Self-referencing enhances recollection in both young and older adults

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Abstract

Processing information in relation to the self enhances subsequent item recognition in both young and older adults, and further, enhances recollection at least in the young. Because older adults experience recollection memory deficits it is unknown whether self-referencing improves recollection in older adults. We examined recollection benefits from self-referential encoding in older and younger adults and further examined the quality and quantity of episodic details facilitated by self-referencing. We further investigated the influence of valence on recollection given prior findings of age group differences in emotional memory (i.e. “positivity effects”). Across 2 experiments, young and older adults processed positive and negative adjectives either for self-relevance or for semantic meaning. We found that self-referencing, relative to semantic encoding, increased recollection memory in both age groups. In Experiment 1, both groups remembered proportionally more negative than positive items when adjectives were processed semantically; however, when adjectives were processed self-referentially, both groups exhibited evidence of better recollection for the positive items, inconsistent with a positivity effect in aging. In Experiment 2, both groups reported more episodic details associated with recollected items, as measured by a memory characteristic questionnaire (MCQ), for the self-reference relative to the semantic condition. Overall, these data suggest that self-referencing leads to detail-rich memory representations reflected in higher rates of recollection across age.

Introduction

Most every individual has a highly elaborated representation of the self. This self-schema guides aspects of daily function, such as how we interact socially with others (Amodio & Frith, 2006), and is important in many cognitive functions, from theory of mind to perspective taking (Frith & Frith, 2003; Vogeley & Fink, 2003). In the context of memory research, processing information in relation to the self, relative to meaning-based semantic processing, enhances subsequent memory performance—called the *self-reference effect* in memory (Rogers, Kuiper, & Kirker, 1977; Symons & Johnson, 1997). In a typical self-reference memory experiment, participants judge whether adjectives describe themselves (i.e., whether they are “charming” or “kind”), judge whether adjectives describe another person (in some experiments), or simply process the adjective for meaning (e.g. whether the word is positive or negative). In this type of task, participants must evaluate incoming information relative to the contents of their self-schema, leading to enhanced elaboration and organization of the newly learned material (Klein & Kihlstrom, 1986; Rogers et al., 1977).

While self-referencing does not eliminate age differences in memory, reports have shown consistent self-reference effects in older adults in tests of recall (Mueller, Wonderlich, & Dugan, 1986) and recognition memory (Glisky & Marquine, 2009; Gutchess, Kensinger, Yoon, & Schacter, 2007). These results suggest that the self-reference effect is somewhat resistant to age-related decline typically seen in many long-term memory paradigms (Park et al., 2002). While the benefit of self-referencing has been established for recognition memory in both age groups, it is not clear whether this benefit is supported by recollection of specific episodic details or familiarity in the absence of recollection, as both processes may support recognition memory (Aggleton & Brown, 1999; Mandler, 1980). Recollection can be tested *objectively* with source memory tests which probe memory for specific details or *subjectively*, using the remember/know procedure (Tulving, 1985). Subjective recollection is equivalent to “recollection” judgments typically used in many Remember/Know experiments, where a person subjectively decides whether or not they are able to remember (R) any episodic details. Objective recollection, by contrast, is a test of recollection for an experimentally controlled detail such as the orienting task performed during encoding, spatial location or temporal details associated with the encoding episode. Evidence suggests that self-referencing boosts recollection in young adults as measured by both approaches. First, Conway and Dewhurst (1995) showed that subjective recollection memory for adjectives was enhanced after self-referential relative to semantic encoding in young adults. Second, in several studies we have reported that source memory accuracy is greater for objects encoded self-referentially (i.e. do you find this object pleasant?) than for objects encoded self-externally (i.e. is this object a certain color? is this a common object?) in both young (Leshikar & Duarte, 2012) and *older* adults (Dulas, Newsome, & Duarte, 2011; Leshikar & Duarte, 2014; Rosa & Gutchess, 2011). Further, a recent study showed that healthy older adults showed a recollection memory benefit from self-referencing (Genon et al., 2014). These studies imply that self-referencing supports the development of detail-rich memory representations that subsequently can be recollected in the young and old. The available evidence suggests that self-referencing leads to enhanced memory of perceptual details of studied materials (Leshikar & Duarte, 2012; Serbun, Shih, & Gutchess, 2011), but it seems likely that this type of processing would enhance memory for internally generated details such as the thoughts and feelings that arise from processing information through the lens of the self. No study, however, has evaluated the type of details that self-referencing facilitates.

