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Research Article

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Turn Off the Music! Music Impairs Visual Associative Memory Performance in Older Adults

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Purpose of the Study: Whether we are explicitly listening to it or not, music is prevalent in our environment. Surprisingly, little is known about the effect of environmental music on concurrent cognitive functioning and whether young and older adults are differentially affected by music. Here, we investigated the impact of background music on a concurrent paired associate learning task in healthy young and older adults.
Design and Methods: Young and older adults listened to music or to silence while simultaneously studying face–name pairs. Participants' memory for the pairs was then tested while listening to either the same or different music. Participants also made subjective ratings about how distracting they found each song to be.
Results: Despite the fact that all participants rated music as more distracting to their performance than silence, only older adults' associative memory performance was impaired by music. These results are most consistent with the theory that older adults' failure to inhibit processing of distracting task-irrelevant information, in this case background music, contributes to their memory impairments.
Implications: These data have important practical implications for older adults' ability to perform cognitively demanding tasks even in what many consider to be an unobtrusive environment.

Key words: Music, Memory, Cognition, Psychology of aging/psychiatry

Music is ubiquitous in our daily lives. We listen to music voluntarily when we are driving, studying, or working and often involuntarily when we go about our days. It is surprisingly unclear whether background music impacts our performance on the kinds of complex tasks that we perform in its presence. Investigating the impact of background music on cognition in an aging population may be particularly relevant when considering the expanding growth of the aging workforce. The U.S. Census Bureau suggests that by 2016, adults aged 50 and older will comprise one third of the total U.S. workforce (Mowbray, 2013). Many of these older adults may find themselves as employees in workplaces playing background music (any retail business, for example). Of course, experiencing background music isn't limited to the aging workforce; retired older adults are also subjected to background music while completing various errands like shopping or dining out. Here, we aimed to determine whether background music has an effect on associative memory performance and whether aging modulates this relationship.

There has been a great deal of interest in the possibility that music facilitates cognition, including memory. For example, there is some evidence that listening to background classical music while performing a category fluency task enhances performance in both healthy older adults and Alzheimer's disease patients (Thompson, Moulin, Hayre, & Jones, 2005). One of the most well known studies showing that listening to music improves cognition reported the so-called "Mozart Effect" (Rauscher, Shaw, & Ky, 1993). Rauscher and colleagues found that when college student participants listened to Mozart's "Sonata for two Pianos" in D major immediately prior to performing a spatial reasoning task from the Stanford-Binet Intelligence test, their scores increased above those of students who listened to silence. Despite the improvement, the gains were short lived, lasting only until the participants completed the spatial reasoning task, approximately 10–15 min, and specific to one spatial task: paper folding and cutting. A meta-analysis of studies investigating the "Mozart Effect" sheds doubt on the consistency and robustness of the effect when observed (Chabris, 1999).

There are two, non-mutually exclusive hypotheses regarding the mechanisms underlying the benefit of music on cognition. One hypothesis in the field of music research suggests that listening to music increases physical arousal and attention, thereby improving cognition. For example, arousing positively valent music from multiple genres (jazz, classical, etc.) played between study and test of abstract images produces greater memory accuracy than does non-arousing music in young adults (Greene, Bahri, & Soto, 2010). Another, non-mutually exclusive hypothesis that may explain the effect of music on cognition is grounded in the encoding specificity principle (Tulving & Thomson, 1973). The principle states that our ability to remember an event depends on the overlap between the way the stimulus is processed at study and the way it is processed at test. For example, cued recall in a verbal paired-associates task is better when the same piece of background music is played during study and test compared to when different pieces, even within the same genre (classical), were played during study and test (Standing, Bobbitt, Boisvert, Dayholos, & Gagnon, 2008). Thus, like other contextual features, music may facilitate memory performance if repeated between study and test.

