Psychology and Aging
2009, Vol. 24, No. 2, 438–449

0882-7974/09/$12.00 DOI: 10.1037/a0015181

Age-Group Differences in Medial Cortex Activity Associated With Thinking About Self-Relevant Agendas

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In this functional magnetic resonance imaging (fMRI) study, we compared young and older adults' brain activity as they thought about motivationally self-relevant agendas (*hopes and aspirations*, *duties and obligations*) and concrete control items (e.g., *shape of USA*). Young adults' activity replicated a double dissociation (M. K. Johnson et al., 2006): An area of medial frontal gyrus/anterior cingulate cortex was most active during hopes and aspirations trials, and an area of medial posterior cortex—primarily posterior cingulate—was most active during duties and obligations trials. Compared with young adults, older adults showed attenuated responses in medial cortex, especially in medial prefrontal cortex, with both less activity during self-relevant trials and less deactivation during control trials. The fMRI data, together with post-scan reports and the behavioral literature on age-group differences in motivational orientation, suggest that the differences in medial cortex seen in this study reflect young and older adults' focus on different information during motivationally self-relevant thought. Differences also may be related to an age-associated deficit in controlled cognitive processes that are engaged by complex self-reflection and mediated by prefrontal cortex.

Keywords: self-reflection, aging, medial prefrontal cortex, posterior cingulate cortex, precuneus

Self-relevant thought (e.g., rating how characteristic trait adjectives are of self vs. others) activates areas of medial cortex, including both anterior (medial frontal gyrus and/or anterior cingulate cortex) and posterior (posterior cingulate cortex and/or precuneus) regions (for reviews, see, e.g., Cavanna & Trimble, 2006; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Northoff et al., 2006; Ochsner et al., 2005; Vogt & Laureys, 2005). Identifying the functional specificity of subregions of medial cortex in self-relevant thought is the focus of current empirical and theoretical work in social-cognitive neuroscience (e.g., Johnson et al., 2006; Schmitz & Johnson, 2007; Uddin, Iacoboni, Lange, & Keenan, 2007; for reviews and conceptual discussions, see, e.g., Lieberman, 2007; Mitchell, 2008; Northoff & Bermpohl, 2004; Northoff et al., 2006; Olsson & Ochsner, 2008). One approach is to investigate the role(s) of medial cortex when individuals process different motivationally significant personal agendas, such as *hopes and aspirations* versus *duties and obligations* (related to a *promotion* or *prevention* self-regulatory focus, respectively; Higgins, 1997) (Johnson, Nolen-Hoeksema, Mitchell, & Levin, 2008; Johnson et al., 2006). Such agendas guide our perception, thought, and behavior, and help to define our "self."

Using functional magnetic resonance imaging (fMRI), Johnson et al. (2006) compared young adults' brain activity associated with thinking about each of these agendas versus thinking about non-self-relevant control topics (e.g., *shape of USA*). Both thinking about hopes and aspirations and thinking about duties and obligations were associated with greater activity than the control condition in an anterior medial region (medial frontal gyrus/anterior cingulate cortex) and a posterior medial region (cingulate cortex/precuneus). This was consistent with previous findings of activity in these areas during self-focused thought (for reviews, see, e.g., Cavanna & Trimble, 2006; Macrae et al., 2004; Northoff et al., 2006; Ochsner et al., 2005; Vogt & Laureys, 2005). In addition, there was a double dissociation. In anterior medial cortex, a more dorsal area (anterior cingulate/dorsomedial frontal gyrus) showed greater activity in both self-relevant conditions (which did not differ) than the control condition, and a more ventral portion of anterior cingulate showed relatively greater activity related to thinking about hopes and aspirations than to thinking about duties and obligations. In posterior medial cortex, a more superior/posterior area (posterior cingulate, cuneus, precuneus) showed

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This research was supported by National Institute on Aging Grants AG09253 and AG15793. We thank magnetic resonance technologists Hedy Sarofin and Cheryl McMurray for assistance in collecting the magnetic resonance data, Erich Greene for functional magnetic resonance imaging analyses, Mara Mather for thoughtful comments on a draft of this article, and Kathleen Muller and William Hwang for life domains and global affect coding.

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greater activity in both self-relevant conditions (which did not differ) than the control condition, and a more inferior/anterior area (lingual gyrus, posterior cingulate, parahippocampus) showed relatively greater activity related to thinking about duties and obligations than hopes and aspirations. This dissociation suggests differential involvement of anterior and posterior medial cortex in self-relevant motivational thinking depending on either the content of such thought or the specific component processes called upon to generate, retrieve, or evaluate such information. Johnson et al. suggested several hypotheses, including that medial frontal cortex is associated with a more inward-directed self-focus, whereas posterior medial cortex is associated with a more outward-directed, social, or contextual focus when thinking about personal agendas (see Northoff et al., 2006, for a similar distinction).

One way to further investigate the relationship of these areas to the processing of motivationally relevant information is to examine the pattern of brain activity associated with thinking about such agendas in populations that show reliable behavioral differences in motivational focus. Normal aging is associated with significant changes in motivational orientation. For example, there is evidence suggesting that older adults are more "other" or "outward" focused, whereas young adults are more "self" or "inward" focused in their motivational orientations. Older adults express, for instance, strong concerns for the state of the world and the future of family members and subsequent generations (McAdams & de St. Aubin, 1998), and family members make up a substantial part of their social networks (Antonucci, 2001). In addition, compared with young adults, older adults consider a more restricted range of motivational goals as self-relevant, for example, they focus on fewer, more central goals and life domains than do young adults (Riediger & Freund, 2006; Staudinger, Freund, Linden, & Maas, 1999). Also, whereas young adults' goals tend to center on growth and acquisition (e.g., of knowledge or physical health), older adults increasingly focus on maintenance and retention of resources and loss prevention (Ebner, Freund, & Baltes, 2006; Heckhausen, 1997; Ogilvie, Rose, & Heppen, 2001). These behavioral findings suggest that we should find age-group differences in activity in anterior and posterior medial cortex when young and older adults think about personal agendas: relatively greater activity in medial prefrontal cortex in young than older adults, related to an inward self-focus and concern for acquisition, and possibly greater activity in posterior medial cortex in older than younger adults, related to an outward focus and concern for loss prevention.