The extent to which self-referencing enhances both subjective and objective measures of recollection in older adults is not well understood. While evidence has shown that older adults exhibit deficits in recollection (Kensinger, 2009; Mitchell & Johnson, 2009; Spencer & Raz, 1995; Yonelinas, 2002), several experiments have found that older adults show disproportionate deficits for objective relative to subjective estimates (Duarte, Henson, & Graham, 2008; Duarte, Ranganath, Trujillo, & Knight, 2006; Mark & Rugg, 1998). For example, Duarte et al (2008) found that subjective recollection measures were intact for a group of high performing older adults, whereas objective recollection measures were reduced relative to those of the young. We argued that objective measures of recollection are more likely than subjective measures to suffer age-related impairments because they are more restrictive, thereby necessitating greater executive demands to evaluate retrieved information with respect to the criterial decision (i.e. was this information spoken by a male or female?). Specifically, given that frontally-mediated executive processes like monitoring and evaluation are affected by aging (Light, Prull, LaVoie, & Healy, 2000; Park et al., 2002; Spencer & Raz, 1995), older adults may experience disproportionate impairments in objective measures of recollection. If these executive processes are diminished due to age-related change, older adults may experience a greater recollection benefit for subjective than objective recollection measures for self-referenced materials. In contrast, because objective recollection shows disproportionate age-related impairment, this measure has the most to gain from processes that enhance recollection memory.

While the prevailing view of aging is that familiarity is age-invariant (Yonelinas, 2002), this is not universally reported. Some studies have found age equivalence (Spencer & Raz, 1995; Yonelinas, 2002), while others have reported age-related reductions in familiarity estimates (Duarte et al., 2006; Light et al., 2000; Prull, Dawes, Martin, Rosenberg, & Light, 2006; Toth & Parks, 2006). One possibility is that self-referencing only supports recollection, with little impact on familiarity. This outcome would be consistent with Conway and Dewhurst (1995) who reported no differences in familiarity for items encoded in self-referential or semantic conditions in young adults. Indeed, Conway and Dewhurst theorized that processes that support familiarity, such as fluency or even implicit memory processes, are not processes that tap the self-schema, and thus, should not be facilitated by self-referencing, yet little work has addressed this question.

The typical self-reference task relies on participants to appropriately judge whether positive or negative personality adjectives are self-descriptive. It is well established that both positive and negative materials are better remembered than neutral materials (Buchanan & Adolphs, 2002; Hamann, 2001). Current theories of aging suggest that memory interacts with valence in a predictable way over the lifespan with young adults exhibiting a “negativity effect,” remembering proportionally more negative items than either positive or neutral ones (Kensinger, 2009; Mather & Carstensen, 2005; Murphy & Isaacowitz, 2008). Though subject to debate, older adults often exhibit a “positivity effect”, remembering proportionally more positive than negative or neutral information (Kensinger, 2009; Mather & Carstensen, 2005; Murphy & Isaacowitz, 2008). Based on these findings, it is reasonable to predict that young adults would show a larger self-reference effect in recollection for the negative items while older adults may show a larger effect for positive items. Yet, valence effects in memory that interact with age are not found ubiquitously (Fernandes, Ross, Wiegand, & Schryer, 2008; Murphy & Isaacowitz, 2008). There is reason to predict that self-referential encoding may enhance recollection for positive relative to negative information, in both young and older adults. Positive autobiographical events, for instance, are remembered with greater contextual detail than are negative events in the young, suggesting a boost to positive materials when particularly salient to the self (D'Argembeau & Van der Linden, 2008). Further, positivity effects have been observed in several self-reference studies in young adults (D'Argembeau et al., 2005; Denny & Hunt, 1992; Kuiper & Derry, 1982; Leshikar, Park, & Gutchess, 2014), and two aging studies found greater self-reference effects for positive than negative adjectives in both age groups (Glisky & Marquine, 2009; Gutchess et al., 2007). It should be noted, however, that recollection was not assessed in any of these previous studies.

Experiment 1 was designed to assess the effects of self-referential processing on subjective and objective measures of recollection in young and older adults. At study, participants studied positive and negative adjectives in one of two conditions: self-referential encoding (judging whether adjectives are self-descriptive) or semantic encoding (judging whether adjectives are commonly used in the English language). During test, participants made two memory judgments to studied and unstudied adjectives. First, they made “remember”, “know”, or “new” judgments (Tulving, 1985), followed by a source memory judgment deciding in which study task (self-reference or common condition) the adjective was initially studied. This two-step recognition task allowed us to obtain both subjective (i.e. “remember”) and objective (i.e. source) estimates of recollection for the same items. In Experiment 2, we assessed the types of episodic details—perceptual details and self-generated thoughts or feelings— participants recollected for self-referenced and semantically encoded events using self-reports modeled after the Memory Characteristics Questionnaire (MCQ) (Johnson, Foley, Suengas, & Raye, 1988).

