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The Effect of Music on Attentional Tasks in Mild Cognitive Impairment Patients and Cognitively Normal Older Adults

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An abstract of
A thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
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Abstract

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By Jessica I. Lake

Studies in older adults both with and without dementia have demonstrated short term improvements in cognitive processes, such as memory and attention, elicited by listening to music. These studies have suggested that an increase in arousal modulates this enhancement of performance by altering the attentional capabilities of participants, allowing them to block out distractions. This study aimed to further address this hypothesis by studying the attentional abilities of cognitively normal older adults and mild cognitive impairment (MCI) patients. Studies of music have never included MCI patients, a population with a high conversion rate to an Alzheimer's disease (AD) diagnosis. Participants were exposed to both a music and a no music condition, each lasting ten minutes. After each condition, they performed Digit Span and Coding tasks, requiring attention for maximal performance. Analyses testing the hypothesis that listening to music, compared to a condition of silence, would enhance the performance of both subject groups did not show a significant main effect of music on either task (Digit Span, $p = 0.32$; Coding, $p = 0.78$), suggesting that an alternative mechanism may mediate the enhancing effects of music. Future studies should include larger sample sizes and address issues such as the timing of stimulus presentation, the degree of patient impairment, and the potential influence of anxiety and familiarity of the musical stimulus on performance.

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TABLE OF CONTENTS

INTRODUCTION

Recently, the enhancing effects of music have drawn much attention from those studying both normal and pathological cognitive decline associated with aging. The potential benefits of music have been of particular interest to caregivers and researchers working with dementia populations as a noninvasive technique for improving the quality of life of their patients. Studies examining the enhancing effects of music therapy have reported reduced agitation, enhanced autobiographical memory, and increased social behavior, alertness, and mood (Lord & Garner, 1993; Pollack & Namazi, 1992; Gerdner & Swanson, 1993; Svansdottir & Snaedal, 2006; Ziv, Granot, Hai, Dassa, & Haimov, 2007). While these studies demonstrating the benefits of music over extended periods of time have been informative, they have often relied heavily on observational data and lacked adequate controls.

Studies demonstrating short term improvements in cognitive function under more stringent laboratory-like conditions have also been reported. Huge interest in the positive effects of music first began with the so-called Mozart effect, published in a study by Rauscher, Shaw, and Ky (1993). These investigators demonstrated that college students' performances on spatial IQ tests increased after exposure to a ten minute Mozart piano piece versus ten minutes of a relaxation tape or silence. This study sparked much controversy over whether or not music had the ability to enhance cognitive functioning. Despite subsequent studies which reproduced the Mozart effect (Rauscher, Shaw, & Ky, 1995; Rideout & Laubach, 1996; Rideout & Taylor, 1997), the debate intensified after additional studies failed to replicate these results or demonstrate similar effects on different spatial tasks (Stough, Kerkin, Bates, & Mangan, 1994; Steele, Bass, & Crook, 1999; Steele, Ball, & Runk, 1997).

The theory proposed by the authors of the Mozart effect was that music enhanced performance on spatial rotation tasks by priming the networks in the brain that respond to the temporal and spatial characteristics of objects (Rauscher et al., 1995). However, multiple studies which have reported an enhancing effect of music have provided evidence to suggest that this improvement in performance is not due to any specific property of the music itself but rather, to an increase in arousal and/or mood as elicited by listening to music. The viability of the arousal hypothesis of music was first demonstrated in a study by W. Thompson, Schellenberg, and Husain (2001), where participants either listened to a Mozart sonata which was deemed “pleasant and energetic”, an Albinoni adagio which was sad and slow, or silence. These researchers found a Mozart effect where an increase in spatial abilities was observed after only the Mozart sonata. However, when ratings of arousal, enjoyment and mood were statistically controlled for, the Mozart effect disappeared. Additionally, a study by Roth and Smith (2008) provided further support for the arousal hypothesis by showing that, while exposure to a Mozart sonata improved cognitive performance relative to a silence condition on a language-based analytical task, so too did other auditory stimuli, such as a rhythmical excerpt, melodic excerpt, and traffic sounds. This study suggests that the enhancing effect of cognitive performance is not limited strictly to music but rather, is mediated by changes in arousal levels due to the presentation of any auditory stimulus. Together these studies have provided support for the idea that improvements in cognitive performance after listening to music are mediated by an increase in arousal. It has also been suggested that this increase in arousal enhances the attentional capabilities of participants by allowing them to block out distractions (Ho, Mason, & Spence, 2007) and, thus, perform better on the task.

