Finding the Self in Metacognitive Evaluations: Metamemory and Agency in Nondemented Elders

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Objective: Metacognitive methodologies are used to examine the integrity of self-referential processing in healthy adults and have been implemented to study disorders of the self-concept in neurologic and psychiatric populations. However, the extent to which metacognitive evaluations assess a uniquely self-evaluative capacity that cannot be explained fully by primary cognitive functions, demographics, or mood is not clear. The objective of the current study was to examine whether metamemory and a metacognitive test of agency shared a self-referential association that would not be explained by cognition, demographics, or mood. ***Method:*** Thirty-eight nondemented older adults (Mini Mental State Examination [MMSE] ≥ 24 and mean age $= 68.13$) participated in metacognitive testing and completed cognitive testing and mood questionnaires. Bivariate correlations were used to evaluate the association between metamemory and agency, and to determine the cognitive (memory, attention, and executive functioning), demographic (age and education), and mood (anxiety and depression) correlates of each. Correlates of metamemory and agency were then entered into linear regression models to determine whether any association between metacognitive measures remained. ***Results:*** Metamemory was associated with agency judgments ($n = 27$), specifically those on self-controlled rather than computer-controlled trials ($r = .41$, $p = .03$). Regression results supported a role for agency in predicting metamemory, above and beyond memory and education ($\beta = .39$, $p = .034$). Metamemory was also an independent predictor of agency judgments ($\beta = .36$, $p = .049$). ***Conclusions:*** The interrelation between metamemory and agency judgments suggests that metacognitive testing captures an important aspect of self-referential processing not otherwise assessed in a standard cognitive evaluation and may provide unique information about self-evaluative capacities in clinical populations.

Keywords: metacognition, metamemory, agency, self, awareness

Metacognitive methodologies offer the unique opportunity to study, in an objective fashion, the integrity of processes involved in self-assessment and the biases or errors that may affect such assessment in the context of neuropathology (Cosentino & Stern, 2005). Recent work from our laboratory has shown that individuals with mild Alzheimer's disease (AD) who are unaware of their memory loss obtain lower scores on episodic metamemory testing than those who recognize their memory loss, with the latter group performing comparably to healthy elders (Cosentino, Metcalfe,

Butterfield, & Stern, 2007). This association between clinically rated self-awareness and episodic metamemory performance was evident despite comparable semantic metamemory, global cognition, verbal memory, and depressive symptoms across the two awareness groups. The selective sensitivity of the episodic metamemory testing to disordered awareness of memory loss in AD suggests that metamemory testing uniquely captures an aspect of self-assessment not measured by standard cognitive tests, and may therefore offer an objective means of investigating the etiology and nature of changes in self-awareness seen in many individuals with dementia.

In the past decade, however, a series of studies examining the cognitive mechanisms of metamemory in healthy elders has demonstrated that metamemory is highly related to the integrity of executive functioning and memory to a lesser extent (Perrotin, Belleville, & Isingrini, 2007; Perrotin, Isingrini, Souchay, Clarys, & Taconnat, 2006; Perrotin, Tournelle, & Isingrini, 2008; Souchay, Isingrini, & Espagnet, 2000). Indeed, executive skills and metacognitive functioning have long been thought to share a cognitive and neural basis (Fernandez-Duque, Baird, & Posner, 2000). It is thus worth asking whether metacognitive tasks capture a specifically self-referential process that may deteriorate in the context of a degenerative disease, independent of primary cognitive abilities such as executive skills, attention, or memory. Because the neuropsychological battery in our above-mentioned

study of AD was limited, we may have failed to identify important aspects of cognition or mood that may mediate the association between metamemory performance and clinical ratings of awareness. To more fully understand the mechanisms that may contribute to metamemory in both healthy and pathological aging, the current study examined how metamemory scores relate to judgments of agency (another aspect of self-assessment), in comparison with demographic characteristics, cognitive functioning, and mood variables in nondemented elders.

Nelson and Narens (1990) described two primary metacognitive processes: monitoring and control. Monitoring relates to knowledge regarding one's own cognitive abilities and performance, while control refers to the decisions one makes based on their perception of their abilities, that is, their self-regulation. In this sense, disordered awareness of memory loss in a subgroup of individuals with AD can be considered a deficit in episodic memory monitoring. Judgment of Learning (JOL) and Feeling of Knowing (FOK) are two common tasks used to measure episodic memory monitoring. Episodic JOLs require individuals to estimate the likelihood that they will *recall* a newly learned item, whereas FOKs apply to the likelihood of *recognizing* nonrecalled information. It is well established that healthy adults make fairly accurate FOK ratings for episodic information (Leonesio & Nelson, 1990; Schacter, 1983), suggesting that their subjective experience of encoding and/or retrieval approximates their actual memory performance. However, the extent to which episodic FOK is preserved with aging is the subject of debate, with some studies documenting no age-related differences (Maclaverty & Hertzog, 2009) and others suggesting that this metamemory ability declines, particularly in relation to executive functions (Perrotin et al., 2006; Perrotin et al., 2008; Souchay et al., 2000; Souchay, Moulin, Clarys, Taconnat, & Isingrini, 2007). As such, the extent to which FOK variability in AD reflects specific information about the integrity of self-referential assessment as opposed to executive abilities in general, for example, is clouded.