While previous studies have sometimes found a benefit for playing music during task performance, the paradigms have not closely mimicked how we experience music in our daily lives. The previous studies showing mnemonic benefits of music may be limited in their generalizability for the following reasons: (a) previous studies played music prior to the experimental task (Rauscher et al., 1993), which isn't representative of the naturalistic environments where we experience background music throughout the duration of a task; (b) the benefit of music in some studies required the integration of the music with the to-be remembered information (e.g., Rubin, 1977), whereas the background music we experience daily is not typically integrated with the tasks we are trying to complete; (c) the two previous studies that found a cognitive benefit in the presence of background music used verbal tasks (Standing et al., 2008; Thompson et al., 2005), which may not be representative of the more complex tasks older and younger adults perform in the presence of music. That is, with regard to aging, verbal tasks like category fluency may not be the ideal test for studying the impact of background music on memory. While many aspects of memory decline with aging, verbal memory does not. Results from a cross-sectional study by Park and colleagues (Park et al., 2002) suggest that older adults perform better than younger adults on verbal ability tests. The benefit for background music may not extend to tasks that are particularly difficult for older adults. Specifically, one well-known deficit in aging is for associative memory accuracy. Associative memory refers to the ability to remember connections or associations between pieces of information in memory. For example, associative memory facilitates remembering what name went with a face or where a conversation took place. A meta-analysis by Old and Naveh-Benjamin (2008) showed that older adults consistently performed more poorly than younger adults on associative memory tests.

Older adults may have particular difficulty completing tasks in the presence of background music due to impairments in executive functioning, which encompasses many cognitive processes including inhibition (Braver & West, 2007). Previous imaging studies have demonstrated that older adults show reduced connectivity in a frontoparietal network thought to be responsible for cognitive control (Campbell, Grady, Ng, & Hasher, 2012). These age related-declines in frontal-based cognitive control are thought to lead to greater distractibility in older adults compared to younger adults, likely due to problems inhibiting task-irrelevant information (Campbell et al., 2012; see Hasher & Zacks, 1988 for review on inhibition). Support for this so-called "inhibitory deficit hypothesis of aging" comes from studies manipulating which information is to be remembered and which information is to be ignored in a task. For example, Connelly, Hasher, and Zacks (1991) asked participants to read blocks of text intermixed with both italicized and not italicized font. Older and younger participants were asked to read only the italicized text and to ignore the not italicized text. When extraneous words were interspersed in the text, reading times for older adults were far slower than that of younger adults. These results suggest older adults had more difficulty inhibiting the irrelevant, not-italicized text than did younger adults. Hasher and Zacks (1988) argue that inhibitory failure occurs at both encoding and retrieval. At encoding, an inability to inhibit distracting information leads participants to attend to irrelevant information. At retrieval, a deficit in inhibition makes it difficult to narrow attention to relevant memory searches. A reasonable prediction is that background music presented during encoding and retrieval may impair memory performance in older adults due to impairments in executive functioning, which lead to difficulty inhibiting task-irrelevant information.

Current Study

In the present study, we sought to determine whether unfamiliar music played in the background, while participants performed a paired associates learning task, would have an effect on associative memory accuracy in the young and old and the mechanisms that might support this effect. We were specifically interested in associative memory due to the well-known and widespread deficits in associative memory accuracy in healthy aging. Abundant data from studies using the paired associates learning task has shown disproportionate age-related impairments in memory for associations relative to memory for items (Old & Naveh-Benjamin, 2008). We were only interested in assessing the effects of instrumental background music since prior research has demonstrated that lyrics are likely to impair performance in simultaneous tasks that contain verbal information (Salame & Baddeley, 1987). This is the first study to our knowledge to study the effects of background music on a complex memory task at both encoding and retrieval in the young and old.

We were also interested in the subjective experience of listening to background music. Background music seems ever-present in our environment, so it seems important to ask for subjective reports from both younger and older adults regarding how distracting, if at all, they find music to be while trying to complete a memory task. It could be the case that age-related hearing loss, which can make it difficult to identify and localize sounds, could lead to older adult's becoming more distracted by the background music than younger adults (see Huang & Tang, 2010 for a review on presbycusis). The present study screened for gross hearing difficulties, but the subtle changes due to presbycusis may impact our older adult sample. Subjective reports could reveal age-related differences in the perception of distraction, which could inform older adult's preferences for work and leisure environments. If older adults find music subjectively more distracting, they may seek out quieter restaurants to dine with friends or employment where background noise is minimal.

We make the following predictions:

1. We predict that playing any music compared to silence will distract participants' attention away from the memory task. Given that inhibition deficits are common in aging (Hasher & Zacks, 1988), we predict that older adults should show greater associative memory impairments in the music conditions than young adults.
2. It is an open question whether or not participants will be subjectively aware of any distraction, or if there will be age-related differences in self-ratings of distraction. It is also unclear if subjective ratings of distraction will match behavioral performance (i.e., higher ratings of distraction associated with impaired performance).

