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The Effects of Song Familiarity and Age on Phenomenological Characteristics and Neural Recruitment During Autobiographical Memory Retrieval

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Recent research suggests that emotional music clips can serve as a highly successful tool for eliciting rich autobiographical memories, and that the utility of these cues may be related to their subjective familiarity. The current study was designed to examine the effects of familiarity on phenomenological characteristics and neural recruitment during retrieval of autobiographical memories elicited by musical cues. Further, we were interested in understanding how these effects differ as a function of age. In an event-related functional neuroimaging study, participants retrieved autobiographical memories associated with age-specific popular musical clips. Participants rated song familiarity, as well as the temporal specificity and emotional valence of each memory. Song familiarity was associated with increased dorsal medial prefrontal cortex (dmPFC) activity and ratings of temporal specificity and positivity across participants. In addition, behavioral and neuroimaging findings suggest age differences in familiarity-related effects in which familiarity was more associated with enhancement of memory detail in young adults and affective positivity in older adults. These findings highlight important age-related shifts in how individuals retrieve autobiographical events and how personally relevant musical cues may be used to facilitate memory retrieval.

Keywords: music, memory, aging, emotion, fMRI

Autobiographical memories are our personal record of the past, making their retrieval integral to our well-being. Since not all memories are associated with the same degree of richness at the time of retrieval, it is important to understand the individual subject and stimulus-related factors that separately or interactively influence the richness of autobiographical memories. In other words, it is important to identify features that enhance memory retrieval, and to consider how such enhancements differ across individuals. Although it is difficult to evaluate retrieval accuracy in autobiographical memory tasks due to a lack of a controlled research environment at encoding, it is possible to isolate factors that increase memory success (i.e., the ability to retrieve a memory associated with a retrieval cue) or memory richness (i.e., subjective or objective ratings of the quality of retrieved events). Prior research suggests that emotional music clips can serve as a highly successful tool for eliciting rich autobiographical memories (Barrett et al., 2010; Cady, Harris, & Knappenberger, 2008; Ford, Addis, & Giovanello, 2011, 2012, 2014; Janata, 2009b; Janata, Tomic, & Rakowski, 2007; Schulkind & Woldorf, 2005). Indeed, Schulkind and Woldorf (2005) found that retrieval success in their

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autobiographical memory study (82%) was higher than that in a similar study utilizing verbal retrieval cues (61%; Rubin & Schulkind, 1997). These findings highlight the potential for musical cues to lead to enhanced retrieval relative to traditional word cues.

There is reason to believe that such mnemonic enhancement may be related to the familiarity of musical cues, where highly familiar musical cues support a richer memory representation. Specifically, self-reported song familiarity has been associated with enhanced ratings of nostalgia (Barrett et al., 2010) and autobiographical salience (Janata et al., 2007) in young adult participants. This relation between song familiarity and autobiographical salience is further supported by functional neuroimaging data showing that these processes have overlapping neural networks. Specifically, these studies reveal significant modulation of prefrontal regions as a function of song familiarity (Janata, 2009b; Plailly, Tillmann, & Royet, 2007; Platel, Baron, Desgranges, Bernard, & Eustache, 2003) and highlight a critical role of these regions in self-referential processing during autobiographical memory retrieval (Gilboa, 2004; Svoboda, McKinnon, & Levine, 2006).

The overlap of regions associated with music familiarity and autobiographical memory retrieval has led Janata (2009a) to propose that the medial prefrontal cortex (mPFC) is a critical hub that is involved in the association of music, emotion, and autobiographical memories. This proposal has been supported by an autobiographical memory study in which the dorsal medial prefrontal cortex (dmPFC) responded parametrically to ratings of both autobiographical salience and song familiarity, and tracked the movements of clips through tonal space (Janata, 2009b). Additionally, an autobiographical memory study from our lab utilized a musical cuing paradigm to identify neural regions associated with increased temporal specificity in a young adult sample. In that study, the dmPFC was linearly related to temporal specificity, showing greater recruitment during retrieval of events relative to lifetime periods, as well as greater recruitment during retrieval of specific events relative to general events (Ford et al., 2011). Together, these findings suggest that the dmPFC may be involved in enhancing phenomenological characteristics during memory retrieval, leading to a richer, more vivid memory representation.

The research described above has largely focused on memory enhancements in young adults; however, the enhancing effects of song familiarity may be more important to consider in populations with reported deficits in memory retrieval, such as healthy older adults. Prior research has revealed significant age-related changes in the phenomenological qualities of autobiographical memories, with older adults retrieving autobiographical information that is overly general (i.e., lacking temporal specificity in place and time) relative to young adults' temporally specific memories (Piolino, Desgranges, & Eustache, 2009). If song familiarity can increase memory richness in young adults, it is possible that it may also enhance richness in older adults, and that this enhancement may reduce age-related deficits during retrieval. There is some evidence to suggest that music may disproportionately facilitate retrieval in older adults; prior research has revealed greater facilitative effects of emotional music on older adults' semantic (Schulkind, Hennis, & Rubin, 1999) and autobiographical (Schulkind & Woldorf, 2005) memory retrieval compared to young adults. This enhancement is consistent with findings that music has been useful in improving retrieval of autobiographical material in individuals diagnosed with Alzheimer's disease (Cuddy & Duffin, 2005; Foster & Valentine, 2001; Irish et al., 2006).

Although studies of retrieval success suggest that the use of musical cues may enhance older adults' memory retrieval, there is reason to believe that increased support during retrieval, in the form of enhanced familiarity, may not lead to corresponding increases in older adults' memory specificity. In a recent study, instructions to provide temporally specific events significantly increased specificity of young adults' memories, but did not affect specificity in older adults (Ford, Rubin, & Giovanello, 2014). This distinction suggests that external support from experimental manipulations may differentially influence retrieval mechanisms across the life span. Song familiarity may serve a similar function as a source of retrieval support intrinsic to the experimental task, increasing temporal specificity in young adults but not in older adults.