A recent fMRI study (Gutchess, Kensinger, & Schacter, 2007) did not find age-related differences in medial cortex activity when young and older participants were asked to rate the self-relevance of trait adjectives. Nevertheless, given the behavioral evidence for age-group differences in motivational focus, we would expect age-group differences in medial cortex related to differences in the processing engaged by young and older adults when they are asked to think about more motivationally relevant themes. This would support the idea that these areas are not simply "self regions" but rather are differentially sensitive to certain types of self-focus or the particular content of self-relevant thought. Thus, the goal of the present study was to assess potential age-group differences in medial prefrontal cortex and medial posterior cortex in self-relevant thinking by examining the pattern of activity of young and older adults as they considered the motivationally significant agendas of *hopes and aspirations* and *duties and obligations*.

Method

Participants

Young participants (n = 21 [14 women], mean age = 21.7 years [SD = 2.8; range = 18–28]) were healthy, college students. Older participants (n = 21 [10 women], mean age = 69.0 years [SD = 6.9; range = 60–84]) were healthy and active, independently living adults from selected communities. All participants were native English speakers. All of the older adults reported being White/Caucasian; 10% of the young adults reported being of Hispanic descent, 5% reported being of Black/African American descent, and 15% reported being of Asian descent. All participants self-reported being in good health, with no history of stroke, heart disease, or primary degenerative neurological disorder. They had normal, or corrected to normal, vision, and none of the participants were taking psychotropic medications. Young and older participants did not differ significantly on self-ratings of physical or emotional health (on a 5-point scale ranging from 1 [*excellent*] to 5 [*poor*]) when asked how they were feeling *today* (physical: M_{young} = 1.9 [SD = 0.8], M_{older} = 1.6 [SD = 0.8]; emotional: M_{young} = 1.9 [SD = 0.9], M_{older} = 1.7 [SD = 0.9]) and *in general* (physical: M_{young} = 1.8 [SD = 0.9], M_{older} = 1.8 [SD = 0.7]; emotional: M_{young} = 2.3 [SD = 0.7], M_{older} = 2.0 [SD = 0.8]; all $ps > .10$). All participants had very low scores on the 15-item version of the Geriatric Depression Scale (Brink et al., 1982), and there were no age-group differences (M_{young} = 1.3 [SD = 1.5], M_{older} = 1.1 [SD = 1.8]; maximum possible = 15). Older adults scored high on the Folstein Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975; M = 29.4 [SD = 1.1]; maximum possible = 30). There were no age-group differences on an abbreviated version of the Verbal subscale of the Weschler Adult Intelligence Scale (Wechsler, 1987; M_{young} = 24.2 [SD = 4.4], M_{older} = 22.0 [SD = 5.1]; maximum possible = 30) or education level (reported in years, 12 = high school diploma; M_{young} = 15.1 [SD = 2.4], M_{older} = 16.3 [SD = 3.0]; all $ps > .10$). All participants were paid. The Human Investigation Committee of Yale University Medical School approved the protocol; informed consent was obtained from all participants.

Design and Procedure

The design was a mixed 2 (Age: young, older) × 3 (Condition: hopes and aspirations, duties and obligations, control), with age as a between-subjects factor and condition as a within-subjects factor.

The procedure followed Johnson et al. (2006, Experiment 2). On each trial participants saw either one of the two agenda cues (*hopes and aspirations* or *duties and obligations*) or a control cue (e.g., *polar bears fishing*, *pattern on oriental rug*, *shape of a tuba*; Nolen-Hoeksema, 2004), pseudorandomly intermixed. They were told to "focus on the idea expressed by the phrase and use your imagination to visualize or think about the idea" and to press a button on each trial when they had formed a clear and complete thought. For the two agenda cues, they were asked to try to generate a specific novel instance of a hope/aspiration or duty/obligation each time they saw the cue. They were further instructed that if they could not come up with a novel exemplar, they could revisit a previous one, but in that case they should consider different aspects of it so that novel information was being generated on each trial. The tasks were fully explained outside the scanner. Participants were given six practice trials, and the task was clarified as necessary before they got into the scanner.

Each trial was 18 s, with the cue shown for 14 s and a cross-hair shown for 4 s. One brain volume (image) was collected every 2 s, or nine full brain images for each trial; there were four runs of 12 trials each (four trials each condition). Thus, there were a total of 16 trials (144 images) per participant per condition.

About 5 min after the scan, in a separate testing room, participants were asked to "write a paragraph or two about the specific things that you thought about in the scanner when you saw the phrase *hopes and aspirations* (*duties and obligations*)." Order of the reports was counterbalanced.

Imaging Details

Images were acquired with a 1.5T Siemens Sonata scanner at Yale University. After anatomical localizer scans, functional images were acquired with a single-shot echoplanar gradient-echo pulse sequence (repetition time = 2,000 ms, echo time = 35 ms, flip angle = 80°, field of view = 24). The 24 oblique axial slices were 3.8-mm thick with an in-plane resolution of 3.75 mm × 3.75 mm; they were aligned with the anterior commissure–posterior commissure (AC-PC) line. Each run began with 12 s of blank screen to allow tissue to reach steady state magnetization and was followed by a 1-min rest interval.

fMRI Analyses

Data were motion-corrected with a six-parameter automated algorithm (AIR; Woods, Cherry, & Mazziotta, 1992). A 12-parameter AIR algorithm was used to coregister participants' images to a common (young) reference brain. Data were mean-normalized across time and participant and spatially smoothed (3D, 8-mm, full width at half maximum [FWHM] Gaussian kernel). We analyzed the data with a voxel-based analysis of variance (ANOVA), with participant as a random factor and all other factors fixed, using NeuroImaging Software (Laboratory for Clinical Cognitive Neuroscience, University of Pittsburgh; and the Neuroscience of Cognitive Control Laboratory, Princeton University).

This approach does not require predefining the shape of the hemodynamic response; the conditions were directly compared. Because we do not model the hemodynamic response, but rather derive it empirically, the best way to identify areas showing event-related changes in activity in response to the cues on each trial (i.e., transient responses) is to include Time Within Trial (Images 1–9) as a factor. We were particularly interested in age-group differences in brain activity as a function of condition, thus, regions of activation were identified as those showing an Age (young, older) × Condition (hopes and aspirations, duties and obligations, control) × Time Within Trial (Images 1–9) interaction with a minimum of six contiguous voxels, each significant at $p < .0001$ (Forman et al., 1995). For each region of activity thus identified, subsequent analyses (e.g., between the conditions within each age group) were conducted on mean percent signal change at Times (Images) 5–7 from Time (Image) 1 averaged across trials in each condition (because of the lag in the hemodynamic response, this range included the peak activations for these areas). That is, we conducted subsequent analyses using mean percent signal change for the time period of interest only on clusters identified in the initial ANOVA. We transformed *F*-maps to Talairach space using AFNI software (Cox, 1996). We localized areas of activation using AFNI and Talairach Daemon software (Lancaster, Summerlin, Rainey, Freitas, & Fox, 1997), and then manually checked them using Talairach and Tournoux's (1988) atlas and/or Duvernoy's (1999) atlas.

