.47

Note. All data are in years and presented as mean ± SEM. All participants were between 18 and 25 years of age, with between 12 and 16 years of education. *$p < .05$, **$p < .01$, ***$p < .001$; represents comparison of groups.

Table 5

Experiment 2 Results

Task	Music (n = 16)	Non-Music (n = 17)	TOTAL (*N* = 33)
Timing Task	d': 3.729 ± 0.14	d': 2.933 ± 0.21**	d': 3.319 ± 0.15
	Hit: 82.95% ± 2.03%	Hit: 65.95% ± 4.98%**	Hit: 74.19% ± 3.09%
	FP: 0.36% ± 0.09%	FP: 0.91% ± 0.22%*	FP: 0.65% ± 0.13%
Visual Task	d': 3.890 ± 0.15	d': 3.542 ± 0.16	d': 3.711 ± 0.11
	Hit: 82.15% ± 2.87%	Hit: 75.82% ± 3.86%	Hit: 78.89% ± 2.45%
	FP: 0.19% ± 0.06%	FP: 0.32% ± 0.09%	FP: 0.25% ± 0.06%

Note. All data are presented as mean ± SEM. "Hit" refers to percentage of correctly identified targets. "FP" refers to percentage of non-target trials that elicited incorrect responses. *$p < .05$, **$p < .01$; represents comparison of groups.

Table 6

Experiment 2 Neuropsychological Test Results

Neuropsychological Test	Music (n = 16)[1]	Non-Music (n = 17)[2]
1. Digit Span Forward	10.94 ± 0.47	11.35 ± 0.49
2. Digit Span Backward	7.44 ± 0.63	7.18 ± 0.40
3. Extended Range Vocabulary Test (ERVT)	19.09 ± 1.26	14.98 ± 1.55*
4. Raven's Advanced Progressive Matrices (APM)	17.67 ± 1.08	15.35 ± 0.98
5. Need for Cognition Scale (NCS)	57.34 ± 1.58	52.06 ± 2.21
6. IPI: Mind Wandering	37.00 ± 1.84	39.00 ± 4.79
7. IPI: Boredom	26.43 ± 1.57	30.40 ± 2.29
8. IPI: Distractibility	35.29 ± 1.80	39.80 ± 2.84
9. SIPI: Mind Wandering	15.29 ± 1.00	16.40 ± 2.42
10. SIPI: Boredom	11.86 ± 0.99	13.40 ± 1.36
11. SIPI: Distractibility	16.57 ± 1.06	18.00 ± 1.41

Note. All data are presented as mean ± SEM. *$p = .05$; represents comparison of groups. IPI and SIPI scales are derived from the Imaginal Processes Inventory (IPI).

[1]Music Group had 14 participants complete the IPI and SIPI scales. Music Group had 15 participants complete Raven's Advanced Progressive Matrices.

[2]Non-Music Group had 5 participants complete the IPI and SIPI scales.

Table 7

Experiment 2 Neuropsychological Test Correlation

	DS For	DS Back	ERVT	APM	NCS	IPI: MW	IPI: Bor	IPI: Dist	SIPI: MW	SIPI: Bor	SIPI: Dist
Timing Overall	-.070	.096	.308	.555**	.143	-.159	-.016	-.016	-.073	-.085	.075
Timing Slope[1]	-.279	-.155	.112	-.285	-.084	.028	-.004	-.004	-.047	.013	-.102
Visual Overall	-.203	.122	.141	.400*	.164	-.316	-.031	-.031	-.190	-.253	-.082
Visual Slope[1]	.002	.024	.262	.124	.187	-.165	.157	.157	.095	.041	.254

Note. Pearson Correlations are shown. Tests refer to the measures listed in Table 6. *p < .05, **p < .01

[1]Linear slopes are typically negative to depict declines in performance.

