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Music Engagement and Episodic Memory among Middle-Aged and Older Adults: A National Cross-Sectional Analysis

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Y. Jin: (1) Conceptualized the project; (2) Drafted the manuscript; (3) Responsible for statistical design and analyses

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ABSTRACT

Objectives: To determine whether music engagement influences middle-aged and older adults' performance on episodic memory tasks.

Methods: Secondary data analysis of a sample (*N* = 4,592) of cognitively healthy adults from the 2016 Health and Retirement Study were used for this study. Multivariable regression models were used to analyze the cross-sectional differences in performance on tasks of episodic memory between participants who listened to music (n= 3,659) or sang or played an instrument (n= 989).

Results: On average, participants recalled 10.3 words out of a possible 20. Regression analyses showed that both music listening and singing or playing an instrument were independently associated with significantly better episodic memory.

Discussion: The findings provide the first population-based evidence that music engagement is associated with better episodic memory among middle-aged and older adults. Future studies should examine whether the association is causal or has a dose response.

Keywords: music, memory, healthcare policy, lifestyle, regression methods, age norms

It has been well-documented that most older adults will experience age-related changes in cognition across time. However, there is significant variability in the magnitude of these changes (Wagster et al., 2012). Previous research has attempted to disentangle these normal age-related changes from changes due to pathology. One aspect of cognition that has been found to be of particular importance in distinguishing these age-related cognitive changes from pathological ones is episodic memory, i.e., a form of long-term memory about personally experienced events (Nyberg et al., 2012). While most older adults experience some form of decline in episodic memory, if the changes in this domain are drastic, then they are believed to be representative of the prodromal stage of Alzheimer's disease (Backman et al., 2001; Boraxbekk et al., 2015). Due to the increasing number of older adults, including those who are projected to be diagnosed with Alzheimer's disease, it is important to examine whether lifestyle changes or interventions that can be easily implemented can ameliorate this deficit in episodic memory.

Recently, researchers have examined the role of arts in life enrichment (Fancourt et al., 2018). Some of these studies in particular found that music activities were associated with better cognitive performance in old age (Abrahan et al., 2019; Hanna-Pladdy & MacKay, 2011; Roman-Caballero et al., 2018; Schneider et al., 2019) and a reduced risk of dementia (Balbag et al., 2014; Verghese et al., 2003). The most robust findings for these positive outcomes are in people who have learned to play instruments. Specifically, older musicians were found to have better performance in auditory conflict resolution, cognitive control (Amer et al., 2013), nonverbal memory, executive processes (Bugos et al., 2007; Hanna-Pladdy & MacKay, 2011), naming (Hanna-Pladdy & MacKay, 2011; Roman-Caballero et al., 2018), processing speed, inhibition, attention, verbal memory, verbal working memory, verbal fluency, flexibility, and visuospatial ability (Roman-Caballero et al., 2018). Balbag and colleagues (2014) further supported these results with findings that among 157 pairs of twins, playing an instrument was associated with significantly reduced likelihood of developing dementia.

Despite the interest in the relationship between music engagement and cognition, there is limited research on the effect of music listening on the cognitive abilities of older adults and none that we are aware of where the results could be generalized to a larger population. The purpose of our study is to utilize a nationally representative sample of middle-aged and older adults to examine how passive and active music engagement is associated with performance on episodic memory tasks. Prior research includes an examination of the effects of listening to classical music (i.e., Vivaldi's 'Four Seasons') on the cognitive performance of healthy older adults (Mammarella et al., 2007). Classical music, no music, or white noise played in the background as the participants were assessed through two memory tasks, with one measuring phonological working memory capacity and the other measuring phonemic fluency. The study reported a significant increase in working memory performance of the group who listened to classical music when compared to both the no music group and the white noise group (Mammarella et al., 2007). Another study by Bottiroli and colleagues (2014) investigated the role of background classical music (i.e., Mozart and Mahler) on the cognitive performance of older adults. Here, they recorded an improvement in performance on tasks of processing speed when music that was perceived to be more positive (i.e., Mozart) was played, and an improvement on tasks of episodic and semantic memory when the music was perceived as either positive or negative (i.e., Mahler; Bottiroli et al., 2014). In a more recent study, Innes et al. (2018) examined whether listening to classical music (i.e., Bach, Beethoven, Debussy, Mozart, Pachelbel, Vivaldi) for twelve minutes a day for twelve weeks would lead to both cognitive and biological benefits for older adults. Participants who completed this intervention were found to perform better at post-assessment on tasks of memory, executive function, psychomotor speed, attention, and working memory.

Further, this improved cognitive performance was maintained for all participants 3 months after the intervention ended. At the biological level, plasma Aβ levels were altered and telomerase activity increased, although the magnitude of this change was related to one's adherence to the intervention protocol (Innes et al., 2018). In another study, music listening was compared to piano training and percussion training interventions for older adults (Bugos, 2019). Results showed that while piano training and percussion training enhanced motor coordination and working memory, music listening instruction benefited cognitive control.