Agency, the registration or experience that we are in control of our own actions (Gallagher, 2007; Synofzik, Vosgerau, & Newen, 2008), is a second area in which to explore objectively the processes and integrity of self-assessment across the spectrum of healthy to pathologic aging. Disruptions in agency have been hypothesized to underlie errors in self-other attribution in schizophrenia such as delusions of control and auditory hallucinations (Blakemore & Frith, 2003; Blakemore, Wolpert, & Frith, 2002; Turken, Vuilleumier, Mathalon, Swick, & Ford, 2003). For example, Knoblich and colleagues (2004) evaluated whether or not individuals with schizophrenia who had symptoms potentially reflecting failures in self-monitoring (e.g., auditory hallucinations), would have greater difficulty detecting external disruptions to their performance on a motor task than those without such symptoms. Indeed, the former group was less likely to identify such disruptions to their movement despite comparable performance on all other motor aspects of the task, lending support to the idea that a breakdown in self-referential processing may contribute to a specific constellation of symptoms in this patient population (Knoblich, Stottmeister, & Kircher, 2004).

Both metamemory and agency judgments may require an explicit self-referential element that is absent from standard cognitive tasks, and that may share fundamental similarities despite the varied nature of the tasks. Successful memory monitoring as measured with FOK

has been theorized to involve partial recovery of the nonrecalled target (Hart, 1967), familiarity with the cue (Reder, 1987; Reder & Ritter, 1992; Schwartz & Metcalfe, 1992) and accessibility of pertinent information about either the cue or target (Koriat, 1993). Recent work has suggested that all of these factors may be important for FOK and may occur in a sequential fashion such that cues that are familiar initiate a search for information about the target in memory storage (Koriat & Levy-Sadot, 2001). FOK thus seems to be made on the basis of several converging factors, relying not only on the accurate communication between search and storage systems, but likely on the integration of task-specific information with more general expectations for one's future performance. The current question is whether FOK judgments reflect an assessment of information in general, or whether they entail a specifically self-referential quality; that is, an assessment of the information in relation to one's own capabilities or self.

The mechanisms by which one determines whether or not one is the agent of an action has been the subject of recent debate and may be more complex than initially proposed (Gallagher, 2007; Synofzik et al., 2008). The forward model (Wolpert, Ghahramani, & Jordan, 1995), one of two primary internal models of the motor system, is one that has been applied to explain the manner in which a sense of agency is determined (Blakemore et al., 2002). This model posits that when an individual executes an action, the motor command and its expected sensory feedback are processed in parallel and ultimately compared. When a mismatch arises, an individual may have the sense that they are not in control of their actions. However, in recent years, it has been proposed that a distinction should be made between the *sense* of agency, and the *attribution* of agency. Synofzik and colleagues have argued that while the "comparator model" may explain how people derive a sense (or feeling) of agency, it does not sufficiently explain how attributions (or judgments) of agency are made (Synofzik et al., 2008). This argument is based partly on the fact that even in cases of sensorimotor mismatches, people can successfully attribute agency to personal or external factors, as well as the fact that subliminal presentations of words such as "I" or "me" can influence agency judgments. In combination with information from case studies, these findings suggest that people use a two-step process of determining agency, with a feeling of agency first determined at a nonconceptual, low level, and with a judgment of agency made second, based on higher order cognitive processes that synthesize contextual cues, personal beliefs, and information about the goal and/or potential external agents to inform their attribution of agency. Miele and colleagues have presented fMRI evidence supporting this distinction, and providing evidence for the self-referential nature of the judgment process (Miele, Wager, Mitchell, & Metcalfe, in press). This "multifactorial" account of agency invokes an explicit, higher-order element of self-evaluation that requires the integration of multiple information streams and may map onto the type of self-evaluation necessary for metamemory tasks.

In the current article, we implement a task in which individuals are asked to make judgments of agency; we treat this task as a second vehicle for self-assessment to examine whether a "self-referential" component of metamemory judgments may be identified. Based on our findings in AD revealing a unique association between clinically rated self-awareness and metamemory scores, our hypothesis is that while both the metamemory and agency tasks may have an executive component, there will also be a specifically self-referential component to metamemory performance that will be evidenced through an asso-

ciation with agency that is not accounted for by executive functioning, attention, memory, mood, or demographic characteristics in nondemented elders. Identifying a self-referential component of metamemory is important because: (a) it provides greater justification for the use of metamemory tools (and metacognitive tools more broadly) to characterize and investigate distortions of self-assessment; and (b) it addresses the question of whether or not information gained from metamemory testing provides information above and beyond that which would be gathered by evaluation of primary cognitive abilities. The current study examines these issues in nondemented elders in an effort to clarify the correlates of metamemory across a range of cognitive abilities. This work will set the stage for future examination of the stability of such associations in the context of AD and other dementias, and for understanding the potential influence of other factors on metacognition that are unique to a dementia population (e.g., regional distributions of neuropathology).

Method

Participants

Thirty-eight nondemented elders were recruited from three sources: the healthy control database available through the Alzheimer's Disease Research Center at Columbia University Medical Center, local senior centers, and market mailing procedures that target a diverse group of elders in New York City with a range of ethnic and educational backgrounds. Controls were thoroughly screened by interview to exclude individuals with neurologic, psychiatric, or severe medical disorders. Participants were considered eligible for the study if they were age 55 or above and scored at least 24 on the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). This cutoff is lower than standard cutoffs for "healthy elders" but accurately characterizes the cognitively diverse yet functionally intact elders in our study, and offers a broad range of performance in which to evaluate the relationship among various aspects of metacognition and cognition.

Procedures

Participants were seen over the course of two, 2-hr test sessions within 2 weeks. The first session included metamemory testing, agency testing, mood questionnaires, and several neuropsychological tests. The neuropsychological battery was completed during the second test session. This study was approved by the Columbia University Medical Center Institutional Review Board, and all individuals provided informed consent prior to participation.

Measures

Metamemory test.