Methods

Participants

We recruited a total of 117 participants, 57 young (aged 18–30 years) and 60 older (aged 60–75 years) for participation in this study. In the young sample, 30 identified as White, 14 as Asian, 4 as Black/African American, 3 as Hispanic, 3 as Multiracial, 1 as American Indian, 1 Egyptian, and 1 younger adult did not report any race. In the old sample, 33 identified as White, 3 as Asian, 20 as Black/African American, 1 as Hispanic, 1 as American Indian, and 2 older adults did not report any race. Four young and 10 older adults were excluded based on neuropsychological assessment, chance level performance on more than two of the task conditions, or a failure to complete the experiment. A final sample of 53 young and 50 older adults was included for all analyses. Young adults were recruited from psychology courses at The Georgia Institute of Technology and were given extra credit in their courses as compensation. Older adults were recruited from the Atlanta community and were compensated $10 for each hour of participation plus an additional $5 for travel. All participants were native English speakers, with no self-reported psychiatric or neurological disorders, vascular disease, current psychoactive drug use, or hearing problems. All participants signed an informed consent form approved by the Georgia Institute of Technology Institutional Review Board. The total session duration, including practice and consent procedures, was approximately 2 hr. Group characteristics are displayed in Table 1.

Neuropsychological Assessment

We administered a standard battery of neuropsychological tests immediately following the memory task so as to ensure

Table 1. Group Demographics and Neuropsychological Test Performance

	Young	Older
Age	20.9 (2.70)	66.3 (4.81)
Education	15.2 (2.29)	16.0 (2.79)
Amusia—differential melodies	86.2 (8.70)	80.4 (9.70)*
Amusia—incongruent pause	86.4 (8.90)	81.0 (7.40)*
Amusia—out of tune note	86.9 (12.1)	82.34 (13.5)
Amusia composite	86.8 (6.73)	81.3 (7.55)*
Verbal span forward	7.35 (1.27)	6.54 (1.39)*
Verbal span backward	4.98 (1.26)	4.81 (1.33)
List learning	31.1 (11.90)	36.09 (13.18)
Immediate face–name recognition	18.2 (1.90)	17.7 (2.66)
Delayed face–name recognition	9.51 (0.93)	9.35 (1.04)
Trail making A	21.3 (5.68)	32.4 (9.02)*
Trail making B	42.3 (11.4)	69.3 (20.3)*
Controlled oral word association	48.0 (13.5)	48.4 (13.6)
Corsi block span	6.11 (0.95)	4.66 (0.82)*

*Significant difference between the age groups

no differences in performance due to clinically-significant decline. In order to assess memory, participants completed several subtests from the Memory Assessment Scale battery (Williams, 1991) including the digit span forward and backward task, verbal list learning, and the face–name paired recognition task. Additionally, participants completed Trail Making tests A and B (Reitan & Wolfson, 1985) as a measure of speed and attention, the Controlled Oral Word Association test (“FAS”) (Benton, 1994) as a measure of verbal fluency, and the Corsi block tapping task (Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000) as a measure of spatial working memory span. Any participant whose score fell 2 *SD*s below their age-adjusted mean score given their level of education was removed from the sample. While it is true that our exclusion criteria may not have excluded participants with early mild cognitive impairment (MCI), it is unlikely that any participants included in the present study were affected. There were no subjective reports of memory complaints by any participants, which is a requirement for an MCI diagnosis (Petersen, 2004). Additionally, performance on the associative memory task was well above floor for all included participants.

Participants were also screened for amusia, a music perception disorder, using an online version of the Montreal Battery of Evaluation of Amusia (Peretz, Champod, & Hyde, 2003). One young and 12 older adults failed the amusia test. Since the normative data for this test are based on young adults’ performance only, and the amusia battery relies on working memory capacity that declines even in healthy older adults, we decided to reinstate older adults to the sample so long as their amusia test scores were within 1 *SD* of the mean of the older adult group. A comparison of the five older adults who passed this criterion with a random selection of five older adults who passed the amusia screening did not reveal any differences in paired associate recognition accuracy for any condition $F(1,8) < 1$. Neuropsychological test scores are shown for both age groups in Table 1.