Despite these promising findings on the positive impact of music on a wide range of community and clinical populations, an important question remains unanswered. That is, whether the previously identified findings from research with smaller populations on the effect of music on the cognitive abilities of older adults would be consistent with those from a population-based study. While more experimental music intervention studies have been conducted, or are being planned in clinical populations (Gold et al., 2019), data from a nationally representative sample can potentially increase our understanding of the beneficial effects of music engagement in non-clinical populations, thereby providing more evidence for community-based prevention trials. The present study aims to shed light on the relationship between music engagement and episodic memory as an indicator of cognitive function in middle-aged and older adult populations from the United States. We hypothesize that habitual music engagement in middle-aged and older adults' daily lives would be related to better episodic memory and that this association would be observed both for passive (i.e., listening to music) and active (i.e., singing or playing an instrument) activities. To our knowledge, our study is one of the first population-based studies to examine these questions. Results from the present study have the potential to provide critical information for future large-scale studies concerning the use of passive and active music engagement as a pragmatic early prevention tool to attenuate age-related cognitive decline and to even reduce the disease burden from Alzheimer's disease at the population level.

METHODS

Participants

This study used cross-sectional data from Wave 13 (2016) of the Health and Retirement Study (HRS; Juster & Suzman, 1995) and Wave 8 (2015) of the Consumption and Activities Mail Survey (CAMS; Hurd & Rohwedder, 2009). The use of these waves ensured that our sample included the baby boomers, an important target because of the aging of this large generation. The HRS is a national longitudinal study that began in 1992 in order to understand the detailed economic and health situation of older adults in the United States. The study surveys a representative sample of Americans 50+ years old, with approximately 20,000 people interviewed biannually (Wallace & Herzog, 1995). Spouses/ partners of participants are included in the HRS regardless of age. Beginning in 2001, the HRS implemented a paper-and-pencil survey called CAMS that is mailed to a sub-set of participants biannually to complete. The primary objective of CAMS is to measure household spending within the last year. The survey also queries about activities that participants engage in, as well as how much time is spent in each activity. The HRS and CAMS is conducted by the Institute for Social Research at the University of Michigan (Sonnega et al., 2014; Wallace & Herzog, 1995).

Participants were included in our data analysis if they had participated in the 2015 CAMS sub-study and the 2016 HRS wave. Specifically, participants were included if they were 50 or older, and if they had completed both questions about their engagement with music. Participants were excluded if they had missing data on the primary predictor of interest (80), did not participate in the 2016 wave of the HRS core survey (376), did not complete the tasks for episodic memory (126), had a score of 8 or less on the episodic memory tasks (41), or were younger than 50 years old (62). Of the 4,682 respondents who met the study inclusion criteria, 4,592 had complete information on all covariates and were included in the final analytic sample (Figure 1).

Episodic Memory Assessment

Episodic memory was assessed via a 10-word immediate and delayed word recall test. In the immediate word recall test, the interviewer read a list of 10 nouns to the respondent and asked the respondent to recall as many words as possible from the list in any order. The maximum score for this task was 10, and the score was the total number of words that were recalled correctly. In the delayed word recall test, the respondent was asked to recall this same list of words approximately 5 minutes later. The scoring for this task was identical to the previous one, with a combined score for both tasks of 20. For this study, the scores from each task were combined to form an overall episodic memory score (Crimmins et al., 2011; Fisher et al., 2014).

Music Activities Assessment

The CAMS survey provided information through two questions about the time each participant spent engaging with music. The first question asked participants to indicate the number of hours spent in the last week listening to music (i.e., passive engagement). For the purposes of this study, participants were dichotomized into groups that indicated whether they listened to music or not (0 = *no*; 1 = *yes*). Participants were also asked to provide the number of hours per month that they spent singing or playing an instrument (i.e., active engagement). A dichotomous variable was then created to indicate whether the participant indicated any hours for this question (0 = *no*; 1 = *yes*). An additional three-level variable (0, 1, 2) was created to represent the differing levels of music engagement among participants in order to test if engaging in both passive and active music engagement would translate into an additional advantage. This variable represented participants who did not listen to music and did not sing or play an instrument (i.e., 0), participants who only engaged in one form of music (i.e., 1), and participants who both listened to music and sang/played an instrument (i.e., 2). This new variable was then used in a sensitivity analysis to account for any possible dose-response relationship found between music engagement and episodic memory performance.

Sociodemographic and Health Assessments

Sociodemographic variables. The demographic variables included in this study were age, gender, race, marital status, and household income. Race was categorized as non-Hispanic White, non-Hispanic African American, Hispanic, and other. Marital status was categorized as married or partnered; separated, divorced, or never married; and widowed. Finally, working for pay was dichotomized as a yes or no response based on if participants reported any hours worked in the last week and household income was classified as less than 100% of the poverty level, 100% to 199%, 200% to 299%, 300% to 499%, and more than 500% of the poverty level.

Health variables. The health variables in these analyses included information about participants' functional status, chronic conditions, and levels of physical activity. Information about participants' functional status was assessed using the standard questionnaire provided by HRS (Saliba et al., 2000). These questions assessed participants' ability to perform both activities of daily living (ADL) and instrumental activities of daily living (IADL). Six ADLs were assessed including walking, dressing, bathing, eating, getting in/out of bed, and using the toilet. Five IADLs were assessed including shopping for groceries, making phone calls, managing finances, taking medications, and preparing a hot meal. In this study, the percentage of participants who reported difficulty with at least one ADL or IADL were recorded and assigned a dichotomous value indicating the presence or absence of difficulty with either of these (0 = *no difficulty*; 1 = *difficulty*), respectively.