Task development. The current metamemory test, a modified episodic FOK task, was designed as part of a larger study on metamemory in AD and thus has three characteristics that require attention. First, FOKs were acquired for each test item regardless of retrieval status. This modification was implemented to prevent floor effects in the patient group that could result in incalculable metamemory scores. To maintain parallel test formats across demented and nondemented elders, all participants received the modified FOK task, but more difficult fake trivia items were used (as determined through pilot testing) to prevent ceiling effects in the

nondemented elders. Second, as participants with AD in the larger study completed three different conditions of the metamemory test (described later) that were counterbalanced across three different trivia sets matched for overall phrase length and content, the nondemented elders included in this study were randomly assigned to one of the three task conditions and one of the three trivia sets. Task condition and trivia set were collapsed across participants in the current study and analyzed to determine the potential effects of these variables on performance.

Task instructions and format. The metamemory task consisted of four trials with five items in each trial, yielding a total of 20 metamemory items. The stimuli consisted of five pieces of "pseudo trivia" regarding a fictitious individual and information about their background. Each trial included global metamemory judgments prior to and following the FOK judgments for each individual item. Specifically, the examiner read the following instructions, "During this task, I am going to tell you about five people. I will tell you their name and something about their background. Your task is to try to remember this information as best you can. Please listen carefully." Immediately after the first learning trial was presented (e.g., *Haxby wrote a nonfiction book about space travel; Corbett was a former mayor in Nevada, etc.*), participants were asked to provide a global judgment of learning (the global JOL; *"Now I am going to test your memory for those names, giving you answer choices. Of the five names, how many do you think you will get right?"*). FOKs were then acquired one at a time for each item by providing written questions on 8.5" × 11" paper (e.g., *Who was a former mayor of Nevada?*) and the following prompt was read aloud by the examiner: "There are eight possible answers on the next page. Will you know which one is right – Yes, Maybe, or No?" Once predictions were recorded, participants were provided with eight answer choices and asked to select the correct answer. The answer choices included the correct response, the correct answers for the remaining 4 stimuli (to control for basic familiarity effects), and 3 new distractors. In the standard condition, the tester moved onto the next item. In the query condition, participants were asked whether they thought their answer was correct prior to moving onto the next item. In the feedback condition, the examiner told the participant whether their answer was correct or incorrect prior to moving onto the next item. At the completion of the 5-item test phase, participants were again asked to make a global retrospective confidence judgment (RCJ) regarding the overall number of memory items out of 5 that they recognized correctly. This process was repeated for learning trials 2 through 4, resulting in a total of 4 global JOLs, 4 global RCJs, and 20 item-specific FOKs. Stimuli were presented in the same order across each of the four learning trials; questions and answer choices were presented in a pseudorandom order.

Dependent variables. Four separate dependent variables were calculated to comprehensively assess metamemory monitoring as described below:

1. *Resolution*, or the relative accuracy of judgments, reflects the extent to which accuracy is high when FOK predictions for performance are high, and accuracy is low when FOK predictions are low. The nonparametric Goodman-Kruskal gamma statistic, a rank order correlation (Nelson & Narens, 1984), was used to measure resolution. Gamma compares the relative number of con-

cordant and discordant prediction/accuracy pairs, discarding "ties," or instances in which either the rating or accuracy in one pair is equal to that in another pair. Limitations of gamma include a tendency to be pulled to an extreme value on the basis of only one concordance or discordance, and a possibility that no score can be calculated in the event of all ties.

2. *Calibration* scores reflect the extent to which an individual is generally over or under confident in their judgments. Calibration can be measured at several levels and was quantified in the following manner for the current study:

- Collapsed item-specific calibration. This variable was calculated by translating ordinal predictions for each item (Yes-Maybe-No) into interval data (1, 0.5, and 0). The proportion correct was then subtracted from the proportion predicted to generate a score ranging from −1.0 to 1.0. Scores were then averaged across the four trials to create the final dependent variable. A score of zero indicates perfect calibration, positive scores indicate overconfidence, and negative scores indicate underconfidence.
- Conditional probabilities. To look more closely at the pattern of performance across different predictive categories, three variables were derived to reflect the conditional probabilities of achieving correct responses based on each of the three predictions including: *P(Correct)/ Yes* = the proportion of items answered correctly when participants predicted that they *would* know the answer; *P(Correct)/ Maybe* = proportion of items answered correctly when participants predicted that they *might* know the answer; and *P(Correct)/ No* = proportion of items answered correctly when participants predicted that they *would not* know the answer.
- Global calibration based on global JOL and RCJ. Scores were determined by subtracting the proportion correct from the proportion predicted correct prior to each trial (global JOL) and following each trial (global RCJ) to generate scores ranging from −1.0 to 1.0. The final two dependent variables were the average global JOL and RCJ calibration scores across all four trials.

Agency test. This computerized task was designed to measure participants' ability to monitor whether they or the computer had controlled the movement of a cursor on the screen, and is based on a task developed by Metcalfe and Greene (2007; Kirkpatrick, Metcalfe, Greene, & Hart, 2008; Metcalfe, Eich, & Castel, 2010; Metcalfe & Greene, 2007; Miele et al., in press) It is a very simple motor task in which, following each trial, people make judgments of agency (Metcalfe & Greene, 2007). To begin the task, the participants were instructed to use the computer mouse to move a square cursor horizontally along the bottom of the screen. Participants were instructed to touch as many 'X's as possible that were falling from the top of the screen and to avoid 'O's. One-third of the 24 trials were *self* trials that had no interference—the cursor moved in accord with the participant's mouse movements. One-third of the trials (*computer* trials) were controlled by the computer such that the cursor moved directly to the nearest falling X in a linear fashion. In this condition, the cursor touched O's as well if they happened to be in the direct path to the X. The final third of the trials (*split* trials) were controlled partially by the participant and partially by the computer, such that one-half of the movements to falling X's were controlled entirely by the participant, as in the *self* condition, and one-half of the movements toward the X's were controlled entirely by the computer. Of every two

X's within the trial, one was randomly assigned to be self-controlled while the other was designed to be computer controlled. Trials were blocked into groups of three including one *split*, one *computer*, and one *self*, and presented in a random order within each block. There were a total of 8 such blocks.