Other studies in the elderly and those with dementia, specifically with Alzheimer's disease (AD), have also focused on short term improvements in cognitive functioning. Using procedures similar to those reported in the studies of the Mozart effect, these investigations have been successful in demonstrating an enhancing effect of music on both memory and attention. Foster and Valentine (2001) reported an increase in autobiographical memory for dementia patients while listening to a musical piece by Vivaldi. While this study did not directly measure arousal levels, the authors interpreted the findings as evidence for an arousal effect. A subsequent study by Irish et al. (2006) aimed to address this hypothesis more directly by partially replicating the experiment by Foster and Valentine (2001), while also directly examining arousal by measuring the galvanic skin responses (GSRs) of participants, sustained attention via the Sustained Attention to Response Task (SART), and anxiety using the State Trait Anxiety Inventory. GSR and SART analyses did not support the modulation of arousal by music in this study; however, it is possible that these results only apply to music used as background noise, as was the case here, and that having individuals fully attend to music would have altered arousal levels to a greater extent.

The hypothesis that music enhances arousal and that this, in turn, improves cognitive performance through an increase in attention was supported by a study of healthy older adults and AD patients (R. Thompson, Moulin, & Jones, 2005). In this study, it was found that both subject groups performed significantly better on a category fluency test, a task requiring attentional mechanisms, while listening to music than when completing the task without music. The results of this study were extended by Mammarella, Fairfield, and Cornoldi (2007). Using a similar experimental procedure, these investigators found that listening to music significantly increased performance on working memory tasks requiring focused attention, such as forward digit span and phonemic fluency in healthy elderly adults. Together, these findings suggest that music may function to reduce distraction and focus attention on an experimental task.

It should be noted, however, that the Mozart effect, as originally proposed, was defined as a temporary enhancement of cognitive performance *after* listening to music. Therefore, demonstrating a cognitive improvement following a music condition, rather than during the presentation of music, would more directly support the arousal hypothesis. Nevertheless, the results of these studies are relevant in better understanding the influence of music on cognitive function, as well as the processes of normal and pathological cognitive decline more generally. The theory that music may influence attentional capabilities is particularly relevant, as recent AD research has emphasized the prevalence of attentional deficits in patients with the disease.

While the main initial sign of AD is a decline in episodic memory, recent studies have shown that attentional abilities also become impaired early in the disease progression (e.g., Baddeley, Baddeley, Bucks & Wilcock, 2001; Belleville, Peretz, & Malenfant, 1996). Study of these functions is therefore important in furthering knowledge of the cognitive decline process. In fact, research on the preclinical stages of AD, most commonly referred to as mild cognitive impairment (MCI), has shown that deficits in attentional abilities may appear before a diagnosis of AD has even been reached

(Belleville, Chertkow, & Gauthier, 2007; Silveri, Reali, Jenner, & Puopolo, 2007; Traykov et al., 2007).

While MCI patients are a somewhat heterogeneous population, with some of these patients developing alternative types of dementia, such as frontotemporal dementia (Whitwell et al., 2007), extensive research has established MCI as a valid concept to characterize a group of patients in a transitional stage between normal aging and dementia who are still capable of everyday functioning (Belleville et al., 2007). Work by Petersen et al. (2001, 2003) following the progression of MCI patients over a period of six years has shown that up to 80% advanced to a diagnosis of AD, with an annual rate of conversion approximately ten times that observed for a normal elderly population (Gauthier et al 2006). Multiple studies have suggested that progression towards AD includes a decline in attentional abilities (Belleville et al., 2007; Silveri et al., 2007; Traykov et al., 2007). It has even been suggested that AD may be caused by a decline in attentional functioning, which increases in severity over time, but is first manifested as an episodic memory deficit (Silveri et al. 2007). It is clear that a better understanding of the control of attentional abilities in MCI patients is crucial to further advancing the distinction between cognitive decline associated with AD and normal aging.