This study controlled for a range of health variables in the analyses. These variables included chronic conditions, depressive symptoms, self-rated health, body mass index (BMI), and physical activities. The chronic conditions assessed were hypertension, diabetes, cancer, lung disease, heart disease, stroke, and arthritis. The total number of chronic conditions present were used in this study (0 to 7). Depressive symptoms were assessed with the Center for Epidemiological Studies Depression Scale (CESD; Turvey, Wallace, & Herzong, 1999; Steffick, 2000). The CESD score was calculated by six negative indicators (i.e., depression, feeling everything is an effort, restless sleeping, feeling alone, feeling sad, and could not get going) and two positive indicators that were reverse coded (i.e., feeling happy, enjoying life). Scores ranged from 0 to 8 with higher scores indicating more depressive symptoms. In addition, self-rated health was categorized by three groups: excellent or very good, good, and fair or poor; and BMI was categorized as underweight (BMI<18.5), normal (BMI 18.5 to 24.9), overweight (BMI 25.0 to 29.9), and obese (BMI>30).

Physical activities were measured by the responses to three questions about the frequency (i.e., every day, more than once per week, once per week, one to three times per month, or never) of each activity level intensity (i.e., vigorous, moderate, or light). Vigorous activities included sports or activities such as running or jogging, swimming, cycling, aerobics or gym workouts, tennis, or digging with a spade or shovel. Moderate activities included sports or activities such as gardening, cleaning the car, walking at a moderate pace, dancing, floor, or stretching exercises. Light activities included activities such as vacuuming, laundry, and home repairs. For this study, the intensity and frequency of all activities were combined to form a variable that indicated the overall level of physical activity (low, moderate, and high; Lee et al., 2011).

Statistical Analyses

We first examined the distributions of the sample's demographic characteristics and health status. Next, we examined differences across music activity groups using chi-square tests for categorical variables and an analysis of variance (ANOVA) for continuous variables. Sampling weights were applied to the descriptive analysis to yield nationally representative estimates. The primary analyses used a single multivariable linear regression model to examine the association between music activity engagement (i.e., listening to music and singing or playing an instrument) and individual performance on episodic memory tasks. In this regression, the predictor variables were (a) listening to music/ passive engagement and (b) singing or playing an instrument/ active engagement, and the total score on the episodic memory tasks was entered as the dependent variable. This analysis adjusted for sociodemographic and health status. To facilitate interpretation, standardized predictions of episodic memory score by age and music activity engagement were generated and then plotted from the regression model. To put the effects of music engagement in context, we also estimated the same model with a linear effect of age to obtain an estimate of the population-based rate of decline in episodic memory, upon which to measure the magnitude of the music engagement effects. If a significant result is found for this model, secondary sensitivity analyses will be conducted to further understand the relationship between music and episodic memory. The same multivariable linear regression described above will be used in these analyses. However, in this regression we used the three-level music variable as a predictor variable. All statistical analyses were conducted with Stata (version 16, Stata Corp., College Station, TX).

RESULTS

Demographics

Of the 4,592 participants from the HRS data set that were included in our data analysis, 856 (18.6%) reported they did not engage with music passively in the last week or actively in the last month, 2,824 (61.5%) reported they engaged with music passively or actively, and 912 (19.9%) reported they engaged with music both passively and actively. Of these participants, 3,659 (79.7%) indicated that they passively engaged with music by listening to music in the last week and 989 (21.5%) indicated that they were actively engaged with music by either singing or playing an instrument in the last month. On average, the sample was over 65 years of age, the majority were married, White, and female, and they had over 12 years of education. Most participants engaged in low levels of physical activity and were considered to be overweight or obese, however they also self-rated their health as excellent or very good and most did not have difficulties with ADLs or IADLs. The overall sample demographics are summarized in Table 1.

Respondents who listened to music were younger, more likely to be married, had higher levels of education and higher household income, and were more likely to be working compared with people who did not listen to music. Those who listened to music had fewer chronic conditions and depressive symptoms, less difficulty with ADLs and IADLs, self-reported their health as excellent or very good, and had higher levels of physical activity. Participants who listened to music performed significantly better on tasks of episodic memory compared to those who did not (p <.001). The between group differences are presented in Table 2.

Participants who sang or played an instrument were younger, more likely to be female, White, married, and working, and had higher levels of education compared with participants who did not sing or play an instrument. Those who sang or played an instrument had less difficulty with ADLs, had fewer chronic conditions and depressive symptoms, reported their health as excellent or very good, and were more likely to have moderate or high levels of physical activity. Finally, participants who sang or played a musical instrument performed significantly better on tasks of episodic memory compared to those who did not sing or play an instrument ($p < .001$). The between group differences are reported in Table 2.

Regression Results

Results from the multivariable linear regression analysis are reported in Table 3. The model accounted for 26.7% of the total variance in episodic memory scores ($R^2 = .267$, $p < .001$). Respondents who reported music listening on average recalled 0.443 more words on the episodic memory tasks than those who did not ($p = .002$), and those who reported singing or playing an instrument on average recalled 0.396 more words than those who did not ($p = .006$). The sensitivity analyses found that participants who both listened to music and sang/played an instrument recalled, on average, 0.809 more words on the episodic memory tasks than those who did not engage in either ($p < .001$).

The results also indicated that age was significantly associated with performance on episodic memory tasks, with older participants performing worse on these tasks (-0.083, $p < 0.001$). In the context of aged-related differences in episodic memory, passive music engagement (i.e., listening to music) was equivalent to a 4.6-year difference, whereas active engagement (i.e., singing or playing an instrument) was equivalent to a 4.4-year difference. Respondents who were older, Black, had difficulties with IADLs, reported more chronic conditions, more depressive symptoms, worse self-rated health, and smoking performed lower on the assessment of episodic memory. Respondents who had higher education, higher income, and higher levels of physical activity performed better on the episodic memory assessment.