It is notable that healthy aging is associated with other significant changes to autobiographical memory retrieval that could be related to song familiarity. Older adults exhibit a positivity effect, or a tendency to retrieve autobiographical memories that are self-rated as more positive than those retrieved by younger adults (Dijkstra & Kaup, 2005; Singer, Rexhaj, & Baddeley, 2007). It has been suggested that age-related changes in motivation lead to a strategic shift in control processes toward affective goals and away from specific detail retrieval (Mather & Carstensen, 2005). Such shifts may cause older adults to focus on aspects of a memory that increase the positivity of the memory at the expense of specific event details. Therefore, while young adults may exhibit enhanced memory specificity as a function of increased familiarity, older adults may instead benefit from increased positivity.

The current study was designed to examine the effects of stimulus familiarity on the phenomenological characteristics and neural recruitment associated with personal autobiographical memories. Further, we were interested in whether these relations would differ in young and older adults. In an event-related fMRI study, participants were presented with age-specific popular musical clips and asked to retrieve related autobiographical information while in the scanner. Participants rated song familiarity, as well as the temporal specificity and emotional valence of each memory. This paradigm is similar to that used in a number of prior behavioral (Barrett et al., 2010; Cady et al., 2008; Ford, Addis, & Giovanello, 2012, 2014; Janata et al., 2007) and imaging studies (Ford et al., 2011; Janata, 2009b). We hypothesized that increased song familiarity would lead to greater memory specificity, and that dmPFC activity would be related to both measures in young adults. Such findings would support prior work implicating the dmPFC in the integration of music familiarity and autobiographical salience (Janata, 2009b). The extant literature leads to two alternative hypotheses regarding the effects of song familiarity on retrieval in older adults: the increased effect of music on memory retrieval in older adults relative to young adults (Schulkind & Woldorf, 2005) suggests that age could be associated with *increased* effects of familiarity on specificity and recruitment, whereas reduced effects of task instruction on memory specificity in older adults relative to young adults (Ford et al., 2014) suggests that age could be associated with *decreased* effects of familiarity. The current study examined these competing patterns, as well as the possibility that another phenomenological characteristic, positive valence, may be associated with increased familiarity in place of increased temporal specificity.

Method

Participants

Fifteen healthy young adults (*M* age = 21.4, *SD* = 2.77, range = 18–27; *M* education = 14.93, *SD* = 2.63, range = 12–21; 8 male) and 16 healthy older adults (*M* age = 70.31, *SD* = 7.27, 61–86; *M* education = 17.94, *SD* = 2.05, 14–21; 5 male) participated in the current study. One additional young adult (age = 27, edu = 16, female), and five additional older adults (*M* age = 71.40, *SD* = 9.42, 63–87; *M* edu = 15.40, *SD* = 3.13; all female) were tested, but excluded. These participants were excluded due to task noncompliance (two older adults), not retrieving enough personal memories to include in the fMRI analysis (fewer than 15 trials; one young adult and one older adult), a high depression score (one older adult), or revealing during testing that she was primarily left-handed (one older adult). Participants were all right-handed native English speakers without a history of psychiatric illness, neurological disorder, or hearing impairment. Young adults were recruited using flyers posted on the University of North Carolina campus. Older adults were recruited from the lab's database. All participants were paid for their participation and gave written informed consent in accordance with the requirements of the Institutional Review Board at the University of North Carolina.

All older adults received a general health screen and completed a battery of neuropsychological tests to assess memory, language, attention, visuospatial abilities, and general cognitive functioning. These tests included the Mini Mental State Examination (MMSE), forward and backward Digit Span, immediate and delayed logical memory test, Trail Making Test parts A and B, Controlled Oral Word Association Test (COWAT), and Vocabulary from the WAIS-III. Older adults were also screened for depression using the short-form Geriatric Depression Scale (GDS; 15-items; Brink et al., 1982; Yesavage et al., 1982–1983), a scale particularly designed to consider the unique characteristics of depression in this population (Jarvik, 1976; Wells, 1979). Mean raw scores are listed in Table 1. All older adults performed within the normal range for each task.

Table 1
Neuropsychological Information for Older Adults

Cognitive test	Mean score (*SD*)	Range
Depression scale (GDS)	.69 (1.40)	0–5
MMSE	29.63 (.50)	29–30
Digit span forward	10.44 (2.99)	5–16
Digit span backward	7.75 (2.29)	4–11
Logical memory immediate	27.50 (8.24)	14–41
Logical memory delay	24.56 (7.80)	14–39
Trails A time	27.88 (9.36)	16–50
Trails B time	56.38 (14.54)	37–86
COWAT	54.06 (12.28)	30–76
Vocabulary (WAIS-III)	53.31 (12.48)	31–66

Note. GDS = Geriatric Depression Scale; MMSE = Mini-mental state exam; COWAT = Controlled oral word association test. Group means are presented; Standard deviations are presented in parentheses.

Materials

In the current study, retrieval cues consisted of 30-s musical clips. Songs were downloaded from the iTunes music store and converted into WAV files. These clips came from three categories of songs. The first two categories (used for the experimental trials) consisted of songs that were popular in the years spanning the late childhood, adolescence, and early adulthood of participants in each age-group (2000 to 2009 for young adults; 1950s for older adults; see Appendix Table A1). Presenting young and older adults with age-specific songs provided the opportunity to control for the age of encoding, an important variable to consider when comparing autobiographical memories. In addition, it was of particular importance that the songs act as salient cues for older adults. Previous research has demonstrated that songs from an individual's youth are remembered best and are associated with greater ratings of emotionality (Schulkind et al., 1999), making these songs ideal for the current experiment. Songs were selected from the top 10 most popular songs from each year, and many of these songs have remained popular. Subsequent exposure to these songs allowed for a greater variety of events that could be retrieved during the task and a range in the recency of older adults' memories.