Materials

Task-related stimuli included 156 unfamiliar male and 156 unfamiliar grayscale female faces from the Face Recognition Technology database (Phillips, Wechsler, Huang, & Rauss, 1998) and various internet sites, paired with 156 male and 156 female names taken from various websites of popular baby names for a total of 312 face–name pairs. Face–name pairs were of the same gender with an equal number of young and older adult faces, and were presented in black and white on a computer screen. Efforts were made to select a diverse sample of faces with respect to race, ethnicity, and age, with an even distribution of young, middle aged, and older adult faces. The majority of faces (2/3) were Caucasian, which matches our participant sample.

Music stimuli were selected from experimenters’ personal collections, and Jamendo.org, a free online music-sharing website. Effort was made to select music that would be unfamiliar to the majority of participants out of concern that familiar songs may aid memory performance, confounding our data interpretations (Purnell-Webb & Speelman, 2008). All music files were normalized to the same volume. Playing volume was set by each participant prior to the beginning of the experiment and was fixed for the entire experiment.

Prior to beginning the experiment, we conducted a pilot study to select songs that were matched for valence and arousal between age groups. A separate group of 28 young and 13 older adults total participated in this pilot study. Pilot participants were recruited and compensated in a similar manner to our experimental participants.

We selected 182 songs to be rated in the pilot study by both age groups from four different genres (jazz, rock/blues, classical, and electronica). In order to facilitate a reasonable study session duration, and to reduce participant fatigue, pilot participants were randomly assigned to one of two groups, each of which rated one half of the total song sample, that is, 91 songs per group, with equal numbers of songs in each genre rated by each group. Participants listened to 15-s clips of each song. Participants rated songs for both arousal and valence based on a modified version of the Likert scales used in the International Affective Picture System rating study (Lang, Bradley, & Cuthbert, 1995). Ratings for valence were made using a −2 to +2 scale, with −2 representing very negative emotion, +2 representing very positive emotion, and 0 representing neutral or no emotion. Ratings for arousal were done using a +1 to +5 scale, with +1 representing minimal arousal and +5 representing high arousal. Participants rated all music for either the arousal or valence dimension first before rating the same music for the other dimension. The order of ratings was counterbalanced across participants.

Ratings of arousal and valence were calculated separately for each age group. Songs with mean arousal ratings greater than 3.5 were classified as high arousal while those with mean arousal ratings less than 3.0 were classified as low arousal. Songs with mean valence ratings of greater than 0.5 were classified as positive. We only selected songs rated as positively valent. In order to choose songs rated similarly by most participants within each group, only songs with standard deviations less than 1.0 were selected. We selected only rock songs to be used in the experiment on the basis that only this genre produced enough songs that satisfied our cutoff criteria for each age group. We selected a total of six high arousal and six low arousal songs for each age group for use in the experimental task. We wanted to select songs within a certain range of arousal and valence ratings, and given the disparity of ratings for individual songs between the age groups, we selected different songs for the age groups. The song selections along with mean arousal and valence ratings are shown in Table 2. Importantly, independent samples *t*-tests confirmed that neither mean arousal nor valence ratings differed between age groups for either high or low arousal songs $t(6)$'s < 1.

Procedure

Within each of the two arousal conditions (high arousal and low arousal), there were two context manipulations wherein we manipulated the music played at paired associate encoding and at the paired associate recognition test: the same song between paired associated encoding and paired associate recognition or different songs between paired associate encoding and paired associate recognition. We also included two control conditions: silence during

Table 2. Descriptive Statistics for Songs Selected as Musical Stimuli Based on Pilot Study of Young and Older Adults