At the beginning of each trial, regardless of condition, the participant had to initiate a movement of some kind to start the trial. This was done to discourage participants from simply watching to see whether the cursor moved on its own, which would have allowed them to easily discriminate self from computer control. Any extended lack of participant-produced mouse movement produced a warning message telling the participant that they had to move the mouse. Once the initial movement was registered on any given trial, the position of the cursor on the screen could be because of self movements, computer movements, or split, depending upon the assigned condition for that trial. Participants were given one practice trial at the start of the experiment to allow familiarity with the task. The practice trial was always a *self* trial.

Agency judgments. After each 10-s trial, participants were asked "Who was in control?" and were directed to choose either "Me" or "Computer" by clicking a button on the screen. Agency judgments on self-controlled trials were considered correct if the participant indicated "Me." Agency judgments on computer-controlled trials were considered correct if the participant indicated "Computer." Split trials were not considered in scoring the accuracy of agency judgments.

Computer Mouse Experience Questionnaire. To evaluate the expected impact of computer mouse experience on agency judgments, participants were given a three-item questionnaire assessing prior mouse use: (a) "How often have you used a computer mouse prior to today?" *Never, A few times in my life, Many times*; (b) "How often have you used a computer mouse in the past year?" *Never, A few times, Several times a month, Several times a week, Daily*; and (c) "How comfortable do you feel using a computer mouse?" *Not comfortable, Somewhat comfortable, Very comfortable.*

Cognitive battery. The following measures were selected to assess a range of cognitive abilities related to memory, attention, and executive abilities.

Philadelphia Repeatable Verbal Learning Test (PVLT). The PVLT (Price et al., 2009) is a list-learning task modeled after the 9-word California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 1987; Libon et al., 1996) in which participants are required to learn 9 words (comprising three different categories: fruit, tools, and furniture) over the course of five trials. The primary dependent variables included total immediate recall across the 5 learning trials, and delayed recall after 20 to 40 min.

Biber Figure Learning Test. This modified version of a nonverbal list learning task (Glosser, Goodglass, & Biber, 1989) consists of 9 black-and-white geometric designs presented over five trials. Designs were presented one at a time in a fixed order, for three s each. During the test phase, participants were asked to draw as many designs as they could remember. After a 20- to 40-min delay, participants were again asked to recall as many designs as possible, and subsequently to copy each of the stimuli to ensure that constructional abilities required for intact performance did not affect memory performance. Each drawing was scored according to strict guidelines on a scale of zero to three.

Dependent variables included total immediate recall across the 5 learning trials and delayed recall.

Visual scanning.   This test consisted of 60 targets among an array of distractor items spread across an 8.5" × 11" page displayed horizontally. Participants were asked to find and circle all of the targets as quickly as possible. The dependent variables were the total number of targets identified in 60 s and the overall time to completion.

Digit span.   This subtest from the third edition of the Wechsler Memory Scales - Third Edition (WMS-III) (Wechsler, 1997) required participants to repeat a series of digits, beginning with only two and increasing until the participant failed two consecutive items at a given series length. The second part of the test required participants to recite the numbers read aloud by the examiner in the reverse order. The dependent variables were the total raw scores on each of the forward and backward components of the task.

Spatial span.   This WMS-III subtest (Wechsler, 1997) required participants to remember a series of spatial locations on a board, beginning with only two and increasing until the participant failed two consecutive items at a given series length. The second part of the test required participants to recall the locations demonstrated by the examiner in the reverse order. The dependent variables were the raw scores on each of the forward and backward components of the task.

Letter fluency.   Participants were given 60 s to generate words beginning with a specified letter (i.e., 'F,' 'A, and 'S') excluding proper nouns. Repetitions and intrusions did not receive credit. The dependent variable was the average number of words recalled across trials.

Design fluency.   This test (Glosser & Goodglass, 1990) consisted of 20 dot matrices across a 22-inch horizontal line. Participants were asked to use four lines within each matrix to create a design, and to draw as many different designs as possible across the row. The test was untimed, and the dependent variable was the total number of unique designs.

Cognitive Index scores.   Scores on the above tests were converted into *z*-scores and compiled into three indices to represent attention, memory, and executive abilities. These indices were defined on a theoretical basis and supported by the bivariate associations between neuropsychological scores. The Memory index was an average of performance across the five learning trials of the PVLT and Biber, as well as the delayed free recall trials of each test. The Attention index was an average of performance across the visual scanning task, Digit Span Forward, and Spatial Span Forward. The Executive index was an average of performance across FAS, Design Fluency, Digit Span Backward, and Spatial Span Backward.

Mood questionnaires.

Geriatric Depression Scale.   This is a 30-item self-report tool (Yesavage, 1986) designed to evaluate nonvegetative symptoms of depression in older adults. Participants were prompted to endorse those items they have experienced in the past week.

Beck Anxiety Inventory.   This is a 21-item self-report assessment tool (Beck & Steer, 1990) designed to capture a wide range of symptoms related to anxiety. Each item was scored on a scale from 0 to 3, depending on the extent to which the item "bothered" the participant over the past week, with 0 being "*not at all,*" and 3 being "*severely—I could barely stand it.*" Scores were totaled across all items to determine the general level of anxiety (none, mild, moderate, or severe).