The third category of songs was utilized during a semantic control task (see below for a detailed description). In this task, participants were asked to listen to music and provide a single adjective to describe each piece. Stimuli for this task were selected from a list of songs from Oscar-nominated movies and were pilot tested to identify the pieces with the lowest levels of familiarity and autobiographical salience for both young and older adults.

Procedure

Thirty experimental trials and 10 semantic control trials were evenly distributed across four sessions in the scanned autobiographical memory retrieval task. The order of the lists was counterbalanced across participants, and trials were randomized within each list. Before each trial, participants were presented with a 2–4-s verbal instruction ("personal" for experimental trials or "adjective" for semantic trials) to orient them to the appropriate retrieval task. During each experimental trial, participants were presented with a 30-s music clip and asked to retrieve a personal memory associated with the cue. They were instructed to retrieve the memory covertly and to press a response button inside the scanner when the memory was retrieved. Following the musical cue, participants rated the memory valence (*1 = highly negative*, *2 = somewhat negative*, *3 = neutral*, *4 = somewhat positive*, *5 = highly positive*) and song familiarity (*1 = highly unfamiliar/no familiarity*, *2 = low familiarity*, *3 = medium familiarity*, *4 = high familiarity*, *5 = very high familiarity*). Participants had six seconds for each response. After completing the ratings, the participants were instructed to prepare for the next trial.

During each semantic control trial, participants were presented with a 30-s clip from a song from an Oscar-nominated movie and asked to provide a single adjective to describe the piece. This task was designed to control for the presence of music, the motor response associated with the button press, and memory processes related to recall of task instructions. These trials were included to allow for examination of individual conditions (e.g., "all autobiographical memory retrieval"), but were unnecessary in the current parametric analysis in which all levels share the same confounds and, therefore, these confounds cancel out in the analysis. As such, these trials were not included in the not current analysis and will not be discussed further.

After all four scanned retrieval runs, participants were removed from the scanner and presented with the musical clips a second time during a recorded postretrieval interview. Such interviews are standard in fMRI studies examining autobiographical memory retrieval (Addis, Wong, & Schacter, 2007; Botzung, Denkova, Ciuciu, Scheiber, & Manning, 2008; Daselaar et al., 2008; Ford et al., 2011), as verbal retrieval during scanning is made difficult by the noise of the machine and the need to restrict head movement. During this interview, participants listened to each musical clip, recorded the memory retrieved in the scanner using a digital audio recorder, and assigned an approximate year for the event. Participants practiced this interview process prior to entering the scanner and were told the importance of only reporting information that came to mind during the original retrieval session. They were instructed to report "I don't remember" if they were not confident about the content retrieved in the scanner.

Participants categorized the temporal specificity of each memory using a scale derived from the literature on autobiographical memory organization that describes autobiographical information as existing in a hierarchy (Conway & Pleydell-Pearce, 2000). Conway and Pleydell-Pearce (2000) describe three levels in this hierarchy: personal autobiographical information devoid of specific episodic information (e.g., "I lived in Virginia during college"), general events that blend across multiple episodic events (e.g., "I used to go to house parties on Friday nights"), and specific events that are isolated in place and time (e.g., "I met my best friend, Alanna, at a party during freshman year"). Because general events can consist of either a category of repeating events (e.g., "I used to go to house parties on Friday nights") or a single extended event (e.g., "I went to North Carolina for beach week"), both levels were included in the scale for the current study. Following retrieval, participants labeled each event as 1 = no memory, 2 = personal fact, 3 = repeated event, 4 = extended event, or 5 = specific event. Unsuccessful trials (ratings of 1) were excluded from the analysis, and repeated and extended events were combined into a single "general events" category. Therefore, analyses discussing specificity were conducted using three levels: personal facts, general events, and specific events.

Data Acquisition

Magnetic resonance images were acquired using a Siemens Trio 3T scanner. Participants' heads were held in place using cushions and a headrest. An initial localizing scan was followed by a high resolution T1-weighted structural scan for anatomical visualization (160 1 mm slices, TR = 1750 ms, TE = 4.38 ms) and four runs of functional scans collected during memory retrieval. Whole brain, gradient-echo, echo planar images (37 5 mm slices, TR = 2 s, TE = 23 ms, Flip angle = 90) were acquired at an angle perpendicular to the long axis of the hippocampus, identified via the T1 scan. To present the stimuli in the scanner, magnet-safe headphones (STAX SR-003) were selected that minimized distortion of the auditory signal. Scanner safe noise-reducing earmuffs were also used to decrease the noise associated with the running scanner. All response data was collected using a magnet-safe button response box.

Preprocessing and Data Analysis

Images were preprocessed and analyzed using SPM8 software implemented in MATLAB (Wellcome Department of Cognitive Neurology, London, United Kingdom). Images were coregistered, slice-time corrected, realigned, normalized and smoothed using a Gaussian 8 mm kernel. Due to the complexity and length of retrieval, autobiographical memory retrieval typically varies by trial and by individual, resulting in a natural jitter (Addis et al., 2007). Only successful memory trials that received a valence rating and a year estimate from the participant were included in this analysis. For the current study, we were interested in the age-related differences in the initial *construction* of autobiographical memories (i.e., the period immediately following stimulus presentation associated with the search, monitoring, and selection of a related autobiographical memory). As such, only memory construction was examined. This phase was modeled as 2-s epoch following cue onset.