We make the following predictions: First, we expected that self-referencing would~~ill~~ support recollection in both young and older adults, suggesting that self-referencing supports the development of context-rich memory representations consistent with our prior work (Dulas et al., 2011; Leshikar & Duarte, 2012; Leshikar & Duarte, 2014). Given limited research examining the effect of self-referencing on recollection of various contextual details (Dulas et al., 2011; Genon et al., 2014; Glisky & Marquine, 2009; Hamami, Serbun, & Gutchess, 2011; Mueller et al., 1986; Rosa & Gutchess, 2011), it is unclear whether self-referencing would~~ill~~ eliminate age-related memory deficits. Second, we predicted that our MCQ approach would~~ill~~ show that self-referencing enhances the recollection of several kinds of episodic details. Our prior work and that of others have already shown that self-referential processing facilitates memory for perceptual details in young and older adults (Hamami et al., 2011; Leshikar & Duarte, 2012; Leshikar & Duarte, 2014; Serbun et al., 2011). Given that self-referencing by definition engages evaluation of one’s internal schema, self-referencing should enhance memory for internally generated thoughts and feelings in addition to perceptual details.

Third, we predicted one of two possible outcomes for valence. The first possibility, consistent with prior ~~findings~~ work (Kensinger, 2009; Mather & Carstensen, 2005; Murphy & Isaacowitz, 2008), would be a positivity effect for recollection in the older adults and a negativity effect for recollection in the young regardless of encoding condition. An alternative prediction, would be similar effects of valence on memory estimates across age that are task-dependent. Evidence suggests that both young and older adults remember more positive than negative items when processed for self-relevance (Glisky & Marquine, 2009; Gutchess et al., 2007). This is consistent with evidence suggesting that positive information, when salient to the self, tend to be remembered with greater detail than negative information (D'Argembeau & Van der Linden, 2008).

Experiment 1 Methods

Participants

Twenty-four young adults (*m*: 21.25, *SD:* 2.09, 14 Females, range 18 – 27) and 24 older adults (*m*: 66.83, *SD:* 4.55, 14 Females, range 60 – 78) recruited from the Georgia Tech campus and community solicitation participated in this experiment. We obtained informed consent in accord with the Institutional Review Board at the Georgia Institute of Technology from all participants. Participants were paid $10 per hour for their involvement or received course credit (young adults).

All participants were given a standardized battery of neuropsychological tests to ensure group differences were not due to clinically significant age-related cognitive decline, such as preclinical dementia in the older adults. Tests included long-term verbal and visuospatial memory, working memory span, and executive function taken from the Memory Assessment Scale (Williams, 1991) , as well as word list learning and recognition, digit span forward and backward, and object recognition and reproduction. In addition, we included the controlled oral word association task (FAS)(Benton, Hamsher, & Sivan, 1983) and Trail-making A and B (Reitan & Wolfson, 1985). Neuropsychological characteristics of both groups are shown in **Table 1**. Group comparisons showed similar levels of education, and that older adults performed more poorly on speeded tasks and measures of fluid intelligence (Trails, Verbal Span Backwards).

(Table 1 about here)

Stimuli

A total of 144 positive and 144 negative adjectives from the Anderson adjective norms (1968) and the Affective Norms of Emotional Words (Bradley & Lang, 1999) were used in this experiment. Words were between four and ten characters in length and sorted into “common” and “uncommon” categories based on lexical frequency (Kucera & Francis, 1967). Items with a frequency rating 16 or higher were considered “common” words (mean frequency: 62.3; range: 16-313), while words below this cut-off were considered “uncommon” (mean frequency: 5.4; range: 1-15). Words were counterbalanced across participants, appearing equally often in the self-reference or common encoding conditions, or as novel items at test. Words were presented on a PC monitor in red, 24-point courier font on a black background and subtended a maximum horizontal visual angle of approximately 9 degrees. Participants were seated 3 feet from the monitor.