Results

Missing Data

Gamma scores were calculable for 30 of 38 healthy elders. The remaining 8 participants demonstrated either no variability in their predictions (Yes, Maybe, No), or in their accuracy, which meant that gammas could not be computed. Four individuals did not have data for the agency test. All analyses examining both gamma and agency were conducted in the 27 individuals who had both gamma and agency scores; the remaining analyses for each variable were conducted in all individuals with available data (gamma, $n = 30$; agency, $n = 34$).

Descriptive statistics.   The mean age and educational level of participants was 68.10 ($SD = 7.82$) and 15.87 ($SD = 2.15$), respectively. Twenty-eight of 38 (74%) participants were women, and 97% indicated non-Hispanic as their ethnicity, with the following breakdown across race: 74% Caucasian, 16% African American, 8% Asian, and 2% Other. Mean metamemory, agency, cognitive, and mood scores are presented in Table 1. Interrelations among the various metamemory scores are presented in Table 2.

Metamemory Task Condition and Stimuli Set

As part of a larger study, healthy elders received one of three conditions of the metamemory test and one of three trivia sets. There was no difference in any metamemory score as a function of task condition (standard, query, or feedback) or trivia set (1, 2, or 3) except for the conditional probability variable: *p(Correct)/Maybe*, which varied as a function of trivia set, $F(2, 31) = 3.66$, $p = .04$. Therefore, trivia set was entered as a covariate in analyses examining the association between this metacognitive variable and judgments of agency.

Agency Test

Because the computer-controlled condition was designed such that the cursor moved directly to the nearest falling X in a linear fashion, touching any O's if they happened to be in the direct path to the X, it was possible that participants could have distinguished between trial types by observing the number of O's hit. To rule out this possibility, we examined the percentage of false alarms (O's hit) in each trial type. The means and *SD*s for the two types of trials were: .20 (.06) for the computer controlled, and .16 (.08) for the self controlled. While this difference is statistically significant ($p = .01$), the magnitude of the difference was small, and it was likely not a major factor in helping the participant to differentiate between trial types.

Computer Mouse Experience

A total of 7% of participants reported never using a mouse prior to the current study, 13% reported having used a mouse a few times in their life, and 80% reported having used a mouse many times. With regard to use in the past year, 16% reported using a mouse a few times, 29% reported using a mouse several times a month, and 55% reported weekly use. Finally, 6% of participants stated that they were not comfortable using a mouse, 13% reported being somewhat comfortable, and 81% were very comfortable.

Table 1
Metamemory, Agency, Cognition, and Mood

Scores	M	SD	Minimum	Maximum
Metamemory task				
Memory percent correct (0–1)	.71	.24	.05	1.00
Gamma (−1 to 1)	0.65	0.53	−1.00	1.00
p (Correct)/Said Yes (0 to 1)	0.90	0.17	0.33	1.00
p (Correct)/Said Maybe (0 to 1)	0.53	0.30	.00	1.00
p (Correct)/Said No (0 to 1)	0.41	0.42	.00	1.00
Collapsed calibration (−1 to 1)	0.04	0.14	−0.18	0.40
Global calibration (JOL; −1 to 1)	−0.05	0.17	−0.45	0.40
Global calibration (RCJ; −1 to 1)	−0.08	0.12	−0.35	0.19
Agency task				
d' for self trials (NA)	1.38	0.54	−0.21	2.20
Total agency judgments (0–16)	10.74	3.14	5.00	16.00
Judgments on self trials (0–8)	6.59	1.88	2.00	8.00
Judgments on computer trials (0–8)	4.15	2.49	0.00	8.00
Attention				
Digit span forward (0–16)	10.69	2.12	7.00	14.00
Spatial span forward (0–16)	7.58	2.13	3.00	12.00
Visual scanning targets (0–60)	47.39	10.25	22.00	60.00
Visual scanning seconds (NA)	130.89	52.29	60.00	338.00
Memory				
List learning total (0–45)	38.97	3.39	33.00	44.00
List learning delay (0–9)	7.26	1.67	3.00	9.00
Figure learning total (0–135)	91.83	20.36	34.00	127.00
Figure learning delay (0–27)	21.17	5.21	5.00	26.00
Executive				
Average verbal fluency (NA)	16.09	4.26	9.00	24.30
Design fluency (0–20)	16.77	2.12	12.00	20.00
Digit span backward (0–16)	7.58	2.13	3.00	12.00
Spatial span backward (0–16)	6.47	1.82	2.00	9.00
Mood				
Geriatric Depression Scale (0–30)	4.34	4.63	0.00	16.00
Beck Anxiety Inventory (0–63)	3.55	3.33	0.00	12.00

Note. NA = not applicable.

Bivariate Correlations

In total, we conducted 24 bivariate correlations described below and reported in Table 3. The hypothesis-driven correlations (the association between gamma and agency as well as those indicated in Table 3) were interpreted as significant at $p < .05$. The remaining correlations were considered significant at a bonferroni corrected p value of .003 (.05/17).

Metamemory and agency judgments. Total correct agency judgments across self- and computer-controlled trials were significantly associated with gamma ($r = .41$, $p = .03$) but unrelated to calibration scores. Follow-up analyses therefore focused on the additional correlates of gamma and agency judgments. Bivariate results are summarized below and presented in Table 3.

Correlates of gamma. The only significant correlate of gamma was agency, ($r = .41$, $p = .03$); this was specifically related to self-controlled trials (see below).