Studies demonstrating the positive effects of music on cognitive performance in the elderly have thus far never included MCI patients. As discussed above, the arousal hypothesis remains the dominant theory to explain the enhancement in performance due to music, likely mediated by increased attention to the task to be performed. As MCI patients exhibit deficits in attentional processes, a comparison between this population and a cognitively normal elderly population might help further our understanding of MCI and its deviation from the progression of normal aging, as well as its relationship to AD. A stronger appreciation for the differences between these groups is crucial in efforts to attenuate the cognitive decline associated with AD.

The purpose of this study was to investigate the effect of music on attentional tasks in both MCI patients and cognitively normal older adults. Performance on the tasks selected was previously shown to be impaired in MCI patients and very early AD (Goldman, Baty, Buckles, Sahrmann, & Morris, 1999; Flicker, Ferris, & Reisberg, 1991). Based on prior studies, it was hypothesized that listening to music would improve performance on these cognitive tasks for both groups. The attentional tests were administered after the experimental manipulation (music or silence) so that participants would directly attend to the music. It was anticipated that this design would more directly address the arousal hypothesis and demonstrate its potential for explaining the temporary improvement in cognitive functioning that immediately follows music listening.

METHODS

Subjects

Study participants were recruited from the Memory Assessment Clinics of the Wesley Woods Center on Aging and from the Emory Alzheimer's Disease Research Center. The study was approved by the Emory University Institutional Review Board, and signed informed consent was obtained from all participants and their representatives. Uniform evaluations included screening for other types of dementia and coexisting conditions that could affect cognition. Participants did not have histories or findings suggestive of stroke, as determined by a review of their medical records and a neurologic exam.

The final sample included 10 patients (mean age=74.7 years, SD=7.6; mean education=15.2, SD=1.8 years; 3 females and 7 males) who were diagnosed with amnestic MCI by experienced neurologists using the criteria of Petersen et al. (2001), including a subjective cognitive complaint (corroborated by an informant), cognitive impairment in memory (> -1.5 SDs below the performance of age and education controls), normal general cognitive functioning, and preserved instrumental activities of daily living. Nine cognitively intact community residing volunteers were recruited as a comparison group (mean age=65.4 years, SD=10.8; mean education=16.1, SD=2.0; 5 females and 4 males). Exclusion criteria for both the MCI and the control subjects were a pre-existing neurological disorder associated with cerebral dysfunction and/or cognitive deficit, pre-existing alcohol or drug abuse, severe psychiatric disorder (e.g., schizophrenia) and mood disorder (e.g., major depression). There were no significant differences in education, or the distribution of gender (p>.05) between patient and control groups. However, there was a significant difference in age (p = 0.04), with the MCI patients older than the controls.

Design

This study used a repeated-measures design with subject group (MCI versus cognitively normal older controls) as the between subject variable and music condition (music versus no music) as the within subject variable. Subjects participated in two trial conditions of attentional tests (Digit Span and Coding). These tests were administered after a 10-minute period listening to music and after a 10-minute period of silence.

Attentional Tests

Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, 1998). The RBANS was used for this study as it contains multiple equivalent versions (A and B) and would therefore control for content practice effects. The different test versions were counterbalanced between the two experimental conditions.

Attention Index. Digit Span and Coding are the two subcomponents of the Attention Index of the RBANS. Digit Span requires participants to repeat, in the same order, a string of numbers read to them which is increased by one digit for each successful trial. The test is terminated when a participant either fails to reproduce the correct sequence for two consecutive strings with the same number of digits or the final nine-digit number sequence is successfully reproduced. Participants receive two points for each successful digit sequence reproduction if correct on the first attempt or one point if correct on the second attempt. Successful reproduction of all digit sequences results in a score of 16.

In the Coding task, participants are given a key in which simple, unique geometric shapes are each paired with a digit ranging from 1-9. Below the key, the same geometric symbols are presented in a random order with empty boxes underneath each symbol. Participants are required to rapidly fill in as many of the boxes as they can in 90 seconds with the digits corresponding to each unique geometric shape, without skipping any. The score is reported as the number of correctly reproduced pairings.