General linear model. Given our prior finding that subjective ratings of specificity were linearly associated with parameter estimates of neural activity in the dmPFC in young adults (Ford et al., 2011), we were interested in examining linear modulations of neural recruitment in this region, as well as other regions, as a function of age and subjective ratings of familiarity, valence, and specificity. Prior studies have examined the correspondence between subjective ratings and the BOLD signal during autobiographical memory retrieval using parametric modulation analyses (Addis, Moscovitch, Crawley, & McAndrews, 2004; Daselaar et al., 2008; Janata, 2009b). At the fixed-effects level, autobiographical memories were modeled in a single condition ("Autobiographical Memory") with self-reported song familiarity as a parametric modulator. This model identified regions in which activity was significantly related to song familiarity for each individual subject. By bringing the results of these individual subject results to the group level, the effect of familiarity on activity during memory search was examined for young and older adults separately (i.e., using separate random-effects models); to identify regions commonly affected in young and older adults, we conducted a conjunction analysis of these two analyses where each group's p value was set at $p < .005$. A two-group independent samples t test was used to identify regions in which song familiarity affected young and older adults' memory search differently. The significance threshold for these analyses was set at $p < .005$ with a 55-voxel extent. A 55-voxel extent in the current study (with 2 mm resampled voxels) is approximately equivalent to the cluster size of the 10-voxel extent (with 3.5 mm voxels) recently shown to be an acceptable balance between Type I and Type II error in neuroimaging studies (Lieberman & Cunningham, 2009). We discuss all clusters that reach this threshold, but report all clusters with a voxel extent of 10 or more in the table, as these results may be relevant for the purposes of future reviews and meta-analyses. Clusters reaching significance were overlaid on anatomical images from MRICron. For localization, the peak MNI coordinates of active regions (reported here) were converted to Talairach space, localized in using the Talairach Client, and confirmed with the Talairach and Tournoux atlas (Talairach & Tournoux, 1988).

Examination of dmPFC region of interest. Two additional models were generated for each subject at the fixed-effects level to examine the relation between activity and ratings of (a) temporal

Table 2
Behavioral Averages and Correlations for Young and Older Adults

Statistic	Young adults	Older adults	Difference *p*-value
Means			
Mean familiarity rating (1–5 Scale)	4.19 (.18)	4.41 (.14)	.32
Mean valence rating (1–5 Scale)	3.79 (.13)	3.90 (.11)	.52
Mean specificity rating (1–3 Scale)	**2.33 (.07)**	**1.84 (.07)**	<.001
Mean year of event	**2006.35 (.28)**	**1964.21 (1.46)**	<.001
Number of successful trials (from 30 possible trials)	24.93 (1.11)	22.5 (.86)	.09
Correlations			
Mean correlation between familiarity and valence	*.25 (.06)*	*.50 (.09)*	.03
Mean correlation between familiarity and specificity	*.16 (.04)*	**.00 (.06)**	.03
Mean correlation between familiarity and recency	*−.12 (.05)*	.00 (.06)	.23

Note. Numbers represent raw values with standard errors presented in parentheses. Correlations that were significantly different from zero are italicized. *P*-values reflect the difference between young and older adults in an independent samples *t*-test; values that are significantly different in young and older adults are in bold. Significance was determined at $p < .05$.

specificity and (b) memory valence for each individual subject. These models were created in the same way as the model for song familiarity (see above). To examine how regions involved in song familiarity may also support phenomenological characteristics in memory, a dmPFC region of interest (ROI; −16, 36, 38) was selected from regions exhibiting significant increases in activity as a function of increased familiarity ratings in both young and older adults. Using the REX toolbox (downloaded from *http://web.mit.edu/swg/software.htm*), individual subjects' parameter estimates of the parametric effects of specificity and valence were extracted from this cluster. The average relations between activity in this ROI and these characteristic ratings were calculated for young and older adults.

Results

Behavioral Results

Behavioral data are presented in Table 2. On average, participants retrieved 23.68 events from the 30 memory retrieval trials (SD = 4.00, Range = 15–30), with no difference between young and older adults (p = .09). Ratings of song familiarity and valence did not differ as a function of age (p = .32 and p = .52 for familiarity and valence, respectively), but young adults retrieved memories that were more temporally specific ($t(29) = 27.43$, $p < .001$) and more recent ($t(29) = 4.81$, $p < .001$) than older adults.

Item-level correlations between familiarity, valence, temporal specificity, and recency were calculated for each individual subject, and then converted to z_r-values using a Fisher r-to-z transform. The average value, across individuals, was evaluated by calculating the mean z_r-value against a null of zero using a single sample t test. The mean z_r-value was then converted back to an r value; both are presented here. Increased familiarity was associated with increased ratings of memory positivity (Mz_r = *.38*, Mcorr = .35; $t(30) = 6.62$, $p < .001$) and increased temporal specificity (Mz_r = *.08*, Mcorr = .08; $t(30) = 2.07$, $p < .05$), such that memories associated with more familiar stimuli were rated as more positive and more temporally specific than those associated with less familiar stimuli. Since familiarity was not associated with the recency of autobiographical memories ($Mz_r = -.06$, Mcorr = −.06; $t(30) = 1.41$, $p = .17$), recency was not considered in further analyses of the effect of familiarity on neural recruitment.

Z-Transformed values representing within-subject correlations between familiarity and positivity, and between familiarity and specificity, were entered into a mixed ANOVA with age (young v. older adults) as a between-subjects factor and correlation measure (familiarity and positivity vs. familiarity and specificity) as a within-subjects factor.[1] These results are presented in Table 2 and Figure 1. There was no main effect of age on correlations, $F(1, 29) = 0.39$, $p = .54$, but the mean relation between familiarity and positivity was significantly greater than the relation between familiarity and specificity, $F(1, 29) = 23.70$, $p < .001$. There was also a significant age-by-measure interaction, $F(1, 29) = 11.39$, $p = .002$, in which the relation between familiarity and positivity was greater in older ($Mz_r = .50$, Mcorr = .46), relative to young ($Mz_r = .25$, Mcorr = .25), adults (independent samples t test: $t(29) = 2.30$, $p = .03$) and the relation between familiarity and specificity was greater in young ($Mz_r = .16$, Mcorr = .16), relative to older ($Mz_r = .00$, Mcorr = .00), adults (independent samples t test: $t(29) = 2.28$, $p = .03$). Additional follow-up contrasts revealed that familiarity was significantly related to *both* valence and specificity in young adults ($p < .001$ for both contrasts) and that these relations were not significantly different from one another, $t(14) = 1.50$, $p = .16$. In older adults, only the relation between familiarity and valence was significant ($p < .001$), and this relation was significantly greater than the relation between familiarity and specificity, $t(15) = 4.86$, $p < .001$.