Correlates of agency judgments. The primary variable of interest on the agency task was the overall accuracy of agency judgments (i.e., who was in control: self or computer?) across the 8

Table 2
Interrelation of Metamemory Scores

	p(Correct) Yes	p(Correct) Maybe	p(Correct) No	Collapsed calibration	Global JOL	Global RCJ
Gamma	.44*	−.04	.02	−.15	−.09	−.01
p(Correct)/Yes		.40*	.38	−.61**	−.51**	−.10
p(Correct)/Maybe			.22	−.68**	−.51*	−.28
p(Correct)/No				.38	−.50*	−.20
Collapsed Calibration					.81**	.45*
Global JOL						.69**

Note. JOL = Judgment of Learning; RCJ = Retrospective Confidence Judgment.
* $p < .05$. ** $p < .01$.

Table 3
Cognitive, Demographic, and Mood Correlates of Metacognitive Scores

	Gamma (n = 30)	Self trials (n = 34)	Computer trials (n = 34)
Education	.48**	−.08	.09
Memory	.48**	.39*	.09
Executive Functioning	.30+	.37*+	.34+
Attention	.26	.23	.51**
Mouse Familiarity	.12	−.02+	.42*+
Age	−.20	−.23	−.36*
GDS	−.05	.02	−.16
BAI	.16	.18	.01

Note. GDS = Geriatric Depression Sale; BAI = Beck Anxiety Inventory.
* $p < .05$. ** $p < .01$. *** $p < .003$. + Hypothesis driven.

self-controlled and 8 computer-controlled trials. The accuracy of agency judgments on self-controlled trials was unrelated to the accuracy of judgments on computer-controlled trials ($r = .01$, $p = .94$). As such, we examined the correlates of these two task components separately, rather than as an overall score. Agency judgments on self-controlled trials was the aspect of agency related to gamma ($r = .48$, $p = .01$), and was also related to the executive index ($r = .37$, $p = .036$). Agency judgments on computer-controlled trials were unrelated to gamma, and uniquely related to computer mouse familiarity ($r = .42$, $p = .02$). See Table 3 for bivariate results.

While several results were significant at $p < .05$ and $p < .01$, no results reached significance at the bonferroni-corrected level of $p < .003$. However, to be sure that we did not miss variables that might mediate the relationship between gamma and agency, any results significant at $p < .05$ were included in the regression models below.

Regression Analyses

Linear regressions were conducted to determine the extent to which metacognitive variables were associated with one another, above and beyond other potential demographic and cognitive correlates. After entering those variables that were correlated with gamma at $p < .05$ including: agency judgments on self-controlled trials, education, and memory, as predictors in a single block, the overall model was significant, $F = 6.91$, $p < .01$. However, only agency judgments on self-controlled trials ($\beta = .39$, $p = .034$) and education ($\beta = .43$, $p = .012$) emerged as independent predictors of gamma. Regression results are reported in Table 4.

Additional analyses were conducted to determine the extent to which metamemory predicted agency judgments on self-controlled trials above and beyond potentially associated demographic and cognitive variables. After entering those variables that were correlated with agency judgments on self-controlled trials at $p < .05$ including: gamma, executive functioning, and memory, the overall model was significant, $F = 4.50$, $p = .01$ but no single variable emerged as uniquely predictive. We then repeated the analysis, excluding memory as it had not been an initially significant correlate of agency, and the overall model remained significant, this time with gamma ($\beta = .36$, $p = .049$) and executive functioning ($\beta = .37$, $p = .044$) both emerging as comparably significant

predictors. Finally, in the model examining predictors of agency judgments on computer-controlled trials (attention, age, and computer mouse familiarity), the overall model was significant, $F = 4.97$, $p = .008$, and attention emerged as the only significant predictor ($\beta = .40$, $p = .047$).

Discussion

Unlike tests of cognition, metacognitive tasks appear to require an explicit element of self-evaluation. This particular task characteristic, revealed in the data presented here, underlines the importance of including metacognitive tasks in evaluations directed at studying distortions of the self concept that are observed in neurologic syndromes such as dementia and schizophrenia. Current results are consistent with recent work in our lab demonstrating a selective association between an episodic FOK task and clinical variability in awareness of memory loss in AD (Cosentino et al., 2007). In this previous study, we found that multiple aspects of episodic FOK performance including both relative accuracy (gamma) and calibration were associated with clinically rated awareness of memory loss, whereas global cognition and verbal memory were unrelated to metacognitive scores or awareness. However, our evaluation of broader cognitive functioning was limited, and there is accumulating evidence in older adults to suggest that FOK accuracy is highly related to executive processes and at least partially dependent on memory (Perrotin et al., 2006; Perrotin et al., 2008; Souchay et al., 2000). As such, metacognitive evaluations may not gather unique information regarding distortions of the self-concept above and beyond that obtained from a thorough cognitive evaluation. The current study was undertaken in an effort to determine whether a self-referential contribution to metacognitive tasks could be identified and to more fully understand the various factors which contribute to metamemory performance in older adults and individuals with dementia.

The primary hypothesis of this study was that metamemory testing assesses a self-referential capacity that is qualitatively different from that measured through cognitive tasks and that cannot fully be explained by the demographic or mood characteristics of participants. Thus, while we expected an association between executive functioning and metacognitive test performance, we predicted an association between metamemory scores and agency judgments (based on a hypothesized shared self-

Table 4
Predictors of Gamma and Agency Scores

Predictors	Gamma	Agency: Self trials	Agency: Computer trials
Education	.43*		
Agency: Self trials	.39*		
Memory	.19		
Gamma		.36*	
Executive Functioning		.37*	
Mouse familiarity			.30
Attention			.40*
Age			−.12

Note. Standardized beta values are reported.
* $p < .05$.

referential component) that would not be accounted for by demographic factors, mood, or cognitive abilities such as executive functioning. As predicted, agency judgments (albeit on self-controlled trials only) independently predicted metamemory after accounting for cognitive and demographic variables. Moreover, gamma remained a significant predictor of agency judgments on self-controlled trials, above and beyond the role of executive functioning (which was also a significant predictor). In contrast to predictions, education rather than executive functioning also exerted an independent effect on gamma scores. The relationship between FOK gamma and agency judgments, two metacognitive variables derived from tasks with entirely different stimuli (auditory vs. visual), divergent demands (memory vs. motor control and visual attention), and variable timing of self-assessment (predictions vs. posttrial evaluations), is compelling and argues for a fundamentally self-referential component to these two metacognitive tasks. In the following sections, we address the correlates of each metacognitive score and conclude by discussing the relevance of the association between gamma and agency.