Measure of Overall Cognitive Status

Mattis Dementia Rating Scale (*DRS; Mattis, Jurica, & Leitten, 2002).* The DRS is commonly used to measure the cognitive status of older adults. Subscales examine attention (e.g., counting targets in an array of distractors), memory (orientation, recall/recognition of sentences, words, and drawings), initiation and maintenance of verbal and motor responses (e.g., grocery store list generation, alternating hand movements), conceptualization (similarities/differences), and construction (design copying). Individual points are assigned to the subscales, with higher points indicating better performance.

In the current study, patients were administered the DRS between the two experimental conditions. The first component of the attentional subscale of the DRS contains a Digit Span task, which was also used as one of the outcome measures of the experimental conditions. Therefore, this component was not administered as part of the DRS.

Musical Stimulus

The musical piece selected was the "Spring" movement of *Four Seasons* by Vivaldi. This piece was selected as previous studies have demonstrated its enhancing effect on cognitive performance (Foster and Valentine, 1999, 2001; Irish et al., 2006; R. Thompson et al, 2007).

Study Procedure

Music was played for participants via headphones connected to a computer. Volume was adjusted for comfort. After each condition (music and silence), subjects completed the Attentional Index of the RBANS, consisting of the Digit Span and Coding subtests. The order in which the participants were presented with each condition (music or silence) was counterbalanced. An assistant began and ended the experimental conditions while the experimenter waited outside the testing room so that the experimenter would be blind to which condition the participant had been exposed.

The DRS was administered between the two trial conditions as a battery of cognitively demanding tasks to reduce practice effects and further assess cognitive performance. After the completion of the second trial condition, all participants were given a brief questionnaire assessing their past and present level of musical experience and exposure. Participants were then debriefed as to the study purpose. The entire procedure took approximately sixty minutes.

RESULTS

Analyses were performed to test the hypothesis that listening to music, compared to a condition of silence, would enhance the cognitive performance of both MCI patients and controls on two attentional measures, Digit Span and Coding (see Table 1). The results of these analyses are reported below.

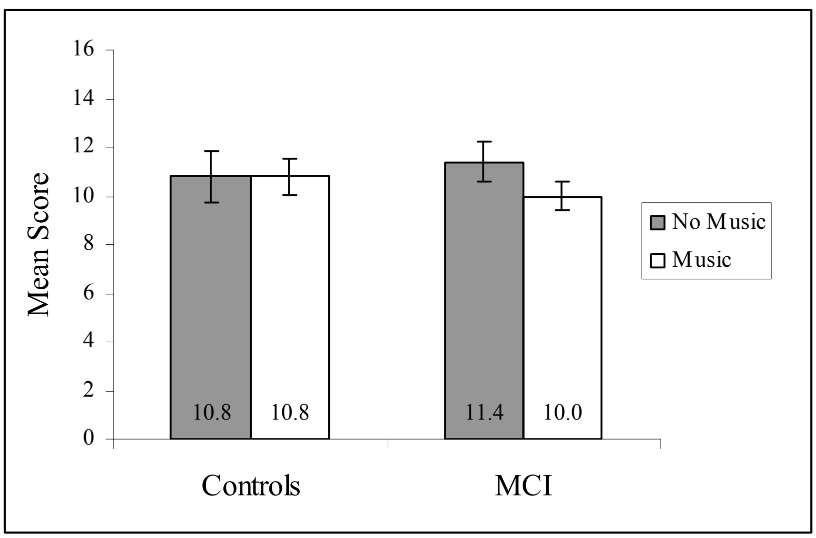
Table 1. Individual Participant Digit Span and Coding Scores with Demographics

		Digit Span		***Coding***						
Subject	**Group**	**No Music**	**Music**	**No Music**	**Music**	**Age**	**Years of Educ.**	**Sex**	**Music Order (0 = M,NoM)**	**Test Order (0= AB)**
C01	Control	10	10	35	35	84	12	M	1	1
C02	Control	8	12	42	39	65	17	F	1	0
C03	Control	8	12	49	51	56	18	F	0	0
C04	Control	7	7	59	56	57	16	F	1	1
C05	Control	15	10	50	58	57	17	F	0	0
C06	Control	10	14	47	47	60	17	M	1	0
C07	Control	11	13	42	45	66	16	F	1	1
C08	Control	12	9	39	48	61	18	M	1	1
C09	Control	16	10	35	37	83	14	M	0	1
M01	MCI	10	10	35	30	69	12	F	1	0
M02	MCI	11	7	22	19	81	18	M	0	0
M03	MCI	14	12	37	36	66	16	M	0	0
M04	MCI	16	12	22	23	80	14	M	1	0
M05	MCI	10	8	30	21	80	14	M	0	1
M06	MCI	11	10	33	32	62	15	F	1	1
M07	MCI	15	13	44	46	70	16	F	1	1
M08	MCI	10	10	25	25	86	17	M	1	1
M09	MCI	8	8	33	36	76	16	M	0	1
M10	MCI	9	10	33	31	77	14	M	1	1