Imaging Results

Regions associated with increased song familiarity in young and older adults. Greater ratings of song familiarity were associated with increased neural activity in a widespread net-

[1] Critically, positivity and temporal specificity were not correlated in young adults ($r = .10$; $t(14) = 1.76$, $p = .10$) or in older adults ($r = .06$; $t(15) = 1.04$, $p = .32$), allowing for these measures to be considered independently.

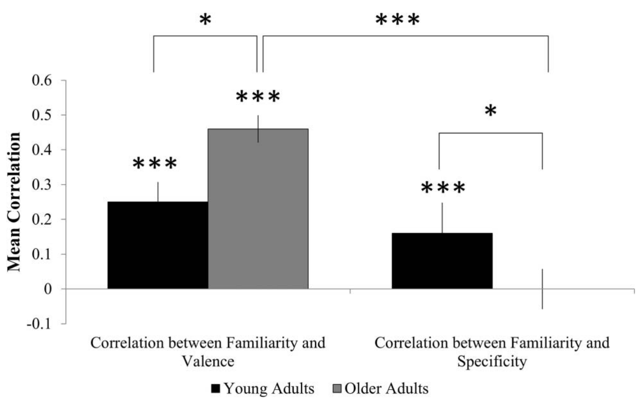

Figure 1. Mean correlations between familiarity and valence and between familiarity and specificity for young (black bars) and older (gray bars) adults. Error bars represent standard error of the mean. * $p < .05$. *** $p < .001$.

work of regions including medial and lateral prefrontal cortex, parietal lobe, and medial temporal lobe in both young and older adults (see Figure 2 and Table 3). Critically, the results of the conjunction analysis reveal that young and older adults include many of the same regions, including the dmPFC, ventral PFC, lateral parietal lobe, and medial temporal lobe. Direct comparisons between young and older adults revealed that young adults' familiarity judgments were associated with greater activation in medial limbic regions, such as the uncus and caudate, whereas older adults' familiarity judgments were associated with greater activation in lateral parietal and temporal regions, as well as superior medial regions including the anterior and posterior cingulate.

Relations between ROI activity and memory characteristics. Parameter estimates of the parametric effects of familiarity, temporal specificity, and emotional valence were extracted from a dmPFC ROI (−16, 36, 38; see Figure 3) based on its close proximity to the cluster reported by Janata (2009b). Estimates revealed significant within-subject relations between activity and ratings of familiarity in both young (*M*est = .15, $t(14) = 5.80$, $p < .001$) and older adults (*M*est = .19, $t(15) = 3.62$, $p = .003$), consistent with the whole-brain analysis from which the ROI was selected.

Based on the behavioral findings showing a significant age-by-measure interaction in correlations with familiarity, a similar analysis was conducted examining the age-by-measure interaction in relation with dmPFC recruitment. Although the interaction was not significant, it trended in the same direction as the behavioral findings, $F(1, 29) = 3.02$, $p = .09$. Consistent with behavioral findings, activity in the dmPFC in young adults was associated with ratings of specificity (*M*est = .09, $t(14) = 2.18$, $p = .05$), but not with memory valence ($p = .38$). In older adults, conversely, activity in the dmPFC was associated with ratings of memory valence (*M*est = .11, $t(15) = 3.36$, $p = .004$), but not with temporal specificity ($p = .44$).

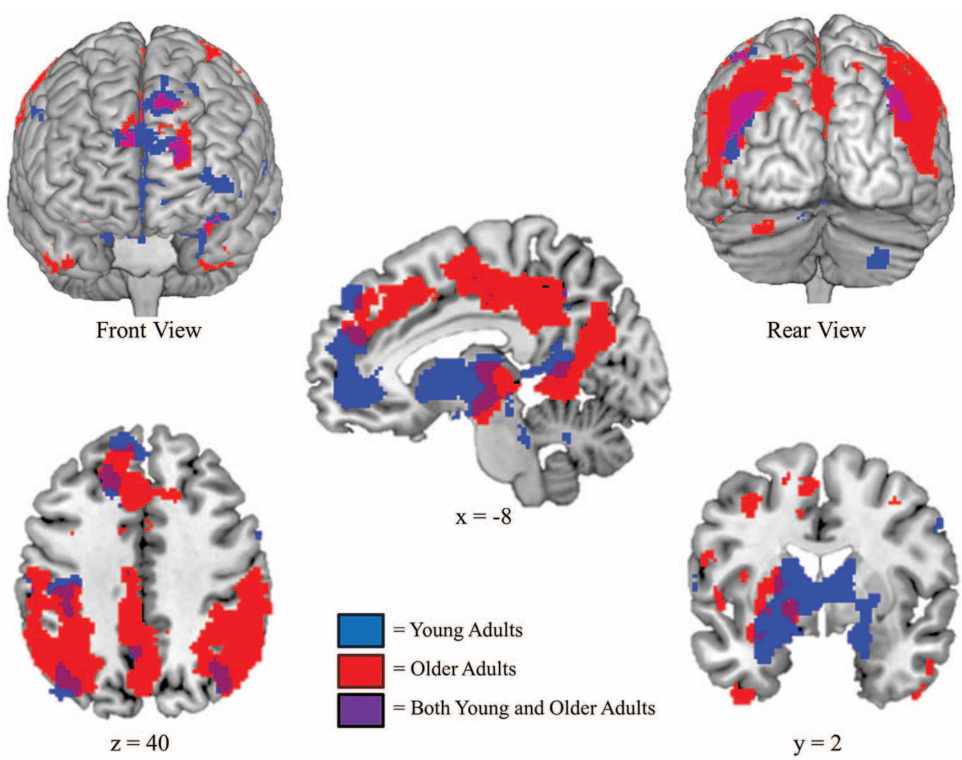

Figure 2. Neural activity associated with increased familiarity ratings in young (blue) and older (red) adults. Regions of overlap (purple) represent regions related to increased familiarity ratings in both young and older adults. Regions reaching an uncorrected p value of $p < .005$, k ≥ 55 voxels, are depicted.