Musical artist, song title	Arousal category	Mean arousal rating (*SD*)	Mean valence rating (*SD*)
Young adults			
Pele, "Mind of Minolta"	High	3.63 (0.89)	1.06 (0.85)
John Mayall and the Bluesbreakers, "Hideaway"	High	3.75 (0.75)	1.33 (0.78)
John Mayall and the Bluesbreakers, "Curly"	High	3.92 (0.67)	1.00 (0.95)
Eric Johnson, "Cliffs of Dover"	High	4.25 (0.75)	1.42 (0.79)
Stevie Ray Vaughn, "Scuttle Buttin'"	High	4.58 (0.52)	1.58 (0.67)
Steve Vai, "Jibbom"	High	4.83 (0.39)	0.75 (1.09)
Mean		4.16 (0.48)	1.17 (0.28)
Brooks Williams, "O Leaozinho"	Low	2.19 (0.98)	1.00 (1.27)
Jefferson Airplane, "Embryonic Journey"	Low	2.42 (0.79)	1.00 (0.85)
Incredible Moses Leroy, "Roscoe"	Low	2.63 (0.96)	0.69 (1.14)
Umphrey's McGee, "Nemo"	Low	2.75 (0.86)	0.63 (1.26)
Eric Clapton, "Signe"	Low	2.75 (1.07)	1.56 (0.51)
Buddy Guy, "Just Teasin'"	Low	2.81 (0.83)	0.56 (0.81)
Mean		2.59 (0.24)	0.91 (0.37)
Older adults			
Eric Johnson, "Cliffs of Dover"	High	3.67 (0.82)	1.17 (0.41)
John Mayall and the Bluesbreakers, "Steppin' Out"	High	3.83 (0.98)	1.00 (0.10)
The Ventures, "Slaughter on Tenth Avenue"	High	4.33 (0.82)	1.00 (0.89)
Stevie Ray Vaughn, "Scuttle Buttin'"	High	4.50 (0.84)	1.17 (0.75)
Umphrey's McGee, "The Fuzz"	High	4.50 (0.55)	1.00 (0.89)
John Mayall and the Bluesbreakers, "Hideaway"	High	4.83 (0.41)	1.67 (0.82)
Mean		4.27 (0.44)	1.16 (0.26)
Pele, "Nighttime Stomach"	Low	2.33 (0.52)	1.00 (0.89)
Incredible Moses Leroy, "Roscoe"	Low	2.50 (0.84)	0.83 (0.75)
Steve Vai, "Tender Surrender"	Low	2.50 (0.55)	0.67 (0.82)
Brooks Williams, "O Leaozinho"	Low	2.67 (1.03)	1.50 (0.84)
Jeff Beck, "Serene"	Low	2.67 (0.82)	0.67 (0.82)
Rush, "Hope"	Low	2.83 (0.75)	0.83 (0.98)
Mean		2.58 (0.18)	0.92 (0.31)

both paired associate encoding and paired associate recognition, and "musical rain" during both paired associate encoding and paired associate recognition. Musical rain is a computer generated randomized vowel sound designed to elicit low levels of neutral arousal in order to control for the effect of arousal on cognitive performance unrelated to music, per se. There were 48 trials for each of the six conditions presented in blocks of 24 trials for each condition separately. The order of blocks was randomized across participants. Participants were told that the music was irrelevant to the memory task and that they should not attend to it and instead focus on studying and retrieving the face–name pairs.

The paradigm is shown in Figure 1. During paired associate encoding, participants studied face–name pairs for 3.9 s each. In order to ensure successful attention to and processing of face–name pairs, participants answered the orienting question "Does this name suit the face?" for each pair. After studying 24 pairs in a row, participants completed a backward counting task for 20 s to prevent rehearsal before test. During the paired associate recognition test, participants viewed 24 face–names pairs and determined whether the same pairs were previously presented together. The positions of the faces and names were swapped between paired associate encoding and paired associate recognition (i.e., face on left at paired associate encoding and on right at paired associate recognition) in order to prevent unitization of the pairs and the possibility that associative memory judgments would be familiarity-based (Diana, Yonelinas, & Ranganath, 2008); potentially reducing the likelihood of observing an age group difference in performance (Light, Prull, LaVoie, & Healy, 2000). Sixteen of the 24 face–name pairs were tested intact with the identical name and face pairing and eight pairs were rearranged. No unstudied faces or names were presented at paired associate recognition. The order of the pairs was randomized at paired associate recognition. Participants completed 12 paired associate encoding-recognition blocks in total (two repetitions for each of the six conditions).

Immediately after each paired associate encoding-recognition block, participants were asked to rate how distracting they found the music to their ability to perform the task. Participants responded on a 1–5 scale: 1 being not at