Figure 2a and 2b show the adjusted effect of music activity engagement with episodic memory by age group. In Figure 2a, the advantage in episodic memory among music listeners was consistent across all age groups. Additionally, while the benefit appeared to be most prominent between the ages of 65-79, the differences did not reach statistical significance. In Figure 2b, the episodic memory advantage for people who sang or played an instrument was also found to be consistent across all age groups.

DISCUSSION

The goal of this study was to examine whether music engagement (i.e., listening to music, singing, or playing an instrument) was related to episodic memory in a nationally representative sample of middle-aged and older adults in the United States. The first major finding is that persons who listened to music performed better on tasks of episodic memory than those who did not listen to music. The second major finding is that persons who sang or played an instrument also performed better on tasks of episodic memory compared to those who did not sing or play an instrument. The final major finding is that those who listened to music and sang or played an instrument performed better on tasks of episodic memory compared to those who did not engage in either forms of music. These findings provide support for our hypothesis that regular music engagement in everyday life, regardless of if passive or active, is associated with higher levels of episodic memory. This study also suggests that persons who engage with music both passively and actively may experience a cumulative advantage toward their episodic memory. To our knowledge, this is the first study documenting this effect in a national sample of middle-aged and older adults in the U.S.

In a study by Innes and colleagues (2017), a music listening intervention (i.e., 12 minutes of listening to instrumental music for 12 weeks) resulted in a subjective improvement of memory abilities, with over 55% of participants reporting better memory performance when compared to baseline. The intervention also led to an enhanced performance on tasks of attention, executive function, memory, and processing speed (Innes et al., 2017). Our results agree with and extend the findings reported by Innes et al. (2017) by virtue of specifically looking at one aspect of memory and by also examining the influence of active music engagement on memory outcomes. Additionally, a study by Bugos (2010) found that participants who were involved in either a piano instruction group or a listening to music group, performed better on cognitive tasks (i.e., processing speed, verbal fluency, and cognitive control) compared to those that did not. The findings from our study also align with these reported by Bugos (2010), providing further support for favorable cognitive outcomes when people engage with music actively or passively. Furthermore, while our study focused on episodic memory, studies such as these that have measured multiple cognitive outcomes, suggest that the effects of music, whether one is simply listening (i.e., passive engagement) or playing (i.e., active engagement), are not localized to episodic memory alone. In addition to the previous findings, the present study contributes to prior research by suggesting that music can be beneficial for adults of different sociodemographic groups that may having varying health conditions. This information is important because it can aid in the creation of future studies to develop prevention tools using music for diseases like Alzheimer's, which has recently been identified as a research priority by the National Institute on Aging.

A number of study limitations should be considered when interpreting the findings. The study used self-reported music engagement data (i.e., listening and singing/playing a musical instrument) as the key independent variable, and this may have led to recall bias. However, because the time window of recall was set at the past week for listening to music and month for singing/ playing an instrument, and we used only the binary variables (any listening and any singing/playing), this concern should be minimized. A second limitation is that the music variables did not have information on how long people had been engaging in music and they did not incorporate questions that asked participants about how they engaged with music (i.e., type of music, type of instrument, nature of listening practices). Therefore, we were not able to assess the effect of the duration of music engagement on episodic memory. Future studies should examine whether longer duration of music engagement is associated with better performance on episodic memory tasks. We were also unable to investigate whether there was any dose response for music engagement in various music activities. Future studies should incorporate analyses to further understand if engagement styles influence episodic memory outcomes. An additional limitation is that there was no clinical assessment for the presence of dementia. Participants therefore could have been in the prodromal stage of dementia, which would have influenced their ability to accurately report their engagement levels with music and their ability to perform well on the episodic memory tasks. To the extent that all proxy respondents were excluded from the analytic sample, we believe this is unlikely to bias our results. Finally, results are representative of middle-aged and older Americans and therefore may not be generalizable to other age groups and in other countries.

In conclusion, this study was one of the first to assess the relationship between passive and active music engagement and performance on tasks of episodic memory in a large population-based sample of adults. We found that persons who listened to music performed significantly better on these tasks compared to those who did not. In addition, we found that those who sang or performed an instrument also performed better on these tasks compared to those who did not. Further research is required to better understand if music engagement can be utilized as a preventative intervention to mitigate age-related declines in cognition, as well as to delay or prevent the onset of dementia.

