Finding the Self in Metacognitive Evaluations:

A study of metamemory and agency in non-demented elders

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ABSTRACT

Metacognitive methodologies are used to examine the integrity of self-relevant 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, an individual's demographic characteristics, or mood variables is not clear. The objective of the current study was to examine whether a modified Feeling of Knowing (FOK) metamemory paradigm shared a self-relevant association with a metacognitive task of agency that would not be explained by cognition, demographics, or mood. 38 non-demented older adults (MMSE >=24 and mean age = 68.13) completed metacognitive testing in addition to extensive cognitive testing and two mood questionnaires. Bivariate correlations were used to evaluate the association between metamemory and agency scores, and to determine the cognitive (memory, attention, and executive functioning), demographic (age and education), and mood (anxiety and depression) correlates of each. Individual correlates of metamemory and agency were then entered into linear regression models to determine whether any association between metacognitive measures remained after accounting for these other variables. As predicted, resolution (gamma) on the metamemory test was associated with the accuracy of metacognitive agency judgments, specifically those on self-controlled rather than computer-controlled trials. Regression results supported a robust role for agency in predicting gamma scores, above and beyond executive functioning, memory, and education ($\beta = .45$, $p = .03$). This interrelation between metamemory and agency judgments suggests that metacognitive testing captures an important aspect of self-specific processing that would not otherwise be assessed in a standard cognitive evaluation, and may provide unique information about self-evaluative capacities in clinical populations.

INTRODUCTION

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 which 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, 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-relevant process that may deteriorate in the context of a degenerative disease, independent of primary cognitive abilities such as executive skills, attention, or memory. As 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. In order to more fully understand the mechanisms which may contribute to metamemory in both healthy and pathological aging, the current study examined how metamemory scores relate to agency (another aspect of self-assessment), in comparison with demographic characteristics, cognitive functioning, and mood variables in non-demented elders.

Nelson and Narens described two primary metacognitive processes: monitoring and control (T. Nelson & Narens, 1990). 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* non-recalled 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-relevant assessment as opposed to executive abilities in general, for example, is clouded.

Agency, one's sense of control over their personal actions (Gallagher, 2000), is a second area in which to explore objectively the processes and integrity of self-assessment across the spectrum of healthy to pathologic aging. The forward model (Wolpert, Ghahramani, & Jordan, 1995), one of two primary internal models of the motor system, is one which has been applied to explain the manner in which a sense of agency is determined (Blakemore, Wolpert, & Frith, 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, allowing people to identify mismatches between intentions and outcomes. 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 et al., 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, such as 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-relevant processing may contribute to a specific constellation of symptoms in this patient population (Knoblich, Stottmeister, & Kircher, 2004). There is also evidence that similar to metamemory, the accuracy of agency judgments may decline with age (Metcalfe, Eich, & Castel, In press). In the current paper, 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 in order to determine whether a common "self-relevant" association between metamemory and agency judgments can be identified.

Based on our findings in AD revealing a unique association between clinically rated self-awareness and metamemory scores, our hypothesis is that there is a specifically self-relevant component to metamemory performance that will be evidenced through an association with agency that is not accounted for by executive functioning, attention, memory, mood, or demographic characteristics in non-demented elders. Identifying a self-relevant component of metamemory is important because: 1) it provides greater justification for the use of metamemory tools (and metacognitive tools more broadly) to characterize and investigate distortions of self-assessment; and 2) 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 non-demented elders in an effort to clarify the correlates of metamemory in the absence of a dementing illness. This work will set the stage for future examination of the stability of such associations in the context of AD and for understanding the potential influence of other factors on metacognition that are unique to a dementia population (e.g., regional distributions of neuropathology).

METHODS

PARTICIPANTS

38 non-demented 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). Although this cutoff is lower than standard cut-offs for "healthy elders", we sought to include a cognitively diverse group of non-demented elders that would offer a range of performance in which to evaluate the relationship amongst

various aspects of metacognition and cognition.

PROCEDURES

Participants were seen over the course of two, 2-hour test sessions within two 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. This study was therefore performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

MEASURES

Metamemory Test

Task Development: The current metamemory test, a modified episodic Feeling of Knowing 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 non-demented 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 non-demented elders. Second, as AD subjects in the larger study completed three different conditions of the metamamory test (described below) that were counterbalanced across three different trivia sets matched for overall phrase length and content, the non-demented 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 subjects in the current study and analyzed to determine potential effects on performance.