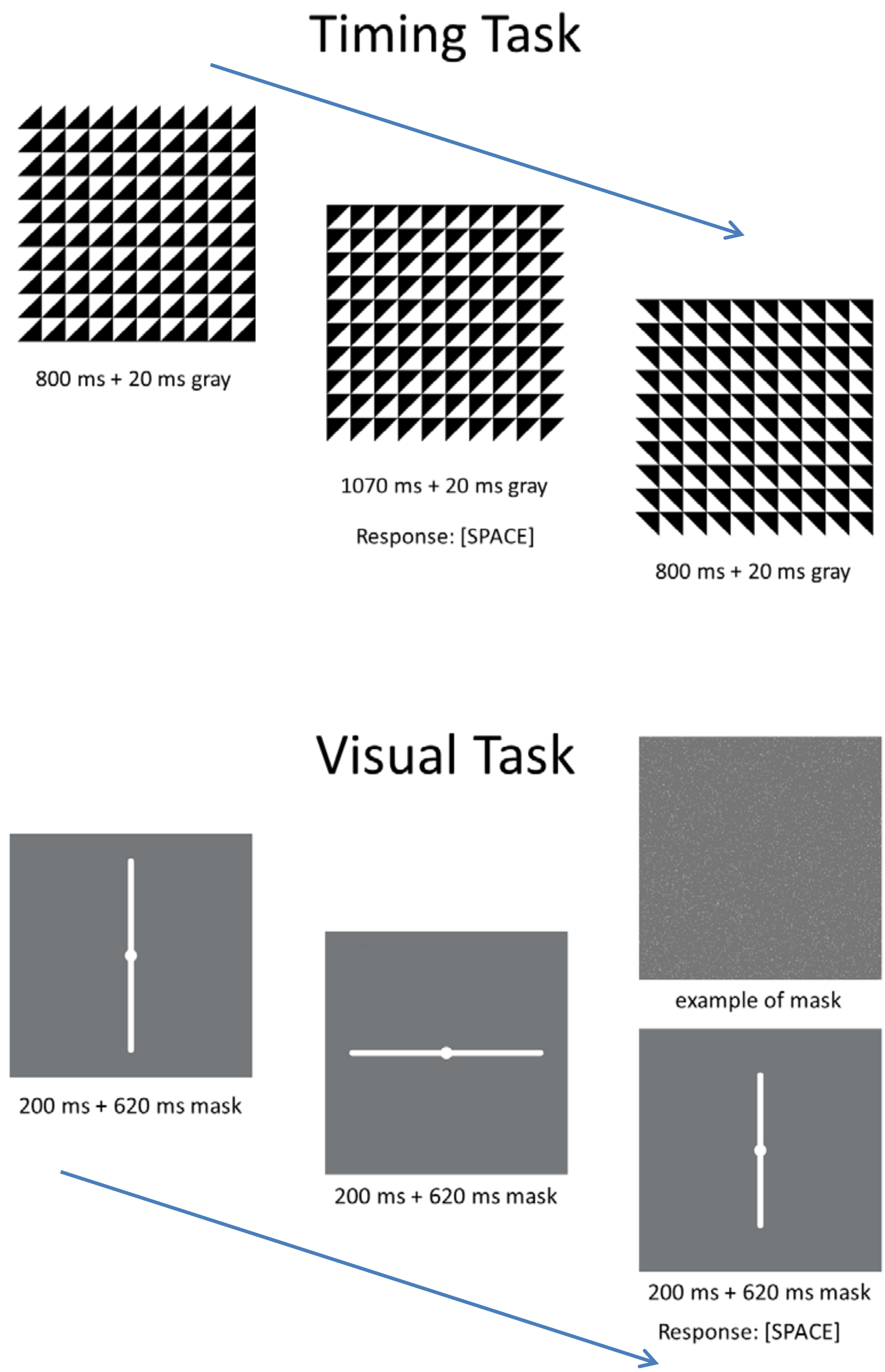
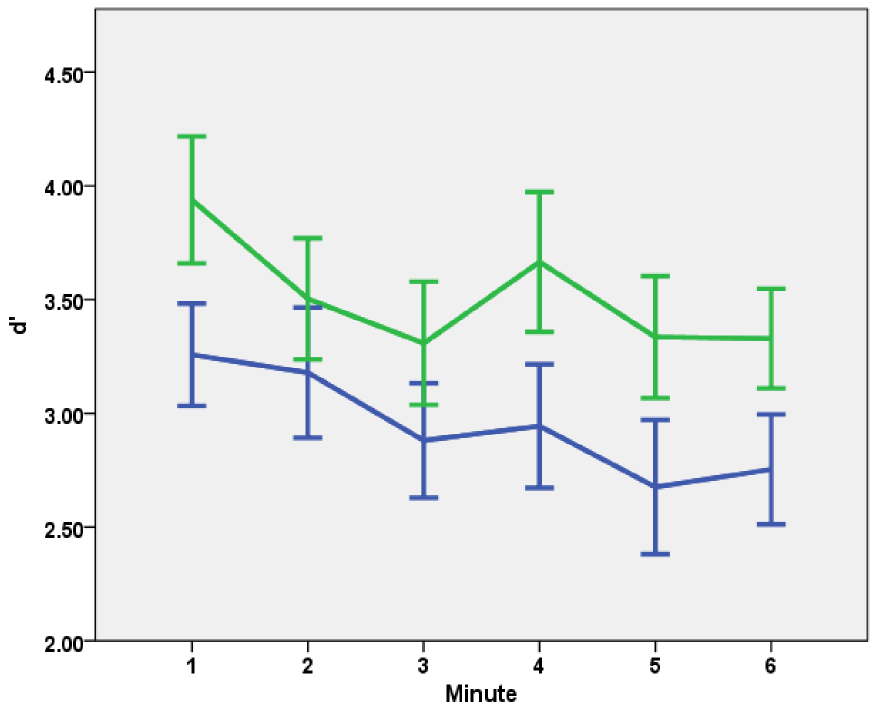
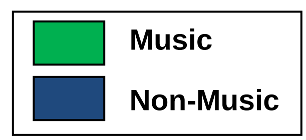