REFERENCES

Abrahan, V., Shrifes, F., & Justel, N. (2019). Cognitive benefits from a musical activity in older

adults. *Frontiers in Psychology, 10*(652), 1-14.

http://doi.org/10.3389/fpsyg.2019.00652

Amer, T., Kalender, B., Hasher, L., Trehub, S., & Wong, Y. (2013). Do older professional musicians have cognitive advantages? *PLoS One*, *8*(8), 1-8. http://doi.org/10.1371/journal.pone.0071630

Backman, L., Small, B., & Fratiglioni, L. (2001). Stability of the preclinical episodic memory deficit in Alzheimer's disease. *Brain*, *124*(1), 96-102. http://doi.org/10.1093/brain/124.1.96

Balbag, M., Pedersen, N., & Gatz, M. (2014). Playing a musical instrument as a protective factor against dementia and cognitive impairment: A population-based twin study. *International Journal of Alzheimer's Disease, 2014*(836748), 1-6. http://doi.org/10.1155/2014/836748

Blood, A., Zatorre, R., Bermudez, P., & Evans, A. (1999). Emotional responses to pleasant and unpleasant music correlate with activity in paralimibic brain regions. *Nature Neuroscience*, *2*(4), 382-387. http://doi.org/10.1038/7299

Bottiroli, S., Rosi, A., Russo, R., Vecchi, T., & Cavallini, E. (2014). The cognitive effects of listening to background music on older adults: Processing speed improves with upbeat music, while memory seems to benefit from both upbeat and downbeat music. *Frontiers in Aging Neuroscience, 6*(284), 1-7. http://doi.org/10.3389/fnagi.2014.00284

Boraxbekk, C., Lundquist, A., Nordin, A., Nyberg, L., Nilsson, L., & Adolfsson, R. (2015).

Free

recall episodic memory performance predicts dementia ten years prior to clinical diagnosis: Findings from the Betula Longitudinal Study. *Dementia and Geriatric Cognitive Disorders, 5*, 191-202. http://doi.org/10.1159/000381535

Bugos, J.A. (2010). The benefits of music instruction on processing speed, verbal fluency, and

cognitive control in aging. *Music Education Research International, 4*, 1–9.

Bugos, J.A. (2019). The effects of bimanual coordination in music interventions on executive functions in aging adults. *Frontiers in Integrative Neuroscience* 13*(68)*, 1-13. http://doi.org/10.3389/fnint.2019.00068

Bugos, J.A., Perlstein, W., McCrae, C., Brophy, T., & Bedenbaugh, P. (2007). Individualized piano instruction enhance executive functioning and working memory in older adults. *Aging and Mental Health, 11*(4), 464-471. http://doi.org/10.1080/13607860601086504

Crimmins, E., Kim, J., Langa, K., & Weir, D. (2011). Assessment of cognition using surveys and

neuropsychological assessment: The Health and Retirement Study and the Aging, Demographics, and Memory Study. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 66B*(S1), I162-I171. http://doi.org/10.1093/geronb/gbr048

Fancourt, D., Steptoe, A., & Cadar, D. (2018). Cultural engagement and cognitive reserve: museum attendance and dementia incidence over a 10-year period. *The British Journal of Psychiatry, 213*(5), 661-663. http://doi.org/10.1192/bjp.2018.129

Fisher, G., Hassan, H., Faul, J., Rogers, W., & Weir, D. (2017). Health and Retirement Study imputation of cognitive functioning measures: 1992 – 2008. Data Description.

Gold, C., Eickholt, J., Assmus, J., Stige, B., Wake, J., Baker, F., Tamplin, J., Clark, I., Lee, Y.,
Jacobsen, S., Ridder, H., Kreutz, G., Muthesius, D., Wosch, T., Ceccato, E., Raglio, A.,
Ruggeri, M., Vink, A., Zuidema, S., . . . Geretsegger, M. (2019). Music Interventions for Dementia and Depression in ELderly care (MIDDEL): Protocol and statistical analysis plan for a multinational cluster-randomised trial. *BMJ Open*, *9*(e023436), 1-14. http://doi.org/10.1136/bmjopen-2018-023436

Hanna-Pladdy, B. & MacKay, A. (2011). The relation between instrumental music activity and
cognitive aging. *Neuropsychology*, *25*(3), 378-386. http://doi.org/10.1037/a0021895

He, W., Wong, W., & Hui, A. (2017). Emotional reactions mediate the effect of music listening
on creative thinking: Perspective of the arousal-and-mood hypothesis. *Frontiers in Psychology*, *8*(1680), 1-12. http://doi.org/10.3389/fpsyg.2017.01680

Hurd, M., & Rohwedder, S. (2009). Methodological innovations in collecting spending data: The
HRS Consumption and Activities Mail Survey. *Fiscal Studies: The Journal of Applied Public Economics*, *30*(3/4), 435-459. http://doi.org/10.1111/j.1475-5890.2009.00103.x

Innes, K., Selfe, T., Brundage, K., Montgomery, C., Wen, S., Kandati, S., Bowles, H., Khalsa,
D., & Huysmans, Z. (2018). Effects of meditation and music-listening on blood biomarkers of cellular aging and Alzheimer's disease in adults with subjective

cognitive decline: An exploratory randomized clinical trial. *Journal of Alzheimer's Disease, 66*(3), 947-970. http://doi.org/10.3233/JAD-180164

Innes, K., Selfe, T., Khalsa, D., & Kandati, S. (2017). Meditation and music improve memory and cognitive function in adults with subjective cognitive decline: A pilot randomized controlled trial. *Journal of Alzheimer's Disease, 56*(3), 899-916. http://doi.org/10.3233/JAD-160867

Juster, F.T & Suzman, R.M. (1995). An overview of the Health and Retirement Study. *The Journal of Human Resources, 30*, S7-S56. http://doi.org/10.2307/146277

Lee, P.H., Macfarlane, D.J., Lam, T.H., & Stewart, S.M. (2011). Validity of the international physical activity questionnaire short form (IPAQ-SF): A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 8*(115), 1-11. http://doi.org/10.1186/1479-5868-8-115