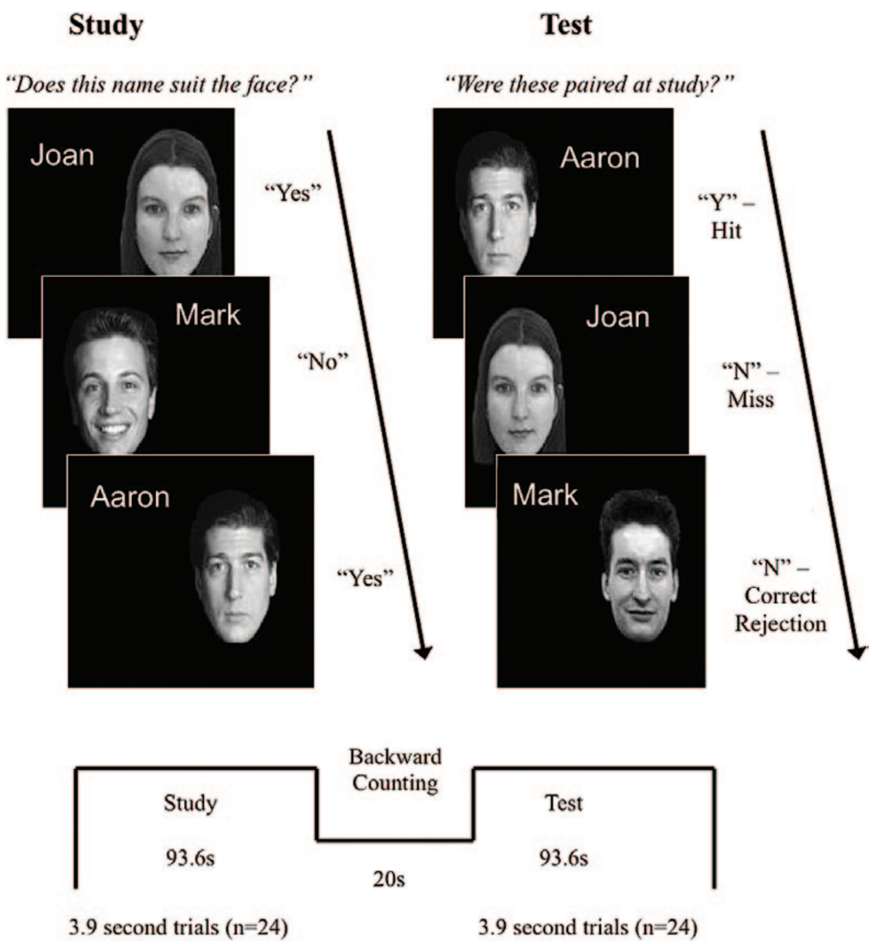

Figure 1. Associative memory task design.

all distracting and 5 being very distracting. The experimental session lasted approximately 50 min.

Results

Mean proportions of hit rates for intact face–name pairs and false alarm rates for rearranged pairs are shown for the different conditions for both age groups in Table 3. Hits and false alarms were defined as "intact" responses to intact and rearranged pairs, respectively. Associative memory accuracy measures are shown in Figure 2. Specifically, "Pr" discrimination measures were calculated as the probability of hits minus the probability of false alarms, where chance is zero (Snodgrass & Corwin, 1988).

Neither the arousal manipulations nor the context manipulations produced any notable results. Comparisons across conditions revealed that there were no differences in memory accuracy between any condition and silence for the young adults $t(52)$'s < 1.347, $ps > .184$. For older adults, all conditions save the low arousal, different song condition $t(49) = 1.411$, $p = .165$ were significantly impaired compared to silence $t(49)$'s > 3.461, $ps < .001$. Thus, we collapsed across all musical conditions for the remaining analyses.

We conducted an omnibus Condition (silence, musical rain, music) × Group (young, old) analysis of variance (ANOVA) on the Pr estimates shown in Figure 2. Huynh-Feldt corrections are reflected in the error term, when necessary. There was a main effect of Condition $F(2, 202) = 7.204$, $p < .001$, Group $F(1,101) = 20.17$, $p < .001$ whereby associative memory accuracy was reduced in the old, as well as an interaction between these factors $F(2,202) = 3.598$, $p = .029$. Follow up ANOVAs for each age group showed that the effect of Condition was reliable in the old $F(2, 98) = 9.458$, $p < .001$ but not young adults $F(1.96,101.94) = .592$, $p = .552$. We followed up the main effect of Condition for older adults with a series of paired-samples t tests. Results indicated that older adults' memory performance was worse in the music condition relative to silence $t(49) = 4.09$, $p < .001$. Performance was also worse in the musical rain than silence condition $t(49) = 3.46$, $p = .001$. Performance was not significantly different between the musical rain and music condition $t(49) = .129$, $p = .90$.