Digit Span

Figure 1 shows the performances of the Controls versus the MCI patients on the Digit Span task. A repeated-measures analysis of variance on the maximum number of points received, with subject group (Control versus MCI) as the between-subject factor and condition (Music versus Silence) as the within subject factor, showed no significant main effect for group, [F(1,17) = 0.01, p = 0.93]. MCI patients' overall performance was comparable to that of the Controls (means = 10.7 and 10.8, respectively). Additionally, there was no significant main effect of experimental condition (Music versus Silence) on performance [F(1,17) = 1.06, p = 0.32], (means= 10.4 and 11.1 respectively). Finally, a lack of evidence for a significant interaction was observed between subject group and condition [F(1,17) = 1.06, p = 0.32].

Figure 1. Means of Digit Span Performance for Controls and MCI Patients



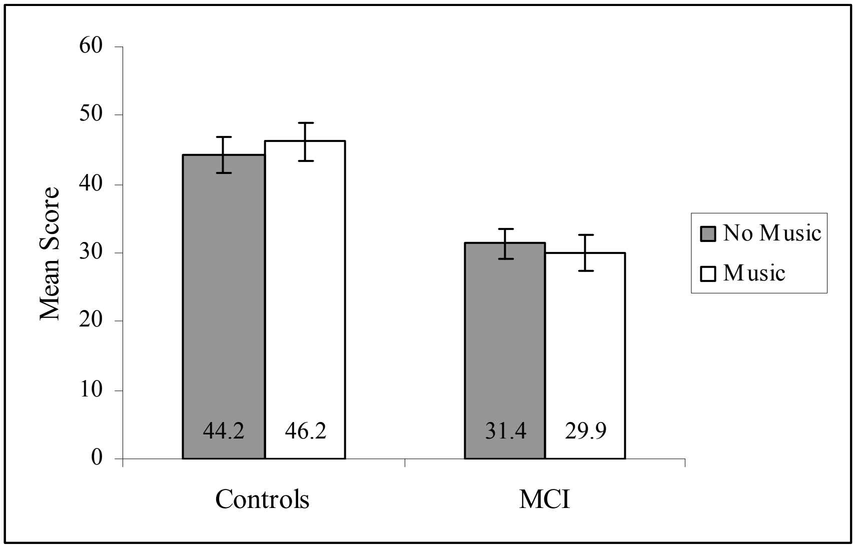
Interestingly, the data suggest that for MCI patients, the music condition may have negatively impacted performance. A post hoc paired t-test analysis for Digit Span showed a significant effect of condition on the performance of MCI patients (t = 2.9, df = 9, p = 0.03), with performance after listening to music significantly lower (mean = 10.0) than after the silence condition (mean = 11.4). Due to the low sample size, a Wilcoxon signed rank test was performed to determine whether the findings of the paired t-test analyses would be replicated. Using this nonparametric test, a significant effect of condition on Digit Span was still observed for MCI patients ($p = 0.03$).

No significant main effects of music order (music then no music versus no music then music) were found for Digit Span in either controls or MCI patients [controls: $F(1, 7) = 1.59$, $p = 0.25$; MCI: $F(1,8) = 1.32$, $p = 0.26$]. Similarly, no main effects of test order (version A then B versus version B then A) were observed in either subject group [controls: $F(1,7) = .23$, $p = 0.64$; MCI: $F(1,8) = .89$, $p = 0.37$]. Lastly, a paired t-test showed no evidence of a practice effect ($p > 0.2$), suggesting that performance on the first trial did not differ significantly from performance on the second.