Task Instructions and Format: 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 non-fiction book about space travel; Corbett was a former mayor in Nevada, etc.*), participants were asked to provide a global judgment of learning (the pre-JOL; "Now I am going to test your m4emory 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" X 11" paper (e.g., *Who was a former mayor of Nevada?*) and the following prompt 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 if 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 JOL (the post JOL) regarding the overall number of memory items out of 5 that they recognized correctly. This process was repeated for learning trials 2 – 4 resulting in a total of 4 pre-JOLs, 4 post-JOLs, and 20 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:

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

Calibration: Calibration scores reflect the extent to which an individual is generally over or under confident in their predictions. 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 Judgments of Learning: Scores were determined by subtracting the proportion correct from the proportion predicted correct at each trial for both the pre and post-estimations of memory performance to generate scores ranging from -1.0 to 1.0. The final two dependent variables were the average global pre-JOL calibration scores and post-JOL 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 Green, 2007. 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 which 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 in order to start the trial. This was done to discourage participants from simply watching to see if 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 due to 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.

<u>Agency Judgments</u>: After each 15 second 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 subject indicated “Me”. Agency judgments on computer controlled trials were considered correct if the subject indicated “Computer”. Split trials were not considered in scoring the accuracy of agency judgments.

Computer Mouse Experience Questionnaire: In order to evaluate the impact of computer mouse experience on agency judgments, participants were given a three-item questionnaire assessing prior mouse use: 1) “How often have you used a computer mouse prior to today?” *Never, A few times in my life, Many times*; 2) “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 3) “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): (Price et al., 2009) The PVLT 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 presented after 20-40 minutes.

Biber Figure Learning Test**:** (Glosser, Goodglass, & Biber, 1989) This nonverbal list learning task 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 seconds each. During the test phase, participants were asked to draw as many designs as they could remember. After a 20 to 30 minute 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” X 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 seconds and the overall time to completion.

Digit Span: (Wechsler, 1997) This subtest from the WMS-III 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: (Wechsler, 1997) This WMS-III subtest 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 seconds to generate words beginning with a specified letter (i.e., 'F', 'A, & '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:(Glosser & Goodglass, 1990) This test 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: (Yesavage, 1986) This is a 30 item self-report tool designed to evaluate non-vegetative symptoms of depression in older adults. Participants were prompted to endorse those items they have experienced in the past week.

Beck Anxiety Inventory: (Beck & Steer, 1990) This is a 21 item self-report assessment tool 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

Descriptive Statistics: The mean age and educational level of participants was 68.10 (SD = 7.82) and 15.87 (SD = 2.15), respectively. 28 of 38 (74%) participants were female, 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.

Gamma Calculations: Gamma scores were calculable for 31 of 38 healthy elders. The remaining 7 participants demonstrated no variability in their predictions (Yes, Maybe, No), or in their accuracy.

Computer Mouse Experience: 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.

Bivariate Correlations

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: In addition to agency as noted above, gamma was also significantly associated with education (r = .48, p < .01) and memory (r = .48, p < .01). The correlation with executive functioning was marginal (r = .30, p = .11).

Correlates of Agency Judgments: The 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 self-controlled and 8 computer-controlled trials. However, 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 = .04) and memory index (r = .39, p = .02). In contrast, agency judgments on computer-controlled trials were associated with age (*r* = -.36, *p* = .04), computer mouse familiarity (*r* = .42, *p* = .02), attention (*r* = .51, *p* < .01) and executive functioning (*r* = .34, *p* = .05). See Table 3 for all bivariate results.

Regression Analyses

A linear regression was then conducted to determine the extent to which agency judgments on self-controlled trials predicted metamemory above and beyond the remaining demographic and cognitive correlates of metamemory. After entering those variables that were significantly or marginally correlated with gamma including: agency judgments on self-controlled trials, education, memory, and executive functioning as predictors in a single block, the overall model was significant (*F* = 4.82, *p* < .01). However, only agency judgments on self-controlled trials (β = .45, *p* = .03) and education (β = .47, *p* = .02) emerged as independent predictors of gamma. Regression results are reported in detail in Table 4.