Analysis of Post-Scan Reports

Reports were scored by two raters[1] at three levels of analysis: individual words, meaning units, and life domains.

Individual words were counted for each occurrence of the following categories: nouns (*train*, *apartment*, *dog*); verbs (*thought*, *travel*, *continue*); "to be" verbs (*was*, *been*, *am*); "want" verbs (*want*, *wanted*, *wanting*); adjectives (*healthy*, *strong*, *new*); adverbs (*particularly*, *well*, *academically*); positive emotional words and whether each was self- or other-focused (*proud*, *happy*, *joyous*); negative emotional words and whether each was self- or other-focused (*upset*, *disgusted*, *complaining*); specific others (*my father*, *his cousin*, *the President*); general others (*people*, *friends*, *family*); time according to whether the reference was abstract or specific and past, present, or future (*yesterday*, *now*, *soon*); explicit references to the self (*I*, *my*, *me*); hope words (*hoping, hopeful*, *hope*); duty words (*duties*, *dutiful*, *duty*); specific quantities (*one*, *none*, *single*); abstract quantities (*some*, *extra*, *several*). At this level, each word was counted only once. If a word could be assigned to multiple categories, "higher level" categories were given priority over formal part-of-speech categories (e.g., *father* would be counted as a person rather than a noun, and *wanted* as a "want" verb rather than just a verb).

Meaning units were defined subjectively by the raters and were recognized as expressions or descriptions of the thoughts or actions associated with a particular plan, activity, or condition of being. Meaning unit content was scored for the inclusion of the following: self- or other-focus, agency (acting with a desired effect on something or someone), action (aiming to do something), prevention (intended to avoid an outcome), acquisition (intended to obtain an object or goal), retention (intended to preserve an existing state or material good), material focus (interacting with a physical object), and emotion (referencing an affective state). Each unit could be rated as ongoing and/or discrete and as occurring in the past and/or present and/or future. Categories were not mutually exclusive (e.g., a unit could be scored as referring to both the present and self or as both emotional and an action).

As used in the social-cognitive literature on age-group differences in goals and motivational orientation (Heckhausen, 1997; Nurmi, 1992; Riediger & Freund, 2006), the life domains coded were as follows: family and partnership; friends and acquaintances; physical functioning and health; personality and emotional well-being; cognitive functioning and intellectual capabilities; lei-

[1] Although the raters were technically "blind" to age group, the content of the reports often revealed the age group of the participant, for example, mention of grandchildren (older adults) versus an upcoming test in class (young adults). Given that report content was rated primarily on relatively objective dimensions (e.g., number of mentions of "I" or specific life domains), any bias created by this knowledge would likely be minimal. Also, the raters were research assistants not familiar with the literature concerning age-related differences in motivational focus.

sure; education, work, and work-related activities; finances and personal belongings; living situation; politics and world issues; and day-to-day activities. Within each report, occurrence of a life domain and frequency of mention were coded.

Interrater reliability (defined as the number of observations rated identically by the two raters, divided by the total number of observations, multiplied by 100; Fleiss, 1973) for scoring at the word and meaning unit levels was 85.6%, and for life domains it was 91.3%. In both cases, discrepancies were resolved by discussion with either Karen J. Mitchell or Natalie C. Ebner.

Two raters also scored the content of each report on "global" positivity and negativity. For this measure, each report was rated for both how positive the content was and how negative the content was on a 4-point scale ranging from 1 (*not at all*) to 4 (*very*). The mean for the two raters was used in analyses.

Results and Discussion

Response Times to Complete Task

Compliance with button pressing on each trial was high, and there were no main effects, nor a significant Age × Condition interaction, for the percentage of trials accompanied by a button press (*M*s = 99.5% overall for both young and older adults, *p*s > .10). Thus, all trials were included in analyses of the fMRI data. A 2 (Age: young, older) × 3 (Condition: control, hopes and aspirations, duties and obligations) ANOVA on response times showed no main effect of Age ($F < 1$). A significant main effect of Condition, $F(2, 76) = 34.38$, $MSE = 436{,}934$, $p < .001$, was obtained because participants were faster on the control trials (3,583 ms) than either of the self-relevant trials (4,619 ms, 4,668 ms for the hopes and aspirations and duties and obligations trials, respectively), which did not differ. There was an Age × Condition interaction, $F(2, 76) = 6.19$, $MSE = 436{,}934$, $p < .01$: On control trials, young adults (3,513 ms) were slightly faster than older adults (3,653 ms), whereas on both self trials, older adults (4,280 ms, 4,255 ms for hopes and aspirations and duties and obligations, respectively) were slightly faster than young adults (4, 957 ms, 5,081 ms for hopes and aspirations and duties and obligations, respectively). Importantly, though, there were no significant differences between young and older adults in any of the three conditions (all *p*s > .10), suggesting that it is unlikely that "time on task" can account for the condition-specific age effects demonstrated with respect to brain activity discussed below.

Post-Scan Report Results

To test whether young and older adults considered different motivationally self-relevant content in the scanner, as suggested by the behavioral literature reviewed in the introduction section, we analyzed the content of the reports that participants wrote after they got out of the scanner. Table 1 shows all significant, or marginal, differences in the reports between young and older participants at each of three levels of analysis (words, meaning units, life domains) separately for hopes and aspirations and duties and obligations. Young adults produced overall more words, more meaning units, and mentioned more life domains than older adults; thus, for all items each person's report content was expressed as a proportion of the total words (meaning units, life domains) that they produced.