Coding

Figure 2 shows the performance of the Controls versus the MCI patients on the Coding task. A repeated-measures analysis of variance on the number of correctly transcribed symbols, with subject group (Control versus MCI) as the between-subject factor and condition (Music versus Silence) as the within subject factor, showed a significant main effect for subject group [$F(1, 17) = 17.76$, $p = 0.001$]. Control participants significantly outperformed MCI patients on this task (means = 45.2 and 30.7, respectively). No significant main effect of experimental condition (Music versus Silence) on performance [$F(1,17) = 0.08$ $p = 0.78$] was observed (means = 37.6 and 37.5, respectively). A trend towards significance in the interaction between subject group and condition was observed [$F(1,17) = 3.846$, $p = 0.07$].

Figure 2. Means of Coding Performance for Controls and MCI Patients



A post hoc paired t-test analysis for Coding showed that the effect of condition on the performance of MCI patients was not significant (t = 1.3, df = 9, p = 0.2). However, MCI mean performance based on condition was in the same direction of that reported in the Digit Span task. The Wilcoxon signed rank test also did not show a significant effect of condition on performance in MCI patients (p=0.26)

No significant main effects of music order (music then no music versus no music then music) were found for Coding in either controls or MCI patients [controls: F(1,7) = 0.14, p = 0.72; MCI: F(1,8) = 0.22, p = 0.65]. Similarly, no main effects of test order (version A then B versus version B then A) were observed in either subject group [controls: F(1,7) = 0.84, p = 0.39; MCI: F(1,8) = .84, p = 0.39]. Lastly, a paired t-test showed no evidence of practice effect (p > 0.9), suggesting that performance on the first trial did not differ significantly from performance on the second.

Repeated Measures ANCOVA

Due to the significant difference in age between the Controls and the MCI patients, the above analyses for Digit Span and Coding were repeated, with age used as a covariate. A repeated measures analysis of covariance (ANCOVA) showed that controlling for age did not result in a significant interaction between music condition and subject group for either Digit Span ($p=0.3$) or Coding ($p=0.6$).

Qualitative Analysis

The data were examined qualitatively to examine whether there was any improvement, regardless of the magnitude of the change, in the performance on the Digit Span and the Coding Tasks for the patients and the controls in the Music versus Silence conditions. This analysis showed that only one MCI patient performed better on Digit Span and only three patients performed better on Coding after listening to music. In addition, only three controls performed better on Digit Span and only five performed better on Coding in the music condition. Thus, a consistent trend towards a benefit of music on cognitive performance was not observed for either group.

DRS

Table 2 shows the mean total score on the DRS, as well as the individual subscale scores for MCI patients and Controls. A main effect of subject group was observed for the mean total DRS score [$F(1,16) = 16.5$, $p = 0.0009$] with controls outperforming MCI patients. Performance of controls on the Memory subscale of the DRS was significantly higher than that of MCI patients [$F(1,16) = 9.4$, $p = 0.01$]. A trend towards significance was found for the Attention subscale [F(1,16) = 3.5, p = 0.08] with performance of controls higher than that of the MCI patients. No significant differences between subject groups were observed for the other subcomponents of the DRS (p > 0.1). These results suggest that the MCI sample was an amnestic group characterized by poor memory with relative preservation of other cognitive domains.

Table 2. Means (SDs) on the Mattis Dementia Rating Scale for Normal Controls and MCI Patients

	Controls	**MCI**	**P-Value**
Total Score (out of 126)*+	122.3 (3.2)	113.0 (6.1)	0.0009
Attention (out of 19)+	18.8 (0.4)	17.7 (1.7)	0.08
Initiation/Perseveration (out of 37)	35.9 (2.6)	34.0 (3.2)	0.2
Conceptualization (out of 39)	38.2 (1.4)	40.6 (10.8)	0.5
Construction (out of 6)	5.8 (0.7)	5.6 (1.0)	0.7
Memory (out of 25)*	24.0 (1.0)	20.0 (3.8)	0.007

+ The digit span test items were not administered. Thus, the Total Score and the Attention Subscale score are prorated.

* Significant p-value.