Table 3
Regions Exhibiting a Significant Relation Between Neural Activity and Ratings of Song Familiarity

Region of interest	Hemisphere	BA	MNI coordinates *x*	*y*	*z*	*t*-value	k
Young adults							
Frontal lobe							
Medial frontal gyrus	L	6	−16	28	40	5.54	248
	L	6	−6	−10	54	3.72	43†
Superior frontal gyrus	L	8	−10	50	46	4.89	1631
Inferior frontal gyrus	R	13	46	22	10	4.41	29†
	R	9	54	6	36	3.66	32†
Anterior cingulate	R	24	8	8	34	3.92	27†
Precentral gyrus	L	6	−64	−2	12	3.87	21†
	R	4	58	−14	26	3.78	33†
Middle frontal gyrus	L	46	−48	20	28	3.66	26†
Parietal lobe							
Precuneus	L	39	−40	−68	36	5.69	705
Inferior parietal lobule	L	40	−40	−34	34	4.75	688
	R	39	36	−66	38	4.28	206
Postcentral gyrus	R	1	54	−18	48	3.22	13†
Temporal lobe							
Middle temporal gyrus	L	21	−68	−26	−14	3.68	55
Other							
Lentiform nucleus	L	na	−10	4	0	9.22	6844
Posterior cingulate	L	30	−12	−54	8	6.13	1547
Putamen	R	na	30	−22	−2	4.77	98
Parahippocampal gyrus	R	36	36	−30	−24	3.5	11†
Declive	R	na	6	−72	−30	3.49	17†
Older adults							
Frontal lobe							
Medial frontal gyrus	R	9	10	50	28	4.05	219
Inferior frontal gyrus	R	47	32	28	−16	3.62	22†
Parietal lobe							
Precuneus	L	31	−6	−72	22	7.32	17879
Inferior parietal lobule	L	40	−36	−50	42	6.12	6744
Temporal lobe							
Middle temporal gyrus	R	21	50	8	−40	5.12	65
	L	20	−34	4	−46	4.35	92
Superior temporal gyrus	R	38	40	16	−42	3.69	15†
	L	38	−42	10	−36	3.14	11†
Occipital lobe							
Fusiform gyrus	L	19	−30	−68	−14	3.97	30†
Inferior temporal gyrus	R		40	−62	−6	3.46	23†
Other							
Parahippocampal gyrus	L	36	−38	−30	−26	5.41	622
Culmen	L	na	−2	−32	−24	5.12	123
Declive	L	na	−28	−70	−28	4.49	129
Lentiform nucleus	R	na	24	−14	2	4.26	310
Putamen	R	na	22	6	−8	3.93	330
Uncus	L	28	−30	−10	−34	3.36	22†
Insula	R	13	44	−8	20	3.34	27†
Caudate	R	na	16	12	8	3.27	25†
Claustrum	R	na	30	12	12	3.22	19†
Both young and older adults (conjunction of $p < .005$ for both age-groups)							
Frontal lobe							
Inferior frontal gyrus	L	13	−32	14	−16	4.34	455
		47	−44	24	−12	3.8	30†
Medial frontal gyrus	L	6	−6	−14	54	4.28	39†
		10	−20	54	12	3.56	110
	R	9	8	54	24	3.93	26†
Superior frontal gyrus	**L**	**9**	**−16**	**36**	**38**	**3.93**	**96**
		9	−8	46	40	3.77	19†

(*table continues*)

Table 3 (*continued*)

Region of interest	Hemisphere	BA	MNI coordinates *x*	*y*	*z*	*t*-value	k
Parietal lobe							
Postcentral gyrus	L	2	−44	−34	56	5.72	486
	R	1	56	−18	48	4.24	13†
Angular gyrus	R	39	48	−70	30	3.98	161
Temporal lobe							
Middle temporal gyrus	L	39	−42	−62	20	4.54	320
Other							
Culmen	R		10	−56	−6	3.3	10†
Posterior cingulate	L	29	−4	−48	6	4.16	121
	R	23	8	−58	10	5.1	349
Parahippocampal gyrus	L	36	−28	−32	−16	4.96	60
Subthalamic nucleus	R	na	12	−12	−10	3.51	22†
Thalamus	L	na	−6	−20	−2	4.57	221
	R	na	12	−30	4	3.53	82
Declive	R	na	26	−60	−20	4.26	118
Lentiform nucleus	R	na	24	−16	2	4.04	34†
Putamen	R	na	22	6	−8	3.93	143
Caudate	R	na	16	12	8	3.27	23†
Young > older adults							
Frontal lobe							
Superior frontal gyrus	R	9	6	62	38	3.33	12†
Other							
Uncus	R	34	22	2	−26	4.13	100
Caudate	L	na	−2	8	2	3.87	96
Culmen	L	na	−14	−36	−20	3.22	12†
Older > young adults							
Frontal lobe							
Anterior cingulate	R	32	18	22	42	4.24	93
	L	24	−10	−8	50	3.4	49†
Precentral gyrus	L	44	−42	12	8	3.8	132
	L	4	−24	−26	52	3.74	26†
Superior frontal gyrus	R	11	18	40	−14	3.34	15†
Medial frontal gyrus	R	9	12	40	32	3.27	42†
Parietal lobe							
Supramarginal gyrus	R	40	46	−48	38	4.46	1939
	L	40	−38	−46	36	3.72	562
Temporal lobe							
Superior temporal gyrus	L	22	−46	−38	0	4.09	122
	R	41	40	−30	6	3.57	58
Middle temporal gyrus	R	39	50	−66	18	2.97	15†
Other							
Posterior cingulate	L	31	−8	−40	36	3.77	58
Putamen	L		−24	−2	20	3.44	25†
Insula	R	13	34	−16	26	3.09	19†

Note. MNI = Montreal Neurological Institute; na = none available; BA = approximate Brodmann Area; L = L; R = R. Cluster used in subsequent region of interest (ROI) analysis highlighted in bold. Clusters significant at an uncorrected threshold of $p < .005$, k ≥ 10 voxels.
† = Indicates a cluster size smaller than the designated cluster size of 55.