Table 1
Differences Between Young and Older Adults in Content of Both Report Types

Report type	Young	Older	*t*(40)	*p*
Hopes and aspirations				
No. of words	119.76	85.38	2.81	.01
Proportion of words dealing with time	0.04	0.07	2.16	.04
Proportion of words dealing with a spec time in the past	0.00	0.004	2.08	.04
No. of meaning units	9.52	6.52	3.43	<.01
Proportion of units mentioning the past	0.01	0.12	2.10	.04
Proportion of units mentioning the present	0.11	0.35	3.38	<.01
Proportion of units involving "do"	0.76	0.58	2.74	.01
Proportion of units involving retaining	0.02	0.12	3.38	<.01
Proportion of different specific people referred to	0.01	0.02	1.91	.06
No. of life domains mentioned	7.62	5.24	3.06	<.01
Proportion of physical functioning & health	0.02	0.19	4.97	<.01
Proportion of education, work, & work-related activities	0.29	0.09	3.09	<.01
Duties and obligations				
No. of words	118.14	84.76	3.37	<.01
Proportion of words referring to self (I, me)	0.10	0.08	2.14	.04
Proportion of words dealing with people	0.05	0.07	2.01	.05
Proportion of references to specific people	0.01	0.04	2.78	.01
Proportion of different specific people referred to	0.01	0.02	2.46	.02
Proportion of words mentioning people in the abstract	0.02	0.01	2.04	.05
No. of meaning units	9.33	7.57	1.92	.06
Proportion of units involving "do"	0.96	0.84	2.45	.02
No. of life domains mentioned	6.14	4.43	2.58	.01
Proportion of education, work, and work-related activities	0.34	0.18	2.85	.01

Note. Young adults produced significantly more words, meaning units, and life domains on both report types; thus, items are expressed as a proportion of the number of words (meaning units, life domains) produced.

For both of the self-relevant conditions, young adults focused more on action (units involving "do") than did older adults. In addition, several age-group differences were specific to either the hopes and aspirations or duties and obligations condition. In line with the literature (Carstensen, Isaacowitz, & Charles, 1999; Fingerman & Perlmutter, 1995; McAdams & de St. Aubin, 1998; Webster & Cappeliez, 1993), older adults mentioned time (both past and present) more often than young adults when writing about their hopes and aspirations and mentioned other people more often than did young adults, especially when writing about their duties and obligations. Young adults were more self-focused, mentioning "I" or "me" more often than did older adults with respect to their duties and obligations.

Consistent with the behavioral literature showing an age-group shift in motivational orientation from growth and acquisition toward maintenance and retention of resources and loss prevention (Ebner et al., 2006; Freund, 2006; Ogilvie et al., 2001), when thinking about their hopes and aspirations, older adults focused more on retention (e.g., *continue working in good health*, *husband and I happy as now*) than did young adults. There was a nonsignificant trend ($p = .09$) for young adults ($M = 0.18$) to focus more on acquisition (e.g., *someday own a home*, *getting a great job*) compared with older adults ($M = 0.09$). The finding that young adults tended to mention a wider range of life domains than did older adults in both types of reports is also consistent with the literature (Hooker, 1992; Lecci, Okun, & Karoly, 1994; Markus & Herzog, 1991; Riediger & Freund, 2006). In addition, whereas older adults showed no difference in the number of life domains they mentioned in their hopes and aspirations (3.62) versus duties and obligations (3.19) reports ($p > .20$), young adults mentioned significantly more domains in their hopes and aspirations (4.81) than their duties and obligations (3.95) reports, $t(20) = 2.76$, $MSE = 0.31$, $p < .05$. As one would expect, older adults reported thinking more about their physical functioning and health, with respect to their hopes and aspirations, but young adults reported thinking more about education, work, and work-related activities in both self conditions.

At the word or idea unit level of analysis, there were few explicit emotional references, and no significant differences between conditions or groups. However, global ratings of the positivity and negativity of the content of the reports showed a significant Age × Report Type × Valence interaction, $F(1, 40) = 8.83$, $p < .01$: For the duties and obligations reports, there was no age difference for positivity (*M*s = 1.33, 1.26 for young and older adults, respectively) or for negativity (*M*s = 1.83, 1.76 for young and older adults, respectively; *p*s > .50). For the hopes and aspiration reports, young adults' reports were rated as significantly more positive (2.86) than were the older adults' reports (2.02), and young adults' reports were rated as significantly less negative (1.07) than were the older adults' reports (1.55; *p*s ≤ .01).

In short, several levels of analysis on the post-scan reports indicated that the content, focus, and valence of young and older adults' thinking differed. Thus, to the extent medial cortex activity is related to the content of motivationally self-relevant thought, we expected to see age-group differences in brain activity in these areas.

fMRI Results

Of primary interest were the areas identified as demonstrating an Age × Condition × Time interaction that showed greater activity for the self-relevant conditions than the control condition in either group. Two areas were thus identified, one in anterior and one in posterior medial cortex (see top of Table 2), consistent with the growing literature associating medial cortex activity with self-relevant thinking, as noted in the introduction section.

We first examined whether the difference in percent signal change between the self conditions, collapsed across hopes and aspirations and duties and obligations, and the control condition (i.e., a "self-relevance" effect) was greater in the anterior or the posterior medial region and whether this differed by age group. In addition to a main effect of Age (young > older), $F(1, 40) = 24.97$, $MSE = 0.03$, $p < .0001$, and a main effect of Area (anterior < posterior), $F(1, 40) = 6.32$, $MSE = 0.01$, $p < .05$, there was an interaction, $F(1, 40) = 7.51$, $MSE = 0.01$, $p < .01$, showing that the difference between young and older adults was larger in anterior than posterior medial cortex.

Because there is evidence that more superior versus more inferior subregions of medial cortex may differ in function with respect to self-relevant thinking (Johnson et al., 2006; for reviews, see also, e.g., Lieberman, 2007; Olsson & Ochsner, 2008), we further examined the anterior and posterior medial areas of activation by conducting an ANOVA on four subregions shown in

Table 2
All Regions of Activation Showing an Age × Condition × Time Interaction (Six Contiguous Voxels at p < .0001)

Pattern	Hemi	BA	Anatomical area	*x*	*y*	*z*	Maximum *F*	# vox
			Self-relevant > control					
	M	10, 9, (32)	medial frontal gyrus, (anterior cingulate cortex)	0	50	16	5.14	93
	M	7, 31, (23, 19)	precuneus, cuneus/cingulate gyrus	−11	−71	43	6.96	262
			Control > self-relevant					
¥, ¥¥ †, †† [.07]	R	19, 37	middle occipital gyrus, inferior temporal gyrus, (fusiform gyrus)	48	−60	−7	3.76	15
¥, ¥¥ ††	L	40	inferior parietal lobule, (postcentral gyrus), intraparietal sulcus	−49	−37	55	4.55	37
¥ †† [.06]	L	40	inferior parietal lobule	−38	−52	42	3.81	8
¥, ¥¥ †, ††	R	7, 40	superior and inferior parietal lobules, (precuneus), intraparietal sulcus	31	−49	52	4.35	34
¥, ¥¥	L	7	precuneus/superior parietal lobule	−22	−68	52	4.57	9
¥, ¥¥	R	6	superior frontal gyrus	16	2	52	3.96	9

Note. Medial areas (top) demonstrated greater activity during self-relevant thinking than during the control condition, as detailed in text and shown in Figures 1 (anterior) and 2 (posterior). All other areas (bottom) showed control > self-relevant ($p < .05$) for one or both age groups, as indicated by symbols in the first column of the table: ¥ = Young, control > hopes and aspirations; ¥¥ = Young, control > duties and obligations; † = Older, control > hopes and aspirations; †† = Older, control > duties and obligations. Talairach coordinates (*x*, *y*, *z*) are given for the peak voxel within the region of activation. Hemi = hemisphere; BA = Brodmann area; # vox = number of voxels in the cluster; L = left; M = medial; R = right. BA and anatomical areas are listed in descending order of approximate size, with approximately equal areas of activation indicated by a slash; parentheses indicate a small extent relative to other areas listed.