Musical Background and Listening Habits

Chi-Square analyses were employed to determine whether the two subject groups differed in their musical backgrounds or weekly listening habits as determined by self reported answers on a brief questionnaire at the conclusion of the experiment (see Tables 3, 4, & 5). As shown below, there were no significant differences between the groups.

Table 3. Percentages for Music Questionnaire Responses for Controls and MCI Patients

	Controls	**MCI**	**P-Value**
Currently Involved in Music	33%	20%	0 .63
Ever Taken Music Lessons	22%	20%	0.99
Listen to Classical Music	78%	80%	0.99
Enjoyed Music Played	100%	70%	0.21

Table 4. Years of Current Music Activity for Controls and MCI Patients (p= 0.99)

	0 Yrs	**1-5 Yrs**	**6-10 Yrs**	**11-15 Yrs**	**16+ Yrs**
Controls	6	1	0	0	2
MCI	8	0	0	0	2

Table 5. Hours of Listening to Music per Week for Controls and MCI Patients (p= 0.36)

	0 Hrs	**1-5 Hrs**	**6-10 Hrs**	**11-15 Hrs**	**16+ Hrs**
Controls	0	4	4	1	0
MCI	1	6	3	0	0

DISCUSSION

Arousal evoked by music has been hypothesized to improve cognitive performance via an increase in attention to task. The results of the current study failed to support the arousal hypothesis, as an enhancing effect of music on the performance of both cognitively normal older controls and MCI patients on attentional tasks was not observed. These findings are noteworthy in light of recent studies which have suggested an improvement on different measures of attention as a result of listening to music (Ho et al., 2007; R. Thompson et al., 2005; Mammarella et al. 2007).

The small sample size of this study necessitates that the negative results be interpreted with caution. However, a qualitative analysis of the pattern of the data suggests that small sample sizes alone do not explain why a significant statistical improvement was not obtained in the music condition, as a consistent trend towards a benefit of music on cognitive performance was not observed. Interestingly, the data suggest that, at least for MCI patients, the music condition may have negatively impacted performance, as suggested by a post hoc paired t test on Digit Span scores. The mean difference score for MCI patients for Coding was also in this direction. Thus, a larger sample size might indicate whether or not these qualitative analyses represent true effects.

A key difference between this study and those which have supported the arousal hypothesis of music in older adults was the timing of the stimulus presentation. In Mammarella et al. (2007) and R. Thompson et al. (2005), music was played during task performance, while in the current study, music was played prior to the assessment of attentional abilities. The Mozart effect, as originally defined, was described as an enhancement of cognitive functioning *after* listening to music (Rauscher et al., 1993) and therefore the current study replicated this methodology. While playing music as background noise may facilitate performance on attentional tasks, playing music prior to testing may not have the same effect. The results of the current study suggest that the beneficial effects of music might not carry over beyond the stimulus presentation.

It has been suggested that the improvement in performance when music is played concurrently with cognitive assessment is due to reduced distraction, allowing more attention to be focused on the task (Foster & Valentine, 2001). If this theory is accurate, it could account for the lack of improvement observed after the musical stimulus in this experiment. A study by Janata, Tillmann, and Bharucha (2002) found that passively listening to music activates domain-general attention and working memory areas of the brain, including the superior temporal gyrus, intraparietal sulcus, and multiple frontal areas, such as the precentral sulcus, inferior frontal sulcus and frontal operculum. This may help explain why cognitive task performance was enhanced in previous studies of attention and music. When the music is turned off, we can assume that these neural activations are also terminated, thus explaining why the enhancement of music is only observed during the concurrent presentation of music and cognitive tasks and not when cognitive tasks are administered after the musical selection. Future neuroimaging studies might analyze the differences in neural activations during task performance both with and without music. Analyzing activations during task performance with less complex auditory stimuli should also be examined, as a recent study showed that auditory stimuli besides music may also improve cognitive abilities (Roth & Smith, 2008). Correlating these activations with performance could further knowledge of the mechanisms through which auditory stimuli might enhance cognitive performance. Additionally, it might be useful to replicate the current study while manipulating when music is presented to further analyze this issue.