Discussion

The current study examined the effects of song familiarity on the phenomenological characteristics and neural recruitment associated with personal autobiographical memory retrieval in young and older adults. The findings support prior research showing that music may facilitate successful retrieval of autobiographical information, and may help to explain underlying mechanisms that support this facilitation. Further, the results of the current study highlight important age-related shifts in how song familiarity influences memory retrieval, potentially reflecting differences in how young and older adults utilize this information to enhance memory representations.

The utility of musical cues in eliciting autobiographical memories has been well-documented in the literature (Barrett et al., 2010; Cady et al., 2008; Ford et al., 2011, 2012, 2014; Janata, 2009b; Janata et al., 2007; Schulkind & Woldorf, 2005), with the efficacy of these cues related to self-reported song familiarity (Barrett et al., 2010; Janata et al., 2007). Familiarity-related enhancements in temporal specificity and emotional positivity in the current study provide additional clarification regarding this relation between song familiarity and autobiographical memory, revealing that song familiarity not only increases the likelihood of retrieving a memory (Janata et al., 2007), but also enhances the subjective memory representation. Specifically, songs that were rated as highly familiar elicited memories that were more likely to be experienced as temporally specific (i.e., isolated in a particular place and time) and as emotionally positive. These findings suggest that future studies

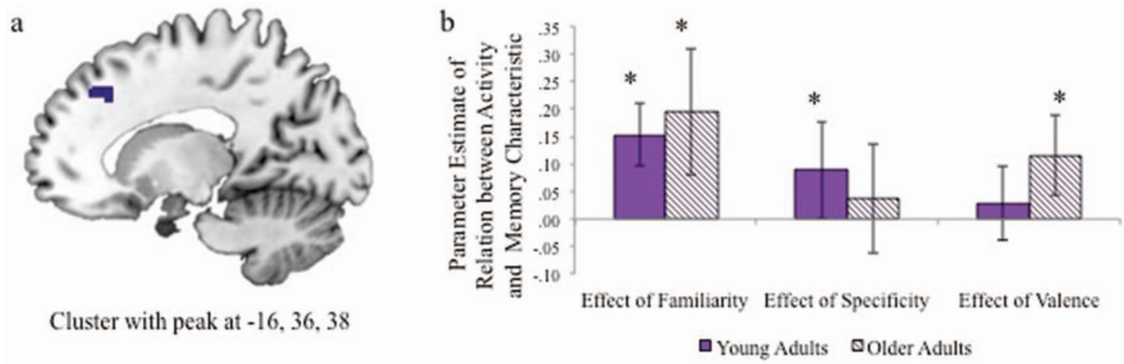

Figure 3. (a) dorsal medial prefrontal cortex region of interest (dmPFC ROI; −16, 36, 38) associated with increased familiarity ratings in both young and older adults. (b) Parameter estimates of relations between ROI activity and memory characteristics as a function of age-group and characteristic. Relations reaching significance ($p < .05$) are marked with an asterisk (*). Standard error bars represent 95% confidence intervals.

can utilize highly familiar musical cues to enhance retrieval of rich, complex events in experimental tasks.

In addition to revealing mnemonic enhancements as a function of song familiarity, the current study extended prior research by showing significant familiarity-related modulations in the dmPFC in both young and older adults. This previous research highlighted the dmPFC as a key region responsible for integrating musical processing and retrieval of autobiographical memories (Janata, 2009b). Further, researchers from other domains have explained the neural overlap among affective, self-referential, and social–cognitive processes as reflecting a role of this region in mental state inference (Frith & Frith, 2003; Olsson & Ochsner, 2008), social cognition (Mitchell, 2006), and emotion regulation (Ochsner & Gross, 2005). Together, these separate lines of literature point to a highly complex role of the dmPFC, where this region is likely involved in both affective and cognitive components of memory retrieval.

A number of other regions were significantly associated with ratings of song familiarity in both young and older adults, including more ventral medial prefrontal regions, bilateral parietal lobe, posterior cingulate, and medial temporal lobe regions. It is notable that these regions also comprise a network of regions known as the "default-mode" network that is associated with deactivations during increased cognitive effort and attention, and has been shown to support tasks involving self-referential processing (Raichle et al., 2001), including autobiographical memory retrieval (Gilboa, 2004; Svoboda et al., 2006). The relation between song familiarity and recruitment of default mode regions is consistent with the findings reported above that familiarity is intimately tied to autobiographical memory retrieval.

Finally, the current study points to an important age-related shift in precisely *how* song familiarity enhances memory retrieval. In young adults, familiarity with the memory cue contributed to both enhanced positivity, as well as an increase in the temporal specificity of the event, suggesting that familiarity was associated with both affective and cognitive processes during retrieval. In older adults, on the other hand, only affective processes were affected by cue familiarity, with a strong relation between familiarity ratings and memory positivity. The elimination of any detail-related facilitation, and the magnification of the valence effect, is consistent with theories suggesting a reallocation of resources in older adults away from a detail-focus and toward an affective-focus (Mather & Carstensen, 2005).