Figures 1A–1B and Figures 2A–2B (see details in the figure legends). There was a significant Region × Age × Condition interaction, $F(6, 240) = 3.27$, $MSE = 0.01$, $p < .01$; thus, we looked at these four subregions separately in planned comparisons.

As shown in Figure 1, in the more superior portion of anterior medial cortex (1A), primarily medial frontal gyrus, young adults showed the following pattern: hopes and aspirations > duties and obligations > control. However, older adults showed no significant difference in activity between conditions. In the more inferior portion that extended into anterior cingulate cortex (1B), young adults showed the same pattern as in Figure 1A, namely hopes and aspirations > duties and obligations > control (see also Johnson et al., 2006). Older adults, in contrast, showed greater activity for each of the self-relevant conditions than the control condition (duties and obligations > control; hopes and aspirations ≥ control [$p < .09$]), but they showed no difference between the two self-relevant conditions (hopes and aspirations = duties and obligations). For both of these anterior subregions, the difference between young and older adults' activity was significant for the control and hopes and aspirations conditions ($ps \leq .01$) but not for the duties and obligations condition.

Consistent with Johnson et al. (2006), in a more superior portion of the posterior medial region (see Figure 2A), primarily precuneus, young adults showed the following pattern: duties and obligations = hopes and aspirations > control. However, in a more inferior portion, primarily posterior cingulate, extending into cuneus, precuneus, and superiorly adjacent to retrosplenial cortex (see Figure 2B), young adults showed the following pattern: duties and obligations > hopes and aspirations > control. In both of these regions, older adults' activity did not differ between the two self-relevant conditions, though they showed greater activity in both self conditions compared with the control condition. For both of these posterior subregions, the difference between young and older adults' activity was significant only for the control condition ($ps < .05$), with no differences in the self-relevant conditions.

All other areas demonstrating an Age × Condition × Time interaction showed control > self-relevant thinking in one or both age groups (see details in Table 2). For completeness, Table 3

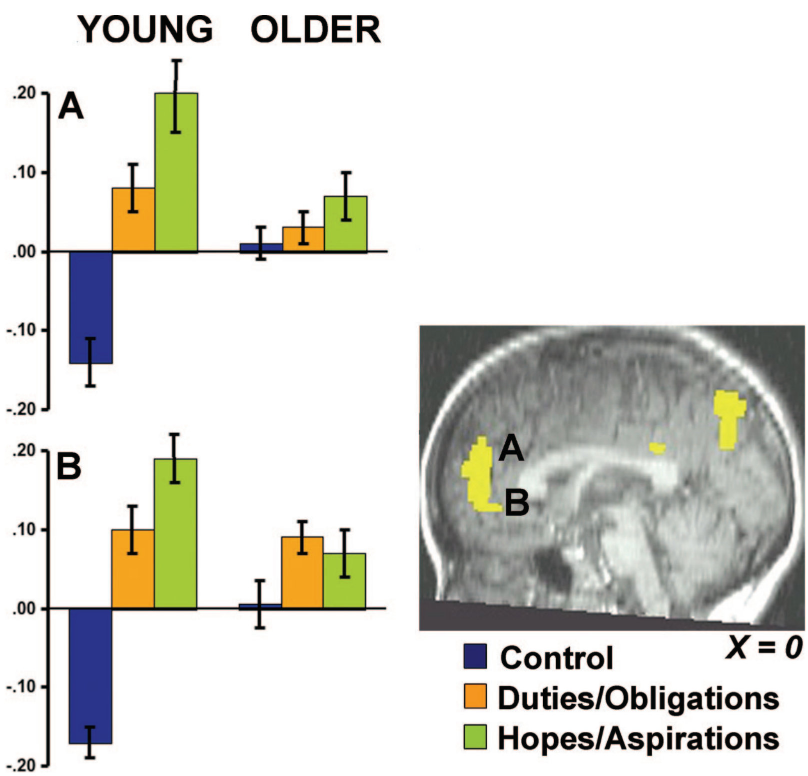

Figure 1. A region of medial prefrontal cortex showing an Age × Condition × Time Within Trial interaction. The region of activation represents the *F*-map of the interaction term; it is displayed on a standard (young) reference brain from our laboratory. Bar graphs show the mean—for Times 5, 6, 7—of the percent change in blood oxygen level-dependent (BOLD) signal from Time 1 (error bars are the standard error of that mean). (A) A more superior area, primarily medial frontal gyrus (BA10[9]; Talairach coordinates for the local maximum: $x = 0$, $y = 50$, $z = 16$), in which young adults showed the following pattern: hopes and aspirations > duties and obligations > control. However, older adults showed no significant difference in activity between conditions. (B) A more inferior area, primarily medial frontal gyrus extending into anterior cingulate cortex (BA10, 32[24]; −1, 48, −1), in which young adults showed the following pattern: hopes and aspirations > duties and obligations > control. Older adults showed greater activity for the self-relevant conditions than the control condition but no differentiation between the two self-relevant conditions (hopes and aspirations = duties and obligations; hopes and aspirations ≥ control [$p < .09$]; duties and obligations > control).