Proponents of the arousal hypothesis have argued that arousal mediates increased cognitive performance by enhancing attention and allowing participants to focus more on the cognitive task. While the designs of previous studies, which have played music at the same time as cognitive testing, have supported the arousal hypothesis, they do not provide an accurate construct for testing the plausibility of this theory as an explanation for the Mozart effect, which is defined as an improvement in cognitive performance *immediately following* the presentation of a music stimulus. While direct measures of arousal were not recorded in this study, the finding that performance on attentional tasks did not increase after music listening seems to suggest that arousal may not be the mechanism through which performance is enhanced. The present study suggests that attention may not be the mediating factor of enhanced performance and that the arousal hypothesis may be as unreliable as the Mozart effect itself has proved to be. Interestingly, only one study aimed at testing the arousal hypothesis as an explanation for the Mozart effect (Irish et al., 2006) directly measured arousal using galvanic skin responses. This study failed to demonstrate a significant difference in arousal levels between the music and silence conditions, further casting doubt on the plausibility of this theory.

Other theories of mechanisms which might enhance cognitive performance following music exposure exist. For example, Irish et al. (2006) found that a reduction in anxiety in the music condition, suggesting that modulation of anxiety might be related to improving cognitive abilities. Additionally, a study by Jefferies, Smilek, Eich, and Enns (2008) found that emotional valence and arousal interact in enhancing attentional control, suggesting that arousal alone may not be sufficient to explain the enhancing effect of music. Future studies should continue to utilize objective measures of arousal, such as galvanic skin responses recordings, and consider additional factors, such as mood and anxiety, to further explore these issues.

It is important to note that numerous studies have reportedly found a beneficial effect of music presented prior to the administration of various cognitive tasks, including those measuring spatial abilities (Rauscher et al. 1993, 1995) and language-based analytical skills (Roth & Smith, 2008). None of these studies, however, have included attentional tasks. This might simply indicate that music has unique effects on different cognitive tasks and, therefore, studying the effect of music on cognitive performance in general and comparing results across different cognitive measures may not be an accurate construct. It may be necessary to study the effects of music using a task-specific approach.

It is believed that the experimental design in the current study may have more accurately portrayed performance patterns than previous studies. Playing music before testing cognitive performance provided a unique advantage in that it enabled the experimenter to leave the room while a study assistant administered the testing conditions. In this way, the experimenter remained blind to whether or not participants had been exposed to music. To our knowledge, no previous study examining the short-term effect of music on cognitive performance has utilized a blind design. This strategy eliminated the possibility of experimenter expectancy influencing the administration of the cognitive tasks. Thus, it is felt that the current results depict participants' performances in a less biased manner than previous experiments.

The nature of the study sample may be another factor that could explain the lack of improvement in attention observed after the music condition in this study. The results indicate that, although the MCI sample demonstrated significant impairments in memory, they did not, as a group, demonstrate significant impairments in attention on two of the three indices of attention measured in this study (Digit Span and the Attention subscale of the DRS), suggesting that attentional deficits in this group were minimal. The third measure of attention, Coding, analyzed in this study has a speeded component which may have led this test to be more sensitive to attentional deficits. Using this information, we might conclude that subjects in each group (MCI patients and controls) were performing at their individual optimal level of attention in the no music condition and, therefore, little improvement was possible during the music condition. Future studies might address this issue by enrolling MCI patients specifically with executive function and attentional deficits. As AD patients are also known to exhibit attentional deficits, often to a more severe degree than MCI patients, their inclusion in such a study might provide valuable comparisons.

Lastly, another factor that might be relevant in this analysis is the familiarity of participants with the musical stimulus. The same musical selection was used in the present study as in Mammarella et al. (2007), which reported an enhancing effect of music on the performance of healthy elderly adults on attentional tasks, including Digit Span. The authors of that study, however, noted that as all the participants in the former study were Italian, it was expected that they would recognize this tune by a famous

Italian composer. A study by Foster and Valentine (1998) did not find any differences in performance while using familiar versus novel music. However, that study played music concurrently with test administration; therefore, participants were not directing attending to the music. Examining whether or not familiarity is relevant to performance when music is played before cognitive testing still requires further analysis.

In conclusion, this study failed to reproduce previous findings supporting the arousal hypothesis for an increase in cognitive performance on attentional tasks after listening to music. Several factors could potentially have resulted in these negative findings. Future research is necessary to further understand the effect of music on attentional processes and how these attentional processes can be modulated in older adults.

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