Table 3. Mean Response Proportions and Standard Deviations for Young and Older Adults

	Young adults	Older adults
Music		
Hit	0.79 (0.11)	0.73 (0.13)
False alarm	0.31 (0.18)	0.47 (0.20)
Musical rain		
Hit	0.79 (0.12)	0.74 (0.14)
False alarm	0.33 (0.23)	0.47 (0.22)
Silence		
Hit	0.80 (0.13)	0.78 (0.14)
False alarm	0.31 (0.19)	0.41 (0.20)

Analysis of Subjective Ratings

Mean ratings of distraction for each of the conditions are shown for both groups in Table 4. Due to a technical error, three young adult participants did not complete these ratings. Consequently, the following analyses are based on responses of 50 young and 50 older adults. A Condition (silent, musical rain, music) × Group (young, old) ANOVA for the subjective ratings of distraction revealed a main effect of Condition only $F(1.75, 169.65) = 148.459$,

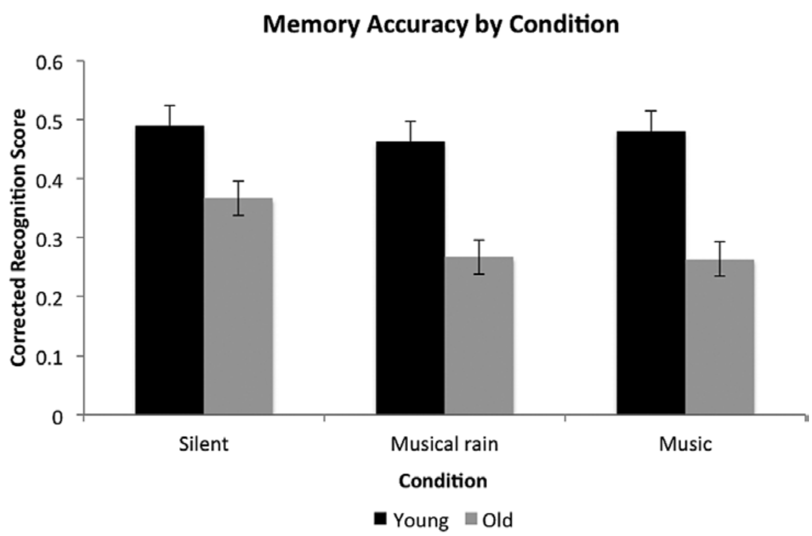

Figure 2. Corrected associative recognition (Pr) estimates as a function of condition for both young and older adults.

Table 4. Mean Ratings of Distraction and Standard Deviations for Young and Older Adults

	Young adults	Older adults
Music	2.23 (0.65)	2.31 (0.85)
Musical rain	3.47 (1.13)	3.21 (1.18)
Silence	1.23 (0.42)	1.36 (0.89)

$p < .001$. Follow up paired t-tests confirmed that participants rated musical rain as more distracting than music and silence $t(98)$'s > 8.662, ps < .001 and music as more distracting than silence $t(98) > 10.564$, $p < .001$.

General Discussion

We conducted this experiment to explore the effects of background music on paired associate recognition memory performance for young and older adults. We found that associative memory accuracy was unaffected by the presence of music in young adults but impaired when any music was played for the older adults, whether it was highly or minimally arousing or the same between paired associate encoding and paired associate recognition. Furthermore, all participants reported that music was more distracting to their memory performance than was silence. Consistent with previous research, older adults showed associative memory impairments relative to the young across all conditions.

In contrast to the young, older adults showed associative memory impairments for music conditions relative to silence. Importantly, a similar impairment was observed when participants listened to musical rain, an arousing non-musical stimulus. This suggests that arousal induced by the noise or sound of music rather than music per se may have contributed to the memory impairments older adults' exhibited. Interestingly, both young and older adults rated music as more distracting to their performance of the memory task than silence. Collectively, these data suggest that rather than being supportive of ongoing memory performance, background music is at best distracting for young adults and at worst distracting and detrimental to performance for older adults. These results differ from previous studies that have found a benefit for music. In previous studies however, the tasks were relatively simple verbal tasks (Standing et al., 2008; Thompson et al., 2005). The results of the present study suggest that potential benefits of music do not extend to demanding tasks like associative memory.