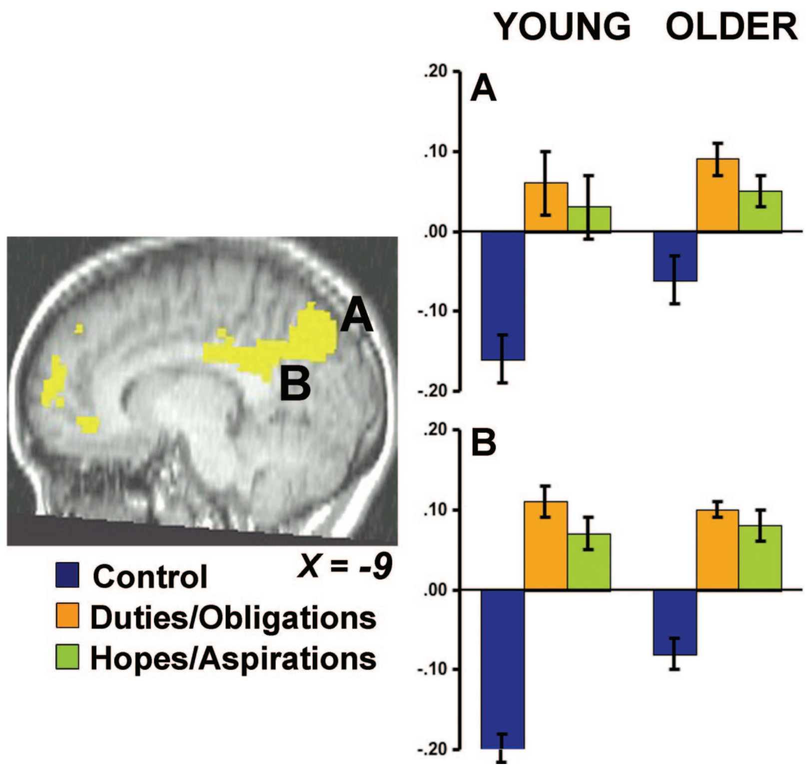

Figure 2. A region of medial posterior cortex showing an Age × Condition × Time Within Trial interaction. The region of activation represents the *F*-map of the interaction term; it is displayed on a standard (young) reference brain from our laboratory. Bar graphs show the mean—for Times 5, 6, 7—of the percent change in blood oxygen level-dependent (BOLD) signal from Time 1 (error bars are the standard error of that mean). (A) A more superior area, primarily precuneus (BA7; −11, −71, 43), in which both young and older adults showed the following pattern: duties and obligations = hopes and aspirations > control. (B) A more inferior area, primarily posterior cingulate cortex, extending into cuneus, precuneus (BA23, 31; −8, −43, 25), in which young adults showed the following pattern: duties and obligations > hopes and aspirations > control. Older adults showed the following pattern: duties and obligations = hopes and aspirations > control.

reports the areas that showed Condition × Time interactions not qualified by an interaction with Age; these were areas of lateral prefrontal and temporal cortex, and all showed control > self-relevant thinking. Table 4 reports all areas identified as demonstrating Condition × Time interactions in analyses conducted for each age group separately (i.e., within-group condition effects). These areas are largely already reflected in the other tables. As would be expected given the attenuated condition differences

Table 3
All Regions of Activation Showing a Condition × Time Interaction That Was Not Qualified by Interacting With Age (Six Contiguous Voxels at $p < .10^{-13}$)

Hemi	BA	Anatomical area	*x*	*y*	*z*	Maximum *F*	# vox
		Self-relevant > control					
none							
		Control > self-relevant					
L	21, 37, (19)	middle temporal, inferior temporal (middle occipital) gyri	−54	−60	−3	24.56	128
R[a]	42, 41	superior, transverse temporal gyri	60	−9	9	8.52	13
R	46, (10)	middle frontal gyrus	42	33	17	10.39	33
R	44, 6, (9)	inferior frontal, precentral, middle frontal gyri	42	7	31	10.90	34
L	44/6, 9	inferior, middle frontal junction	−50	4	26	8.63	10

Notes. Talairach coordinates (*x*, *y*, *z*) are given for the peak voxel within the region of activation. Hemi = hemisphere; BA = Brodmann area; # vox = number of voxels in the cluster; L = left; M = medial; R = right. BA and anatomical areas are listed in descending order of approximate size, with approximately equal areas of activation indicated by a slash; parentheses indicate a small extent relative to other areas listed.
[a] Control > hopes and aspirations only, and only for young adults.

Table 4
All Regions of Activation Showing a Condition × Time Interaction in Analyses of Each Age Group Separately

Effect	Hemi	BA	Anatomical area	*x*	*y*	*z*	Maximum *F*	# vox
			Young adults ($p < .10^{-13}$, 6 contiguous voxels)					
			Self areas					
HA > DO > C								
	M	10, 32, 9	medial frontal gyrus, anterior cingulate cortex	−1	51	4	12.53	131
HA = DO > C								
	M	7, 31, 40, (23)	precuneus, cingulate/cuneus (posterior cingulate)	−7	−67	31	26.90	578
			Control areas					
C > HA = DO								
	B	37, 19, 20	inferior and middle temporal,	52	−56	−7	18.58	66
			middle occipital gyri	−51	−60	−7	19.20	87
	R	46/45	middle, inferior frontal gyri	45	36	17	10.33	21
	R	6, 44, (9)	middle frontal, inferior frontal, inferior precentral sulcus	46	7	31	10.90	33
	L	40, 2	inferior parietal lobule, postcentral gyrus	−57	−29	44	14.17	98
			Older adults ($p < .0001$, 6 contiguous voxels)					
			Self areas					
HA = DO > C								
	M	10, 32	medial frontal gyrus, anterior cingulate cortex	−8	47	8	3.98	15
	M	**7, (29, 23)**	**precuneus, parietal occipital sulcus, (posterior cingulate)**	**−7**	**−70**	**31**	**12.50**	**370**
			Control areas					
C > HA = DO								
	L	21, 37, 22	middle, inferior, superior temporal gyri	−54	−56	−7	8.80	166
	R	**37, 19**	**middle, inferior temporal gyri**	**49**	**−53**	**−2**	**4.81**	**36**
	R	22, 42	superior, transverse temporal gyri	49	−15	4	4.27	17
	R	46, 45	middle, inferior frontal gyri	45	33	17	3.92	10
	L	6/44	inferior frontal, precentral gyri	−49	4	30	3.67	10
	L	19	superior occipital gyrus	−38	−86	31	4.02	17
	R	40	intraparietal sulcus, (supramarginal gyrus)	38	−44	39	3.59	10
C > HA > DO								
	R	40, 22	superior temporal gyrus, inferior parietal lobule, (supramarginal gyrus)	49	−46	18	3.64	15
C > DO[a]								
	L	40, 42, (2)	inferior parietal lobule, postcentral, (superior temporal) gyri	−65	−35	27	5.92	202