Figure 1. Schematic of tasks. Targets appear 6 times per minute, and each task has five runs of six minutes each.

a) Timing Task





b) Visual Task

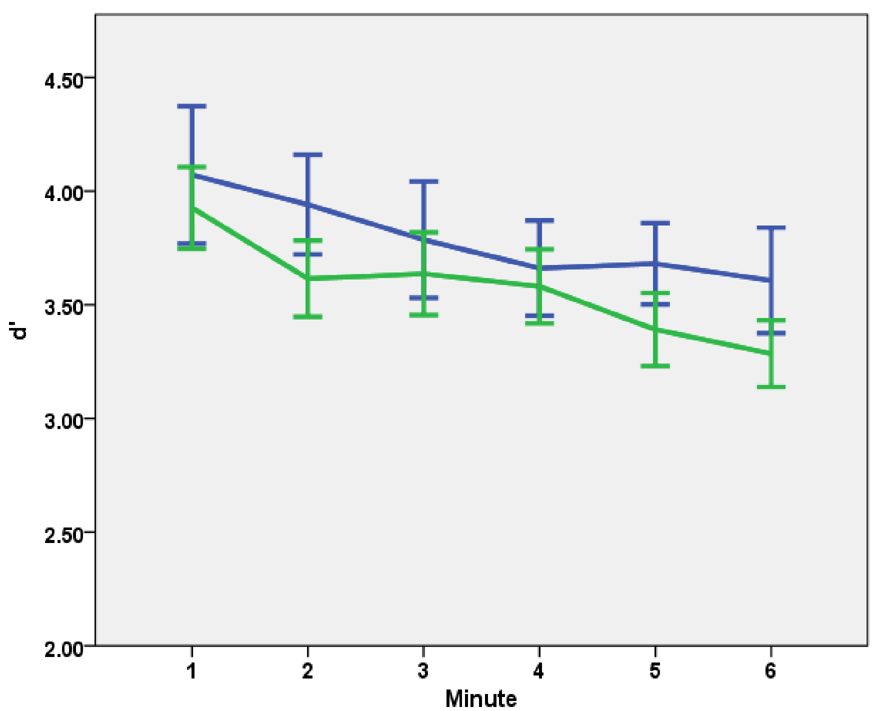


Figure 2. Experiment 1 results. All data are d′ and presented as mean ± SEM. There is a significant decline between Minute 1 and Minute 6, consistent across tasks and groups ($p < .01$).