Additional analyses were conducted to determine the extent to which metamemory predicted agency judgments on self-controlled trials above and beyond associated demographic and cognitive variables. After entering those variables that were significantly or marginally correlated with agency judgments on self-controlled trials including: gamma, memory and executive functioning, the overall model was significant (*F* = 4.50, *p* = .01) but no single variable emerged as uniquely predictive. Similarly, in the model examining predictors of agency judgments on computer-controlled trials, the overall model was significant (*F* = 3.71, *p* = .02) but none of the individual predictors (executive functioning, attention, age, or computer mouse familiarity) was independently significant.

DISCUSSION

Unlike tests of cognition, metacognitive tasks require an explicit element of self-evaluation. This defining characteristic lends metacognitive tasks to studying distortions of the self concept that are observed in neurologic syndromes such as dementia and schizophrenia. For example, recent work in our lab examined the ability of an episodic FOK task to capture variability in the clinical phenomenon of disordered awareness of memory loss in AD (Cosentino et al., 2007). 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, it is possible that 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-specific contribution to metacognitive tasks could be identified, and to more fully understand the various factors which contribute to metamemory performance in older adults. Such information will also inform the relevance of metamemory variability seen in the context of dementia.

The primary hypothesis of this study, based on our findings in early AD as described above, was that metamemory testing assesses a self-evaluative 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, we predicted a robust association between metamemory scores and agency judgments based on their shared reliance on self-assessment, and one which would not be accounted for by demographic factors, mood, or cognitive abilities such as attention, memory, and executive functioning. As predicted, agency judgments (on self controlled trials) independently predicted metamemory after accounting for cognitive and demographic variables. The relationship between gamma and agency, two metacognitive variables derived from tasks with entirely different stimuli (auditory versus visual), divergent demands (memory versus motor control and visual attention), and variable timing of self-assessment (predictions versus post-trial evaluations), is compelling and argues for a fundamentally self-relevant 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). 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 only marginally related to executive function and unrelated to age; rather, this metamemory score was more clearly related to agency, memory and education. The lack of a strong 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 difference in the nature of the FOK task used in our study. Perrotin and colleagues implemented a standard paradigm with FOK judgments for non-recalled 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 non-recallable information, memory functioning holds greater importance for making judgments that take advantage of both recallable and non-recallable information. Overall, however, neither memory nor executive processes appeared as critical for metamemory performance as either agency or education.

<u>Agency</u>

Interestingly, the accuracy of agency judgments on self-controlled trials was unrelated to that on computer-controlled trials. We did not necessarily expect this dissociation; however the largely non-overlapping correlates of these two types of judgments reinforce the idea that there are different processes that contribute to each. It is important to note that executive functioning was related to both types of judgments, and this is in line with idea that skills relevant to the executive tasks (e.g., self-monitoring on fluency tests) are also relevant for making self-judgments. Gamma was selectively related to agency judgments on self-controlled trials and although regression analyses did not support a unique role for gamma in predicting agency above and beyond its cognitive correlates (executive functioning or memory), neither did these cognitive processes account for the association between metamemory and agency. That is, both cognitive and metacognitive processes appeared to play an important role in predicting agency judgments on self-controlled trials. Specifically, higher metamemory scores, higher memory scores, and higher executive scores were all associated with the tendency to accurately identify when the self was in control. It is not entirely clear why memory would be related to agency performance; one possibility is that memory for experience on earlier trials would enhance one's ability to determine their relative control over the computer mouse in later trials.

The accuracy of agency judgments on the computer trials was also best explained by a combination of variables, albeit mostly different ones. Specifically, older age, lower attention, lower executive scores, and less familiarity with the computer mouse were all associated with the tendency to say the self was in control when in fact it was the computer. The prominent role for variables such as attention and mouse familiarity (rather than metamemory) in determining agency judgments on computer-controlled trials specifically 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: 1) move the mouse; 2) observe the behavior of the cursor; and 3) make a judgment about their control. In the context of computer interference, however, an individual must: 1) move the mouse; 2) observe the behavior of the cursor; 3) recognize differences between cursor behavior and mouse movement; 4) attempt to reconcile differences in cursor behavior with mouse movement; 5) recognize that they cannot reconcile differences; and 6) 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 the seemingly greater demands on self-assessment under self-controlled conditions than other-controlled conditions.