Note. Thresholds were chosen for each group that allowed interpretable regions of activation to be identified; as would be expected on the basis of the attenuated condition differences demonstrated by older adults, the threshold used for the older adults was lower than that used for the young adults. Subregions of the bolded areas for older adults survived thresholding at the same level used for the young adults, $p < .10^{-13}$. Subsequent analyses between the conditions within each age group were conducted on mean percent signal change at Times (Images) 5–7 from Time (Image) 1 in each condition. C = control condition; HA = hopes and aspirations condition; DO = duties and obligations condition. Talairach coordinates (*x*, *y*, *z*) are given for the peak voxel within the region of activation. Hemi = hemisphere; BA = Brodmann area; # vox = number of voxels in the cluster; B = bilateral; L = left; M = medial; R = right. BA and anatomical areas are listed in descending order of approximate size, with approximately equal areas of activation indicated by a slash; parentheses indicate a small extent relative to other areas listed.
[a] Although C > DO only, DO = HA; perhaps with more power we may have picked up the C > HA difference.

shown by older adults, the threshold was dropped for the older adults to identify significant regions of activation. Full activation maps for the areas shown in all tables are available from Karen J. Mitchell.

General Discussion

The current study compared young and older adults' brain activity as they thought about motivationally self-relevant agendas—their *hopes and aspirations* and *duties and obligations*—and concrete, non-self-relevant control items, such as *polar bears fishing*. Young adults' pattern of activity in anterior and posterior medial cortex was in line with previous evidence relating these regions to self-relevant thinking across a range of tasks (e.g., Cavanna & Trimble, 2006; Lieberman, 2007; Macrae et al., 2004; Mitchell, 2008; Northoff et al., 2006; Olsson & Ochsner, 2008; Vogt & Laureys, 2005). More specifically, it replicated the double-dissociation found previously using these same tasks with a different sample of young adults (Johnson et al., 2006): Medial frontal cortex showed relatively greater activity for thinking about hopes and aspirations, whereas medial posterior cortex, primarily posterior cingulate, showed relatively greater activity for thinking about duties and obligations. Compared with young adults, older adults showed attenuated differences in activity between self and control conditions in both anterior and posterior medial areas, significantly more so in anterior medial cortex. In addition, unlike the young adults, older adults showed no difference between the two self conditions in anterior or posterior medial cortex.

Consistent with other evidence that, compared with young adults, older adults offer less detailed and embellished episodic and autobiographical memory reports (Alea, Bluck, & Semegon, 2004; Piolino et al., 2006; but see Comblain, D'Argembeau, & Van der Linden, 2005) and give less detailed reports when asked to envision future events (Addis, Wong, & Schacter, 2007; Levin, Svoboda, Hay, Winocur, & Moscovitch, 2002), older adults in the current study produced less information in their post-scan reports than did young adults (see Table 1). Autobiographical retrieval is associated with activity in both anterior medial and posterior medial cortex (Lieberman, 2007; Northoff & Bermpohl, 2004). Thus one possibility is that the age-group differences in activity are related to the amount of autobiographical information processed (e.g., generated, retrieved, or evaluated). In addition, considering complex agendas—such as hopes and aspirations and duties and obligations—involves interrelated processing of past, present, and future aspects of the self in various contexts (see, e.g., Johnson & Sherman, 1990). There is considerable overlap in the medial brain regions involved in episodic memory tasks, envisioning future events, and self-relevant processing (Buckner & Carroll, 2007; Hassabis & Maguire, 2007; Schacter, Addis, & Buckner, 2007, 2008). Thus, older adults may have engaged in less prospection, self-projection, or self-reflection, or they may have created (or retrieved) less embellished self-related scenarios when thinking about their self-relevant motivational agendas, than young adults. Interestingly, whereas older adults produced shorter post-scan reports in both hopes and aspirations and duties and obligations conditions, they only showed reduced activity, compared with young adults, in anterior medial cortex in the hopes and aspirations condition. This suggests that older adults may have relatively more difficulty envisioning some, but not other, kinds of future possibilities.

Johnson et al. (2006) suggested that differences between anterior and posterior activity associated with thinking about hopes and aspirations versus duties and obligations may be related to the specific focus or content of such thoughts. Older adults' reports (see Table 1) suggested they were less inwardly self-focused and more likely to consider agendas with respect to other people than were young adults. It has been argued that medial frontal cortex is relatively more involved in the evaluation and reappraisal of self-relevant stimuli, and posterior medial cortex is relatively more involved in putting self-relevant information in context, integrating it with other self-relevant knowledge (Northoff et al., 2006). Older adults' relatively greater attenuation of activity in anterior medial than posterior medial cortex in the self conditions thus may signal a motivational change in focus from considering details specifically with respect to one's self to considering the "bigger picture," for example, the interpersonal context (Blanchard-Fields, 2007). In addition, the fact that older adults showed more similar activity associated with the two self conditions in anterior medial cortex than did young adults is consistent with behavioral evidence that although both young and older adults are more promotion than prevention oriented, the promotion > prevention difference is greater among young than older adults (Lockwood, Chasteen, & Wong, 2005; see also Ebner, 2008).

Interestingly, older adults' thoughts about their hopes and aspirations were less positive and more negative than young adults' thoughts, as determined by global affect ratings of their reports. This is an interesting contrast to other literature showing that under some circumstances (e.g., perceptual attention and memory tasks), compared with young adults, older adults tend to focus more on positive information (perhaps to modulate their emotions), and that young adults sometimes show a bias to focus on negative information (for reviews, see Charles & Carstensen, 2007; Mather, 2006; but see, e.g., Leclerc & Kensinger, 2008). It could be that in the current task, older adults' greater focus on retention and loss prevention with respect to their hopes and aspirations gave their reports a somewhat more negative tone, whereas young adults' marginally greater focus on acquisition gave their reports a somewhat more positive tone.

The finding of age-group differences in the valence of the hopes and aspirations reports raises the possibility that the age-group difference in medial prefrontal activity reflects this difference in valence of young and older adults' thoughts. This interpretation is not supported by other findings regarding the anterior medial areas associated with valenced self-relevant thinking. For example, a recent study of only young adults by Yoshimura et al. (2009) identified areas of superior anterior medial cortex, similar to the area in Figure 1A, in which activity during self-relevance rating of both positive ($x = 2$, $y = 55$, $z = 17$) and negative (0, 51, 12) trait adjectives was greater than during a semantic control task (*is the word easy or hard to define*)—the comparison most comparable with our manipulation—but they did not report that this area was differentially sensitive to positive and negative valence during self-processing in young adults. In addition, Gutchess et al. (2007) identified a medial prefrontal region that showed an Age × Valence interaction for self-rating of trait adjectives (greater activity for negative than positive adjectives for young adults and greater activity for positive than negative for older adults), but it was more dorsal (11, 38, 36 [Talairach coordinates derived from the Montreal Neurological Institute coordinates reported]) than the area in Figure 1A. Manipulating valence more directly in motivationally relevant tasks in future studies with young and older adults may help clarify which medial brain regions are associated with differential affective components of self-relevant thought.