It may seem somewhat surprising that both young and older adults reported that music was distracting to their performance but only older adults demonstrated significant memory impairments compared to silence. There are a few possible explanations for this pattern of results. One possibility is that the older adults deliberately attended to the music perhaps because they were confused about what stimuli were relevant to their performance and/or because they found the music familiar, enjoyable, or irritating. Thus, participants may have split their attention between listening to the music and the associative memory task. This may have approximated a divided attention task for the older adults, which numerous studies suggest would result in reduced memory accuracy for the old (e.g., Castel & Craik, 2003; Old & Naveh-Benjamin, 2008). However, we think that this explanation is unlikely for a couple of reasons. First, we took care to choose music rated as both unfamiliar and positively valent in order to reduce the possibility that it would capture attention. Furthermore, post-experimental debriefing confirmed that all included participants understood the task procedures and none reported deliberately attending to the music. We do note that a possible limitation of this study is that we asked for several subjective reports of distraction, which may have unintentionally encouraged the older adults to attend to the background music. That is, older adults may have been better able to ignore the background music if their attention hadn't been drawn to its presence by asking if it was distracting after each paired associate encoding-recognition block. Future studies should be cognizant of this possible confound and consider collecting subjective reports of distraction at the end of the study. This was not possible in the present study because we wanted to explore any potential differences in distraction ratings after each arousal manipulation.

A non-mutually exclusive possibility for the lack of music-induced memory impairments in the young is that young adults may have more real world experience listening to music while engaged in cognitively demanding tasks (i.e., "practice effects"). This experience may enable young adults to more efficiently ignore the music and perform the memory task. If young adults were spared from music-induced impairments due to practice effects, older adults should also be spared from impairments when the background stimuli are highly practiced as with ambient familiar sounds. Alternatively, if older adult's performance is suffering due to inhibition deficits, both background music and ambient sounds should impair performance. A recent study by Haj, Omigie, and Clément (2014) offers evidence in support of an inhibition deficit account. In their paradigm, participants listened to silence, classical music, or ambient sounds (street noise) during the encoding phase of a source memory task (remembering the location of an object). Haj and colleagues found that both background music and ambient noise impaired memory performance on a subsequent recognition test in older adults relative to silence. Music did impair young adults' performance (though less so than older adults' performance), but ambient sounds did not. Based on these results, it seems unlikely that practice performing cognitively demanding tasks in the presence of background music in the young can fully account for their lack of associative memory impairments in the present study.

Results of the present study are most consistent with the theory that older adults' failure to inhibit processing of distracting task-irrelevant information, in this case background music, contributes to their memory impairments. Hasher and Zacks (1988) argued that this process is two-fold, and that inhibitory failure occurs at both encoding and retrieval. During encoding, inhibitory mechanisms allow participants to attend to task-relevant stimuli rather than task-irrelevant stimuli. During retrieval, these inhibitory mechanisms allow participants to narrow attention to relevant memory searches. In the current study, we played music during both encoding and retrieval, and the failure of older adults' inhibitory mechanisms likely impaired both processes, distracting older adults and resulting in their generally poorer performance during those conditions.

Independent of the music manipulation, older adults' impaired performance in the silent condition of the associative memory task compared to young corroborates previous research suggesting that relational processes are impaired in aging. An imaging study by Dulas and Duarte (in press) investigated age-related differences in source memory, which required associating an item representation and context information (e.g., a green truck or a blue apple). Behavioral results revealed reduced associative memory performance in older adults compared to younger adults (correctly recognizing an item as the same color from encoding). Imaging results revealed an underrecruitment of lateral anterior pre-frontal cortex in the older adults compared to the young, which is thought to mediate relational processes. These results from Dulas and Duarte (in press) are consistent with other reports of age-related declines in frontal-based executive control processes (Braver & West, 2007; Campbell et al., 2012). In the present study, we found that background music further burdened executive function (particularly inhibition), which is compromised in the old, leading to poorer performance on the associative memory task.

Our results have practical implications for older adults', and perhaps some young adults', ability to perform cognitively demanding tasks in the presence of the kinds of background noise, like music, that pervade our environment. These results are particularly relevant when considering the large proportion of older adults that comprise the current and future workforce. Older adults may have difficulty performing complex tasks in work environments like retail shops where background music is present. Additionally, given the subjective ratings of distraction by older adults, it seems prudent for developers of senior centers and other establishments dedicated to serving older clients to consider maintaining a quiet ambiance for the enjoyment of older adults.

Important future work is to determine the effects of background music on other tasks such as driving, where music is also commonly present. It could be the case that older adults' driving performance is harmed more than younger adults' performance by the presence of music. It might also be the case that older adult performance benefits more by turning the radio off, which would be important for maintaining safe driving practices and independence, by extension.

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