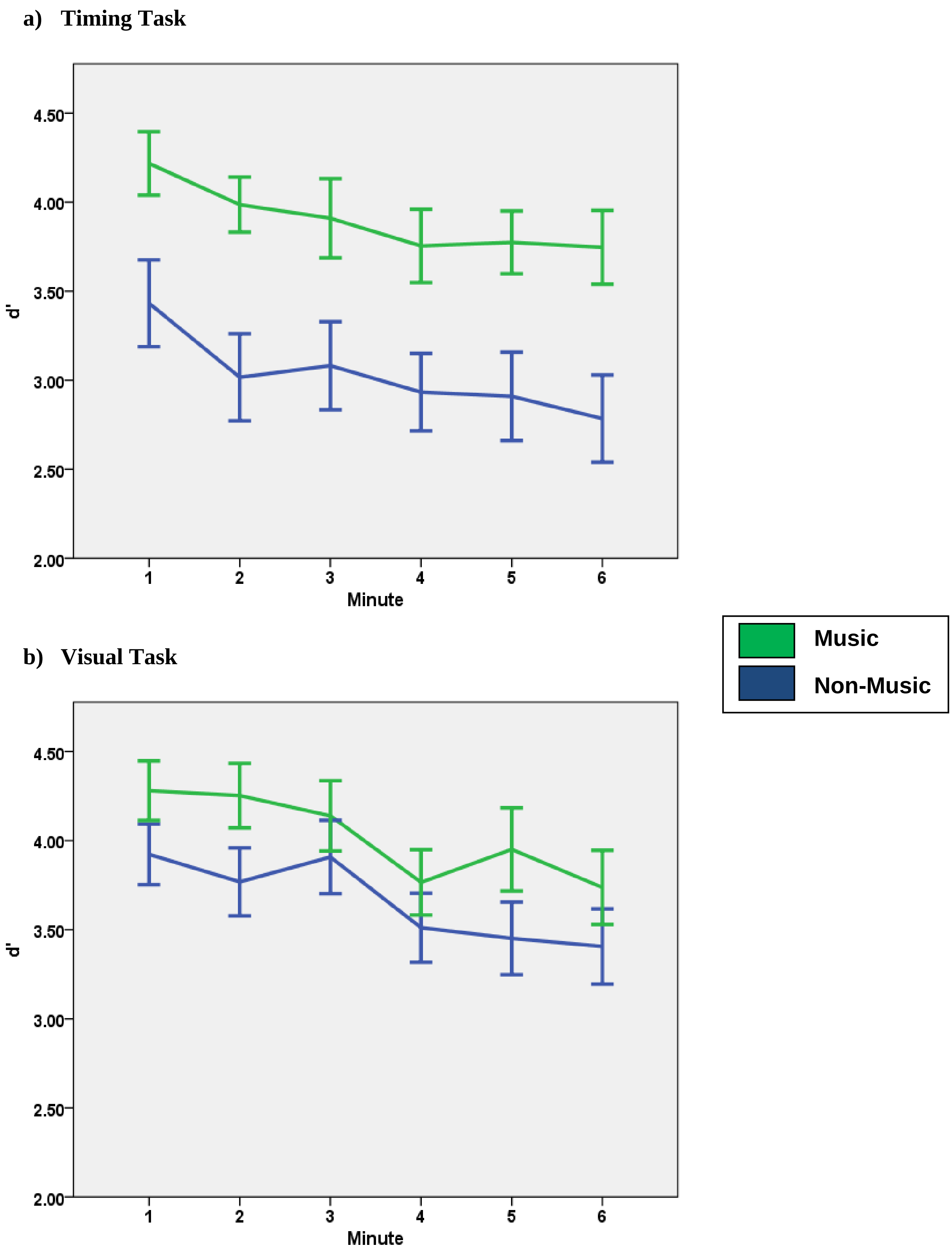


Figure 3. Experiment 2 results. All data are d′ and presented as mean ± SEM. There is a significant decline between Minute 1 and Minute 6, consistent across tasks and groups ($p < .01$).