Given that the post-scan reports in the current study were retrospective, further analytic studies are needed to better evaluate the relationship between age-group differences in medial cortex activity and the specific content of self-relevant thinking. We also note that differences in motivationally relevant thinking could occur in these groups for reasons other than age, per se (e.g., cohort effects, differences in racial/ethnic composition). It is important to note that our post-scan report findings show age-group differences in content similar to those reported in other investigations. Nevertheless, the role(s) of individual differences in the content of self-relevant thinking both between and within groups should be explored in future studies.

The discussion thus far has presumed that age-group differences in brain activity result from differences in what is motivationally relevant or salient (which presumably produce differences in the representations processed, or processes engaged, by young and older adults). Another possibility is that changes in brain function precipitate changes in motivational focus. However, note that Gutchess et al. (2007) found no difference between young and older adults' activity in anterior medial cortex when participants rated the self-relevance of presented trait adjectives[2] (that study did not find task-related posterior medial cortex activity in either group). This suggests that whether age differences are seen in medial cortex may be task specific. For example, superior medial frontal cortex may be involved in more controlled, reflective processing of complex self-relevant information and more inferior medial frontal cortex in more automatic processing (for reviews, see, e.g., Lieberman, 2007; Olsson & Ochsner, 2008). The medial prefrontal area related to self-relevant thinking in Gutchess et al.'s study corresponds most closely to our more inferior frontal area. Making judgments about adjectives with respect to self versus others may be done via relatively automatic activation of well-established and familiar concepts (see Gutchess et al., 2007, for a similar suggestion), whereas generating examples of personally relevant agendas may be more cognitively complex (for a similar argument regarding emotions, see, e.g., Johnson & Multhaup, 1992), requiring more controlled (i.e., executive) processing or more coordination between inferior and superior medial frontal regions. If so, our findings are consistent with evidence from cognitive tasks indicating that aging has more deleterious effects on higher level reflective processes (e.g., refreshing, retrieving) than less reflectively demanding processes, such as those that support perceptual priming (Craik & Grady, 2002; Johnson, Mitchell, Raye, & Greene, 2004; Light, 1991). Given that most neuroimaging evidence of age-related changes in brain activity associated with reflective processes involves lateral prefrontal cortex, the current findings add to the growing evidence regarding age-related changes in prefrontal functioning (for reviews, see, e.g., Daselaar & Cabeza, 2008; Rajah & D'Esposito, 2005).

Finally, we note that age-group differences in medial cortex between self-relevant and control conditions in this study were not due only to less activity for older than young adults on self-relevant trials but also to less deactivation during control trials for older than young adults. These medial areas usually activate during rest periods and deactivate during cognitive tasks, leading to the suggestion that self-reflective thought is a common "default mode" (D'Argembeau et al., 2005; Gusnard, Akbudak, Shulman, & Raichle, 2001). There is evidence of age-related attenuation of medial cortex activity during resting state (Damoiseaux et al., 2008; Lustig et al., 2003) and reduced anterior–posterior medial functional connectivity (Andrews-Hanna et al., 2007) in studies looking at this "default mode network." Given the findings of Gutchess et al. (2007) in combination with the present findings, it seems unlikely that attenuated activity in medial cortex exclusively reflects age-related physiological changes in these areas. Rather, the patterns may reflect, in part, that older adults engage less in self-relevant thought during rest than do young adults and/or that older adults have difficulty moving between self-reflection and cognitive tasks (e.g., imagining the control items; see also, e.g., Grady, Springer, Hongwanishkul, McIntosh, & Winocur, 2006; Persson, Lustig, Nelson, & Reuter-Lorenz, 2007). Such functional relationships may be associated with age-related increases in distractibility or age-related changes in the ability or motivation to inhibit task-irrelevant thoughts during on-going cognition (Hasher & Zacks, 1988; Zacks & Hasher, 1994; for fMRI evidence, see, e.g., Stevens, Hasher, Chiew, & Grady, 2008). Alternatively (or in addition), the level of deactivation seen during cognitive tasks may depend on the level of engagement of these regions during self-reflection; older adults may psychologically disengage from self-relevant thought as well as young adults, but less activation during rest (or self-reflection) may require or evoke less deactivation during a task.

In sum, the current study provides novel evidence that, compared with young adults, older adults show less of a self-relevance effect (self conditions > control) in anterior and posterior medial cortex in response to thinking about motivationally relevant personal agendas (hopes and aspirations, duties and obligations). This attenuation was greater in medial prefrontal cortex, where older adults showed less activation in response to thinking about hopes and aspirations than did young adults. The correlational nature of fMRI data does not allow us to differentiate whether (a) the observed age-group differences in medial cortex activity signal a shift with age in what is motivationally significant or salient during self-relevant thinking, and the change in focus or content results in changes in medial cortex activity, or (b) age-related changes in the functioning of medial cortex result in differences in the content or focus of young and older adults' self-relevant thinking and personal agendas (for related discussion, see Buckner, Andrews-Hanna, & Schacter, 2008). Nevertheless, consistent with other evidence in the literature and on the basis of a content analysis of the current post-scan reports, we provisionally suggest that the age-group difference in medial cortex is related to the fact that young and older adults focus on different information with respect to personal agendas because of changes with age in what is motivationally most salient. Such changes also may be associated with an age-related deficit in controlled, reflective processes supported by prefrontal cortex and engaged during complex, motivationally relevant self-reflection.

[2] We also note that medial frontal cortex shows less structural change (e.g., cortical thinning) with normal aging than do many other brain areas (Salat et al., 2004). In addition, although Alzheimer's dementia is related to both metabolic and functional changes in medial cortex, it tends to affect posterior rather than anterior medial cortex (Buckner et al., 2008; for further discussion of age-related brain changes, see, e.g., Dennis & Cabeza, 2008). A global reduction of the blood oxygen level-dependent (BOLD) signal of older adults also is an unlikely explanation for the current findings, as there were other areas of activation that were sensitive to condition but did not show age effects (see Table 3).

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Received June 23, 2008
Revision received January 6, 2009
Accepted January 12, 2009 ■