Mammarella, N., Fairfield, B., & Cornoldi, C. (2007). Does music enhance cognitive performance in healthy older adults? The Vivaldi effect. *Aging Clinical and Experimental Research, 19*(5), 394-399. http://doi.org/10.1007/BF03324720

Nyberg, L., Lovden, M., Riklund, K., Lindenberger, U., & Backman, L.(2012). Memory aging

and brain maintenance. *Trends in Cognitive Science, 16*(5), 292-305. https://doi.org/10.1016/j.tics.2012.04.005

Roman-Caballero, R., Arnedo, M., Trivino, M. & Lupianez, J. (2018). Musical practice as an enhancer of cognitive function in healthy aging- A systematic review and meta-analysis. *PLoS One, 13*(11), 1-23. http://doi.org/10.1371/journal.pone.0207957

Saliba, D., Orlando, M., Wenger, N., Hays, R., & Rubensetin, L. (2000). Identifying a short functional disability screen for older persons. *The Journals of Gerontology: Series A, 55*(1), M750-M756. http://doi.org/10.1093/Gerona/55.12.M750

Schneider, C., Hunter, E., & Bardach, S. (2018). Potential cognitive benefits from playing music among cognitively intact older adults: A scoping review. *Journal of Applied Gerontology, 38*(12), 1763-1783. http://doi.org/10.1177/0733464817751198

Sonnega, A., Faul, J., Ofstedal, M., Langa, K., Phillips, J., & Weir, D. (2014). Cohort profile: The Health and Retirement Study (HRS). *International Journal of Epidemiology, 43*(2), 576-585. http://doi.org/10.1093/ije/dyu067

Steffick, D.E. (2000). Documentation of affective functioning measures in the Health and Retirement Study. *HRS Documentation Report DR-005.* http://hrsonline.isr.umich.edu/sitedocs/userg/dr-005.pdf

Thompson, W., Schellenberg, E., & Husain, G. (2001). Arousal, mood, and the Mozart effect. *Psychological Science, 12*(3), 248-251. http://doi.org/10.1111/1467-9280.00345

Turvey, C., Wallace, R., & Herzog, R. (1999). A revised CES-D measure of depressive symptoms and a DSM-based measure of major depressive episodes in the elderly. *International Psychogeriatrics, 11*(2), 139-148. http://doi.org/10.1017/s1041610299005694

Verghese, J., Lipton, R., Katz, M., Hall, C., Derby, C., Kuslansky, G., Ambrose, A., Silwinski, M., & Buschke, H. (2003). Leisure activities and the risk of dementia in the elderly. *The New England Journal of Medicine, 348*(25), 2508-2516. http://doi.org/10.1056/NEJMoa022252

Wagster, V., King, J., Resnick, S., & Rapp, P. (2012). The 87%. *Journal of Gerontology: Medical Sciences, 67*(7), 739-740. http://doi.org/10.1093/gerona/gls140

Wallace, R. & Herzog, A. (1995). Overview of the health measures in the Health and Retirement Study. *The Journal of Human Resources, 30*, S84-S107. http://doi.org/10.2307/146279

TABLES

1

Variable	Total
Age, years, M±SD	68.02±9.84
Female	55.69%
Race/ethnicity	
White	82.23%
Black	8.13%
Hispanic	6.91%
Other	2.73%
Marital status	
Married or partnered	65.48%
Separated, divorced, or never married	20.58%
Widowed	13.93%
Education, years, M±SD	13.64±0.06
Household income (% of poverty level)	
<100	5.76%
100-199	13.14%
200-299	13.32%
300-499	19.24%
>=500	48.54%
Working for pay	39.59%
Health and Functional Status	
Difficulty in ADL	13.47%
Difficulty in IADL	11.13%
Number of chronic conditions, M±SD	2.21±1.37
Depressive symptoms, M±SD	1.25±1.49
Self-reported health	
Excellent/very good	42.54%
Good	34.85%
Fair/poor	22.60%
BMI, kg/m^2, M±SD	28.46±6.06
BMI category	
Underweight	1.43%
Normal	25.94%
Overweight	38.73%
Obese	33.90%
Level of physical activity	
Low	42.31%
Moderate	21.42%
High	36.27%

Note. All estimates have been adjusted for the complex survey design. ADL= Activities of Daily Living; IADL= Instrumental Activities of Daily Living; BMI= Body Mass Index.

2

Variable	Listening to music			Singing or playing musical instrument		
	Yes	No	p value	Yes	No	p value
Total word recall score	10.54	9.31	<.001	11.05	10.11	<.001
Sociodemographic Variables						
Age, years (M)	67.09	71.96	<.001	66.40	68.45	<.001
Female	55.11	58.16	0.227	65.51	53.04	<.001
Race/ethnicity (%)						
White	82.06	82.99	0.167	81.04	82.55	0.034
Black	8.57	6.27		10.38	7.52	
Hispanic	6.74	7.63		5.66	7.25	
Other	2.64	3.12		2.92	2.68	
Marital status (%)						
Married or partnered	66.26	62.17	0.001	69.40	64.43	<.001
Separated, divorced, or never married	21.13	18.24		20.58	20.58	
Widowed	12.61	19.59		10.02	14.99	
Education, years (M)	13.73	13.22	<.001	14.04	13.53	<.001
Household income (% of poverty level)						
<100	5.28	7.80	<.001	4.33	6.14	0.064
100-199	11.83	18.76		12.14	13.41	
200-299	12.63	16.28		12.27	13.61	
300-499	19.79	16.84		22.55	18.34	
>=500	50.47	40.32		48.72	48.50	
Working for pay	42.92	25.34	<.001	44.30	38.32	0.019
Health and Functional Status						
Difficulty in ADL (%)	12.00	19.75	<.001	11.41	14.02	0.083
Difficulty in IADL (%)	9.89	16.44	<.001	10.20	11.38	0.372
Number of chronic conditions (M)	2.14	2.55	<.001	2.09	2.25	0.030
Depressive symptoms (M)	1.20	1.44	0.005	1.12	1.29	0.053
Self-reported health (%)						
Excellent/very good	43.92	36.65	<.001	48.35	40.98	0.003