In addition, although song familiarity was tied to recruitment of regions within the default mode network in both young and older adults, the current study reveals substantial variation in recruitment between the two age-groups: whereas young adults' familiarity ratings tended to be associated with more ventral and medial neural regions, older adults' ratings were associated with more dorsal and lateral regions. Interestingly, these distinctions are similar to those made in a recent study suggesting that the default mode network is made up of two distinct subsystems—the dorsal medial prefrontal cortex (dmPFC) subsystem and the medial temporal lobe (MTL) subsystem—that interact with a core network that includes the posterior cingulate and anterior medial prefrontal cortex (Andrews-Hanna, Reidler, Sepulcre, Poulin, & Buckner, 2010). The dmPFC subsystem is composed of the dmPFC, temporoparietal junction, lateral temporal cortex, and temporal pole, whereas the MTL subsystem is made up of the ventromedial PFC, posterior inferior parietal lobule, retrosplenial cortex, parahippocampal cortex, and hippocampal formation.

The current study suggests that song familiarity is more closely related to recruitment of the dmPFC subsystem in older adults and the MTL subsystem in young adults. Andrews-Hanna et al. (2010) found that the dmPFC subsystem is associated with tasks involving emotional evaluation and self-referential processing and the MTL subsystem is involved in scene construction and episodic thinking, suggesting age-related shifts in how song familiarity may relate to these processes in the current autobiographical memory task. Indeed, song familiarity in the current study was more strongly associated with temporal specificity (i.e., time and place detail) in young relative to older adults, and with positivity in older relative to young adults. This reversal may have significant implications for research investigating how stimulus and task-related support may be used to facilitate memory retrieval differently across individuals, suggesting that older adults may rely on these supports to enhance distinct aspects of memory compared to young adults. Patterns of parametric modulation in the dmPFC are consistent with this interaction, although this pattern was insignificant in the current study. Future work is needed to understand how this region may serve to both integrate affective and cognitive information, and to differentially support affective and cognitive components across the life span.

Understanding age-related changes to autobiographical memory retrieval is particularly important due to the role of personal memories in daily functioning. It has been suggested that emotion (Kensinger, 2009), and more specifically positive emotion (Charles, Mather, & Carstensen, 2003), may help mitigate memory impairments in older adults. This age-related enhancement of positive information has been of great interest in the cognitive aging literature, as it represents a special circumstance in which age-related cognitive declines may be reduced by specific task-related factors. Familiarity-related positivity enhancements in older adults may reflect age shifts in motivation to regulate one's emotional state during cognitive tasks (Mather & Carstensen, 2005). Age changes in motivation may cause older adults to recruit available resources to regulate emotion to a greater extent than young adults (Mather, 2004), which may explain why older adults exhibit a relation between familiarity and enhanced positive emotion rather than increased temporal specificity.

Limitations

Due to the nature of the experimental design, older participants retrieved memories that were more remote than those of young adults. Specifically, both age-groups tended to retrieve events from the years in which their age-specific cues were popular. It is possible that differences in recency could introduce phenomenological or neural differences that are not related to the changes associated with healthy aging. Another potential concern for the current design was the presentation of age-specific stimuli in the memory task. Since young and older adults received different cue sets, with different musical and acoustic characteristics, it is possible that age differences may be related to stimuli rather than mnemonic processes. To reduce the impact of such differences, the current analysis focused on parametric effects within each age-group. Such an analysis isolates differences related to familiarity across trials in a sample rather that averaging them together and, in doing so, diminishes the influence of any factor that does not covary with familiarity. The behavioral results confirmed that recency was not associated with familiarity in the current study, and it is unlikely that musical or acoustic properties varied systematically with familiarity in a consistent way across participants, making this analysis method suitable for these data.

Conclusions

The current study is the first to examine the common and distinct effects of song familiarity on autobiographical memory retrieval in young and older adults. Familiarity was associated with increased dmPFC activity and increased ratings of temporal specificity and positivity across participants, supporting prior research implicating the dmPFC in the interaction of musical and autobiographical salience (Janata, 2009b) and demonstrating the value of highly familiar music as a retrieval cue. Further, behavioral and neuroimaging findings highlighted important age-related distinctions in how music may be used to facilitate mnemonic retrieval, where familiarity was associated with enhancement of more cognitive features in young adults and more affective features in older adults.

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(*Appendix follows*)

Appendix

List of Songs Presented as Memory Cues to Young and Older Adults

Young adults		Older adults	
Song	Year of release	Song	Year of release
Bye bye bye	2000	Mona Lisa	1950
Gonna Be Me	2000	Music! Music! Music!	1950
Jumpin Jumpin	2000	The Tennessee Waltz	1950
Butterfly	2001	Come on a my House	1951
Fallin	2001	On top of Old Smokey	1951
Lady marmalade	2001	We're Not Too Young	1951
Complicated	2002	Rock Around the Clock	1952
In the end	2002	That Doggie in the Window	1952
Thousand Miles	2002	That's Amore	1952
Beautiful	2003	Goodnight Sweetheart	1953
Crazy in love	2003	Open Your Arms	1953
Miss independent	2003	Your Cheating Heart	1953
Leave (get out)	2004	Mambo Italiano	1954
She will be loved	2004	Mr. Sandman	1954
Yeah	2004	Shake, Rattle, and Roll	1954
Don't cha	2005	Lonesome Whistle	1955
Hollaback girl	2005	Memories are Made of This	1955
Since you been gone	2005	Unchained Melody	1955
Hips don't lie	2006	Don't be Cruel	1956
How to save a life	2006	Love me Tender	1956
SexyBack	2006	Singing the Blues	1956
Before he cheats	2007	April Love	1957
Big girls don't cry	2007	At the Hope	1957
Say it right	2007	Jailhouse Rock	1957
Gives you Hell	2008	He's got the Whole World in his Hands	1958
No air	2008	Sugartime	1958
I Kissed a Girl	2008	The Yellow Rose of Texas	1958
Boom Boom Pow	2009	Stagger Lee	1959
Down	2009	The Battle of New Orleans	1959
I Gotta Feeling	2009	Venus	1959

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