Metamemory

Our results were not entirely in line with a series of studies suggesting that age-related decrements in FOK (gamma) are largely mediated by executive functioning (Perrotin et al., 2006; Perrotin et al., 2008; Souchay, Isingrini, Clarys, Taconnat, & Eustache, 2004; Souchay et al., 2000). For example, Perrotin and colleagues demonstrated a double dissociation in older adults such that performance on executive tasks including the Wisconsin Card Sorting test and the Stroop Color Word test contributed to FOK scores whereas performance on processing speed tasks contributed to cued recall (Perrotin et al., 2006). A later study by the same group demonstrated that while memory and education were associated with FOK accuracy, executive functioning was the most powerful predictor, and cognitive shifting emerged as the most relevant component of executive abilities in contrast to updating or inhibiting (Perrotin et al., 2008).

In the current study, gamma was unrelated to executive function or age. The lack of an association between executive tasks and gamma may reflect the difference in executive tasks selected, with the current tasks placing demands on working memory (verbal and nonverbal backward span) and generation of novel information (verbal and nonverbal fluency) rather than cognitive set shifting. An equally important consideration is the nature of the FOK task used in our study. Perrotin and colleagues implemented a standard paradigm with FOK judgments for nonrecalled information only whereas the current study acquired FOK judgments for all test items regardless of recallability. In this sense, the current framework might be thought of as a recognition-based JOL paradigm. Consistent with this distinction, Souchay and colleagues demonstrated that executive functioning was selectively related to FOK and not JOL performance in healthy elders (Souchay et al., 2004). Therefore, it may be that while executive processes are highly relevant for assessing the availability of nonrecallable information, they play less of a role in making judgments that take advantage of both recallable and nonrecallable information.

Agency

The agency task evaluated the extent to which individuals could distinguish between instances in which they were in control of the cursor on the computer screen versus when the computer was in control. In order to make such a judgment, individuals attempted to complete the assigned task, namely to catch the X's as they fell from the top of the screen while avoiding the O's, and detect mismatches between their self-generated movements and the perceptual effects of those movements (behavior of cursor) on the computer screen. The basic goal of the task, catching X's and avoiding O's, required elements of visual attention and scanning, speed, inhibition, and planning, and was pertinent to all trials. It was therefore interesting that the accuracy of agency judgments (i.e., Was I in control of the cursor?) on self-controlled trials was unrelated to that on computer-controlled trials. We did not necessarily expect this dissociation; however, the nonoverlapping correlates of these two types of judgments reinforce the idea that there are different processes that contributed to each. With regard to self-controlled trials, both gamma and executive functioning were independently related to agency judgments. Specifically, higher metamemory scores and higher executive scores were both associated with the tendency to accurately identify when the self was in control.

In contrast, the accuracy of agency judgments on computer-controlled trials was related to computer mouse familiarity, but best explained by performance on the attention index. The prominent role for these variables (rather than metamemory) in determining agency judgments on computer-controlled trials may be better understood by considering the processes involved in judgments on each type of agency trial. In the absence of computer interference, the individual has simply to: (a) move the mouse; (b) observe the behavior of the cursor; and (c) make a judgment about their control. In the context of computer interference, however, an individual must: (a) move the mouse; (b) observe the behavior of the cursor; (c) recognize differences between cursor behavior and mouse movement; (d) attempt to reconcile differences in cursor behavior with mouse movement; (e) recognize that they cannot reconcile differences; and (f) decide whether or not their failure to reconcile differences reflected poor performance on their part or external interference. Computer mouse familiarity may thus be expected to influence agency judgments on computer-controlled trials more so than self-controlled trials. It is also arguably the case that the seemingly increased complexity of judgments on computer-controlled trials requires greater attentional resources than self-controlled trials. Future work is needed to more fully understand whether differential demands of decisions under self-controlled conditions versus other-controlled conditions persist in other tasks, and the relevance of such differences.

Although the current study was not designed to evaluate different models of agency, in many respects, the current results appear to be in line with the multifactorial model of agency. First, the association between metamemory and agency suggests that agency judgments encompass an explicit element of self-evaluation that goes beyond a bottom-up comparison of motor intention and sensory feedback processes. Second, the dissociation between the accuracy of judgments on computer and self-controlled trials, and

the distinct cognitive correlates of each type of agency judgment, implicate factors other than sensory feedback as contributors to judgments of agency.

Association Between Metamemory and Agency

The current results suggest that the association between the metamemory and agency tasks reflects a shared "self-referential" component rather than a superficial aspect of the tasks such as the requirement to make a judgment. Because our battery did not include tasks which required judgments about factors other than one's own performance, we do not have a specific control for this possibility. However, data from an fMRI study on this agency paradigm implicates an area activated in making agency judgments—the anterior PFC—that is also implicated in making other self-referential assessments such as whether certain adjectives describe the self (Miele et al., in press). Furthermore, the present data argue strongly against the idea that the requirement to make any kind of judgment links the two tasks, because judgments of agency on self-controlled trials and computer-controlled trials were unrelated and had different correlates. The basis of an association between FOK and agency judgments on self-controlled trials, in which the two judgments were fairly different (*Will you know the right answer* vs. *Were you in control*), is thus likely to reflect similarities in the processes required for both tasks rather than similarities in task format.