Good	35.52	32.00		33.37	35.25	
Fair or poor	20.55	31.35		18.28	23.77	
BMI, kg/m2 (M)	28.51	28.22	0.227	28.50	28.44	0.801
Underweight	1.27	2.07	0.392	0.81	1.59	0.300
Normal	25.62	27.32		26.39	25.82	
Overweight	38.97	37.68		38.87	38.69	
Obese	34.13	32.93		33.93	33.90	
Level of physical activity						
Low	39.45	54.55	<.001	34.30	44.48	<.001
Moderate	22.10	18.50		25.10	20.42	
High	38.45	26.95		40.60	35.10	

Note. ADL= Activities of Daily Living; IADL= Instrumental Activities of Daily Living; BMI= Body Mass Index.

3

Variable	Estimates	SE	p value
Listening to music	0.443	0.137	0.002
Singing or playing	0.396	0.139	0.006
Age			
50-64	Reference		
65-75	-0.180	0.182	0.327
75-85	-0.722	0.181	<.001
85+	-2.341	0.208	<.001
Female	1.051	0.105	<.001
Race/ethnicity			
White	Reference		
Black	-1.02	0.202	<.001
Hispanic	-0.068	0.236	0.774
Other	-0.300	0.386	0.441
Marital status			
Married	Reference		
Separated, divorced, or never married	-0.091	0.186	0.628
Widowed	0.097	0.168	0.565
Education	0.243	0.018	<.001
Household income			
<100	Reference		
100-199	0.176	0.249	0.482
200-299	0.488	0.293	0.102
300-499	0.565	0.227	0.016
>=500	0.909	0.255	0.001
Working for pay	0.326	0.140	0.024
Difficulty in ADL	0.061	0.175	0.728
Difficulty in IADL	-0.613	0.188	0.002
Number of chronic conditions	-0.115	0.045	0.014
Depression symptoms	-0.047	0.038	0.235
Self-reported health			
Excellent/ very good	Reference		
Good	-0.265	0.119	0.030
Fair or poor	-0.294	0.196	0.139
BMI category			
Normal weight	Reference		
Underweight	0.526	0.492	0.289
Overweight	0.154	0.144	0.290
Obese	0.350	0.141	0.016
Level of physical activity			
Low	Reference		
Moderate	0.478	0.146	0.002
High	0.450	0.127	0.001

Note. ADL= Activities of Daily Living; IADL= Instrumental Activities of Daily Living; BMI= Body Mass Index.

Table Titles and Figure Captions

Figure 1

Flowchart Depicting How the Participants Were Obtained for This Study.

Table 1

Characteristics of the Sample of U.S. Adults.

Table 2

Sample Characteristics by Type of Engagement in Music Activities.

Table 3

Regression Results of Music Activities on Total Word Recall Score

Figure 2

Covariate-Adjusted Association Between (A) Age, Music Listening, and Episodic Memory and (B) Age, Singing/Playing an Instrument, and Episodic Memory.