Association between Metamemory and Agency

The current results suggest that the process of self-assessment involved in both metamemory and agency tasks may have fundamental similarities. The basis of such similarities is not entirely evident and might reflect a host of factors. In one respect, the association between the tasks that we have interpreted as "self-relevant" might only be a reflection of superficial aspects of the task such as the requirement to make a judgment. As 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, what argues strongly against the idea that the requirement to make any kind of judgment links the two tasks is the fact that judgments of agency on self-controlled trials and computer controlled trials were unrelated and had largely different correlates. The basis of an association between FOK and agency judgments on self-controlled trials, in which the two judgments are fairly different (*Will you know the right answer* versus *Were you in control*), is thus likely to reflect similarities in the process required for both tasks rather than similarities in task format.

Certainly, models of agency and metamemory are quite different, and involve different parameters. FOKs have been theorized to reflect both familiarity with the cue (Reder, 1987; Reder & Ritter, 1992; Schwartz & Metcalfe, 1992) or accessibility of the target information (Koriat, 1993). Recent work has suggested that both processes are important for FOK and may occur in a sequential fashion such that cues which are familiar initiate a search for information about the target (Koriat & Levy-Sadot, 2001). The majority of work suggests that FOK is associated more closely with executive abilities than with memory (Souchay et al., 2004), and may rely heavily on regions in the prefrontal cortex (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) is implicated in assessing the accuracy of the retrieved information (Schnyer et al., 2005).

In contrast, the forward model of motor control is often used to explain how a subjective sense of agency is achieved (Blakemore et al., 2002). In this model, 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. 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), are regions that appear to contribute to this comparison and give rise to the subjective sense of agency. However, it may be that a subset of these regions, or different regions, facilitate the explicit *judgment* of agency (David, Newen, & Vogeley, 2008; Synofzik, Vosgerau, & Newen, 2008). Indeed, it has been shown that when planned actions and sensory-motor feedback conflict, individuals with prefrontal lesions can make the appropriate sensorimotor adjustments, but are not consciously aware of such adjustments (Slachevsky et al., 2001). Recent work in our lab has also supported the neural dissociation between sensations of agency and subsequent judgments (Miele, submitted for publication).

With this in mind, it may be plausible to consider a similar basis for both metamemory (FOK judgments) and agency judgments. It is conceivable that a shared reliance on prefrontal regions integral for supporting explicit representations of states of the self (Frith & Frith, 1999) underlies the observed association between these two metacognitive tasks. However, given that regions in the PFC are also clearly implicated in a host of executive functions (Fassbender et al., 2004), 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-relevance. Our results support the idea that metacognitive tasks incorporate an explicit element of self-assessment that is not required for standard executive tasks. However, we must acknowledge that 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 association between metacognitive tasks. In this vein, it will be important to select executive tasks that are not self-relevant in order to tease apart the basic skills of monitoring and detection from those that are applied to oneself. Nonetheless, the fact that our executive index was associated with both the metamemory and agency tests suggests that all three tasks shared important similarities, and despite this, neither executive performance nor other cognitive processes accounted for the association between the metacognitive tasks.

Moving forward, knowledge of the factors which contribute to various metacognitive scores in non-demented 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 which arise in the context of dementia or other syndromes. For example, in our previous study examining metamemory in AD, gamma was unrelated to education or verbal memory. This may simply reflect differences in the measures used to assess memory or 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, or cognitive factors such as memory which are universally impaired in a clinical sample. 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.

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Table 1. Metamemory, Agency, Cognition, and Mood

	Scores	Mean	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	0.90	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 (-5 to 5)	0.04	0.14	-0.18	0.40
	Pre Global JOL (-5 to 5)	-0.05	0.17	-0.45	0.40
	Post Global JOL (-5 to 5)	-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)	21.22	5.28	5.00	28.00
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)	6.75	2.42	2.00	16.00
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

Table 2. Interrelation of Metamemory Scores

	P(Correct) Yes	P(Correct) Maybe	P(Correct) No	Collapsed Calibration	Pre Global JOL	Post Global JOL
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**
Pre Global JOL						.69**

Note. * p < .05; ** p < .01.

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

	Gamma	Self Trials	Computer Trials
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.

Table 4. Predictors of Gamma and Agency Scores

Predictors	Gamma	Agency: Self Trials	Agency: Computer Trials
Education	.47*		
Agency: Self Trials	.45*		
Memory	.20		
Executive Functioning	-.15		
Gamma		.29	
Executive Functioning		.32	
Memory		.20	
Mouse Familiarity			.27
Attention			.32
Executive Functioning			.42
Age			-.16

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

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