Certainly, models of agency and metamemory are quite different, involving varied parameters and brain regions. However, the association between these two metacognitive processes in the current study suggests that they may employ a shared set of cognitive processes and/or neural networks. The majority of work suggests that FOK is associated closely with executive abilities (more so than with memory) (Souchay et al., 2004), consistent with studies suggesting an important role for the prefrontal cortex in supporting FOK (Schnyer, Nicholls, & Verfaellie, 2005; Schnyer et al., 2004). In particular, there is work to suggest that the inferior frontal cortex (IFC) supports the attempted retrieval of information from temporal areas, while the ventromedial prefrontal cortex (VMPFC) has been implicated in assessing the accuracy of the retrieved information (Schnyer et al., 2005). There is also evidence to suggest that midline cortical structures such as the cingulate, believed to be important for internally directed cognition as well as executive control processes (Hedden & Gabrieli, 2010), play an important role in metamemory versus memory (Chua, Schacter, & Sperling, 2009). It is interesting to note that the current results suggest that the processes and/or networks involved in self-referential judgments are not necessarily synonymous with those invoked during standard executive tasks (or at least the ones chosen for this study). That is, while FOK was not associated with our index of executive functioning (potentially for reasons discussed above), it was clearly related to agency judgments on self-controlled trials. This association implies that the aspects of FOK which may relate to executive functioning are perhaps different than those that relate to self-reference more specifically.

With regard to agency, the most recent accounts postulate a multifactorial model, including both bottom-up and top-down processes. At a basic level of online action monitoring, the motor command and its efferent copy are compared with one another, allowing individuals to detect mismatches between their intentions and the sensory outcomes of an action (Blakemore et al., 2002). In a second step of self-referential metacognitive judgment, higher order cognitive processes are brought to bear to determine the attribution of agency (Gallagher, 2007; Synofzik et al., 2008). Existing work suggests that a network of brain regions (generally right more so than left) involving the posterior parietal cortex (Chaminade & Decety, 2002; Farrer et al., 2008; Farrer & Frith, 2002; Fink et al., 1999), the posterior superior temporal sulcus (Leube et al., 2003), prefrontal cortex (Fink et al., 1999), and cerebellum (Blakemore, Frith, & Wolpert, 2001), appear to contribute to bottom-up action monitoring. The prefrontal cortex may also be particularly important for higher level attributions of agency, as individuals with damage to this area make appropriate sensorimotor adjustments without conscious awareness of such adjustments (Slachevsky et al., 2001), indicating that the action monitoring system can function in the absence of the self-referential metacognitive assessment. The current results, in which both FOK and executive processes emerged as independent predictors of agency, support the idea that agency attributions in self-controlled trials consist of an explicitly self-referential process though they are informed by more general executive processes.

In the context of the multifactorial model of agency, it may thus be plausible to consider a similar basis for both metamemory (FOK judgments) and agency judgments. It is conceivable that a shared reliance on prefrontal or cortical midline regions integral for supporting explicit representations of states of the self (Frith & Frith, 1999; Moran, Heatherton, & Kelley, 2009) contributes to the observed association between these two metacognitive tasks. However, given that regions in the PFC and midline are also clearly implicated in a host of executive functions (Fassbender et al., 2004; Hedden & Gabrieli, 2010), that executive and metacognitive abilities are linked conceptually (Fernandez-Duque et al., 2000), and that these abilities have been shown to covary with one another in previous studies as well as the current study, we again return to the question of whether fundamental "executive" processes (e.g., error monitoring, mental set shifting, response conflict) constitute metacognition, or whether the latter is dissociable from executive processes with regard to self-reference. Our results support the idea that these processes are dissociable, with metacognitive tasks incorporating an explicit element of self-assessment that is not required for standard executive tasks. This finding echoes results from an important study by Koren and colleagues who examined whether metacognitive indices were more highly related to disease insight in schizophrenia than standard executive tests (Koren et al., 2004). Using a modified Wisconsin Card Sorting paradigm, the authors asked participants to judge the accuracy of their sorts and to determine if they wanted their sorts counted toward their overall score. As predicted, several metacognitive metrics of both monitoring and control were associated with disease insight whereas standard WCST (i.e., executive) scores were not, suggesting that metacognitive tasks capture an important self-referential element that is not required for standard executive tasks.

Nonetheless, we must acknowledge that in the current study, a separate set of executive tasks may have mediated the association between metamemory and agency. Our study was limited by the absence of tasks that measured highly specific executive skills such as conflict monitoring and error detection, and future work should examine the extent to which such skills mediate the asso-

ciation between metacognitive tasks. In this vein, it will be important to select executive tasks that are not self-referential to tease apart the basic skills of monitoring and detection from those that are applied to oneself.

Moving forward, knowledge of the factors which contribute to various metacognitive scores in nondemented elders will provide important information for understanding variable self-awareness in AD and other neurologic populations. However, it is possible that the factors which contribute to or are associated with metamemory and agency in normal aging may be different than those in young adults, or those that arise in the context of dementia or other syndromes. For example, in our previous study examining metamemory in AD, gamma was unrelated to education. This may simply reflect differences in the distribution of education across the samples; however, it might also indicate that in the presence of pathology, compromise to brain regions that provide critical support for processes of self-assessment is more influential on metamemory performance than are premorbid factors such as education. Ongoing work is examining the structural and functional neural correlates of metamemory and agency in both healthy elders and patients with AD to achieve a deeper understanding of the brain regions relevant to these aspects of metacognition and self-awareness more broadly. Future work should also directly examine whether or not metacognitive functions and their correlates vary over the life span.

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