Figure 1

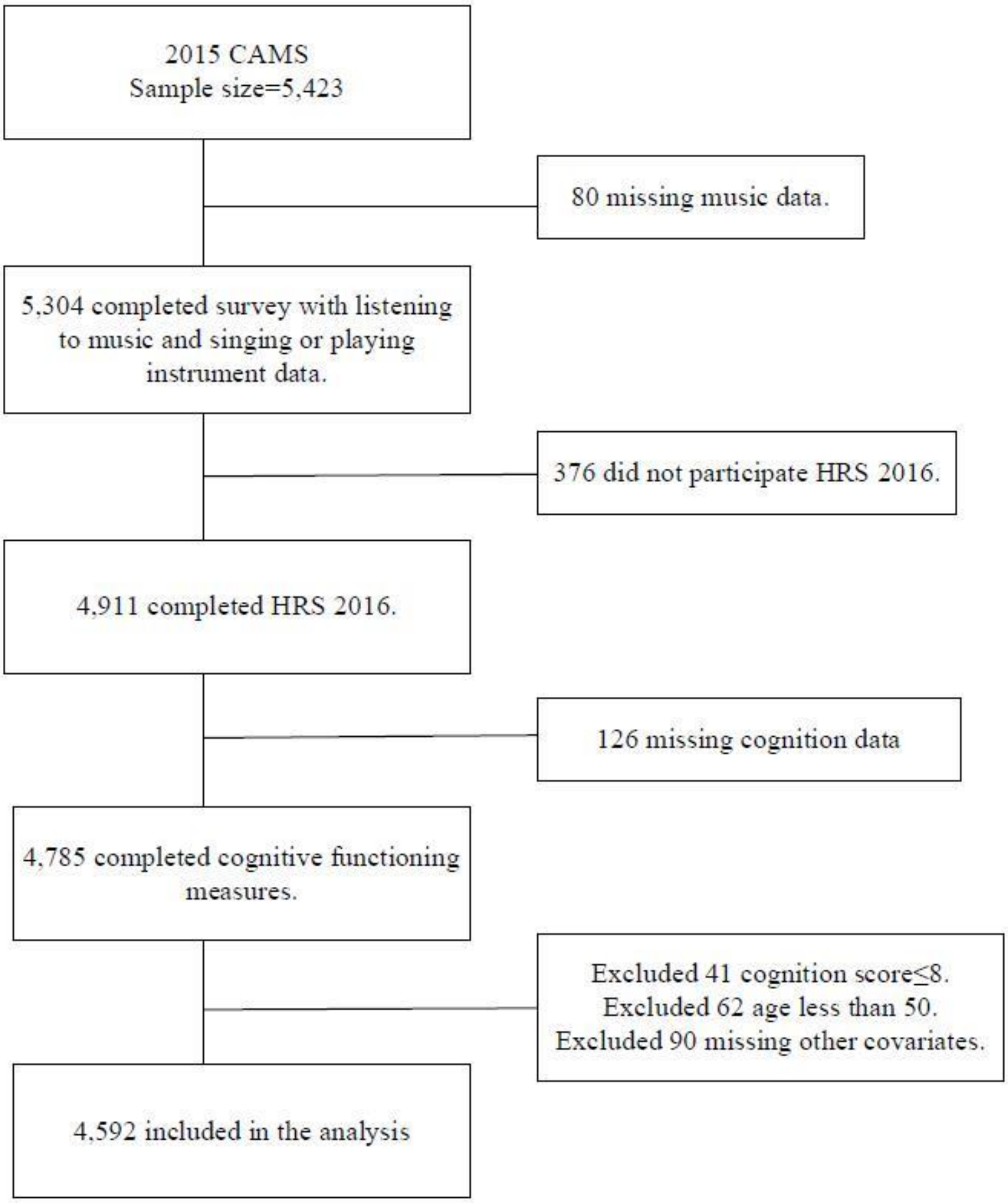
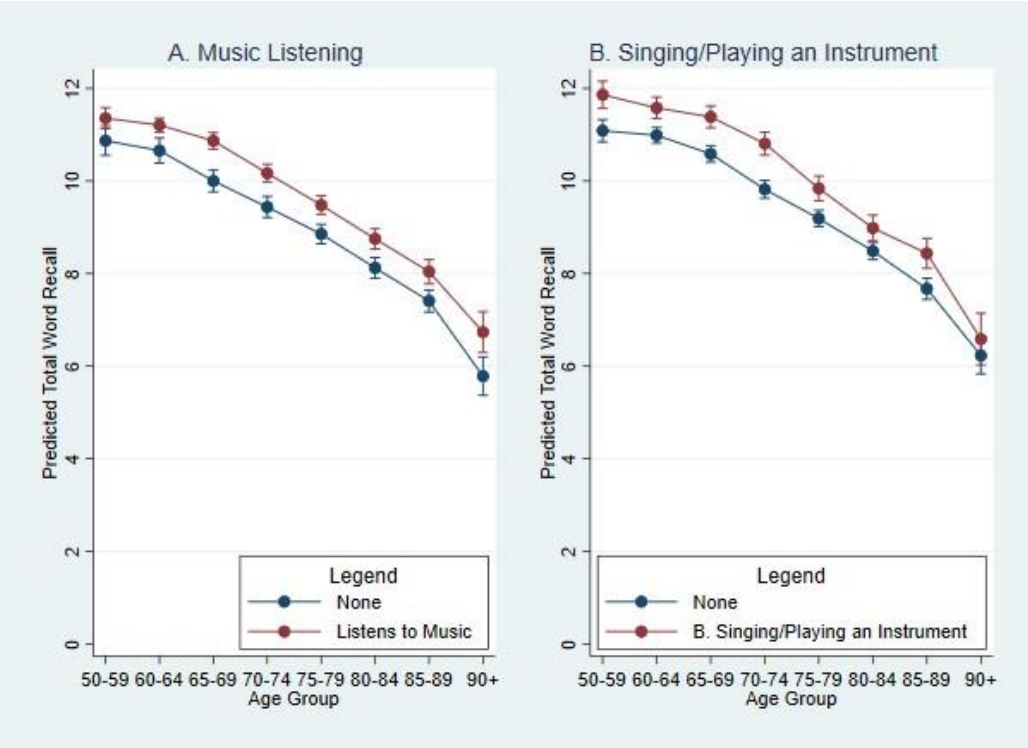

2015 CAMS
Sample size=5,423
80 missing music data.
5,304 completed survey with listening to music and singing or playing instrument data.
376 did not participate HRS 2016.
4,911 completed HRS 2016.
126 missing cognition data
4,785 completed cognitive functioning measures.
Excluded 41 cognition score≤8.
Excluded 62 age less than 50.
Excluded 90 missing other covariates.
4,592 included in the analysis

Figure 2



A. Music Listening
Predicted Total Word Recall
Legend
None
Listens to Music
50-59 60-64 65-69 70-74 75-79 80-84 85-89 90+
Age Group
B. Singing/Playing an Instrument
Predicted Total Word Recall
Legend
None
B. Singing/Playing an Instrument
50-59 60-64 65-69 70-74 75-79 80-84 85-89 90+
Age Group