Procedure

Participants were tested individually in a quiet a room. All participants completed the study phase, which lasted approximately 15 minutes, and the test phase which lasted approximately 35 minutes. Prior to the start of the experiment, participants practiced the study and test phase tasks after being given written and oral instructions. The practice session contained 14 study and 21 test phase trials (14 old and 7 new items). Immediately after practice, the participant started the study phase of the experiment. No items from the practice appeared in the experiment. At study, participants ran through 4 blocks of 48 trials block (half in each encoding condition) resulting in 192 studied trials. Blocks were separated by a few moments of rest. Study trials lasted 3250 ms and included presentation of the adjective for 3000 ms followed by a 250 ms central fixation. There were two study phase experimental conditions: in the *self* condition, participants decided whether the adjective was self-descriptive (yes or no), while in the *common* condition, participants decided whether the word was a commonly used word (yes or no). Task instructions for both tasks emphasized that the questions were subjective without a correct response. We explicitly chose a semantic comparison task that required a subjective choice to match the self-reference judgment, which is by definition subjective. To alleviate potential task-switching costs within a block, especially for older adults, trials were presented in short “mini-blocks” containing 8 consecutive trials of the same encoding condition (e.g. the *self* task). Prior to each mini-block, an instruction prompt was displayed for 6000 ms, cueing the participant to the upcoming task (“Get ready to do the Self Task”). All study phase yes/no responses were made with the index and middle fingers of the right hand. Trials with no response or more than one response as well as trials with response times less than 200 ms were excluded from analysis.

The test phase of the experiment immediately followed the study phase. A total of 288 words, which included all 192 studied items, as well as 96 novel words, were included in the recognition test. Memory was tested over four experimental blocks with 72 trials per block (24 items studied in the self and common tasks, as well as 24 unstudied items). Test phase trials consisted of a remember/know/new item recognition decision (Tulving, 1985) followed by a source decision. The term “familiar” replaced “know” to ease exposition. Test trials lasted 7250 ms and proceeded as follows: First, adjectives were displayed for 3500 ms with the prompt “1 = remember | 2 = familiar | 3 = new” written below the word in white font. The text prompt served as the cue to the participant to make the item recognition response. Participants were instructed on the appropriate use of the “remember”, “familiar”, and “new” response categories during practice (Rajaram, 1993). The text subsequently changed to display “1 = self | 2 = common | 3 = don’t know” for 3500 ms which served as the cue to make the task source judgment. Following this text prompt a fixation cross was presented for 250 ms. The “don’t know” source option was used to reduce potential source contamination by guesses, a procedure implemented in prior source memory studies (Duarte et al., 2008; Duarte, Henson, Knight, Emery, & Graham, 2009; Gottlieb, Uncapher, & Rugg, 2010; Morcom, Li, & Rugg, 2007; Smith, Dolan, & Rugg, 2004). Trial types (e.g., self task, negative item; common task, positive item; unstudied negative item, etc.) were presented in a pseudorandom order with no more than 4 trials of the same type presented in a row. Only test trials that contained responses for both recognition decisions were included in the behavioral analysis. All test phase responses were made with the first three fingers of the right hand. Trials with greater or fewer than two responses as well as trials with response times less than 200 ms were excluded from analyses.

Data analysis

Data were analyzed using both participant-based and multinomial model-based approaches. For the participant-based analysis, three separate measures of recognition memory were calculated. First, item recognition was calculated using Pr ([p(Hits) – p(False alarms)]) (Snodgrass & Corwin, 1988), collapsed across remember (R) and familiar (F) responses, where chance is 0%. Second, estimates of recollection and familiarity were calculated using the independence of remember/know (IRK) procedure (Yonelinas, 1995). Specifically, recollection estimates were calculated by subtracting the proportion of remember (R) false alarms (FA) from proportion of remember hits (e.g., [p(R, Hit)-p(R, FA)]). Throughout this manuscript this estimate of recollection will also be referred to as "subjective recollection". To accommodate the underestimation of familiarity inherent in the remember/familiar (F) procedure, familiarity estimates were calculated as follows: [p(F, Hit)/(1−p(R, Hit)] – [p(F, FA)/(1−p(R, FA))] (Yonelinas, 1995). Third, source accuracy for items eliciting a "remember" response was calculated according to Pr by subtracting the incorrect source trials from the correct source trials [p(correct) – p(incorrect)], excluding the "don't know" responses, where chance is 0% Given that many participants did not make source attributions after giving F judgments, instead opting for "don't know source" responses, as would be expected, the Pr measure of source accuracy was limited to R judgments. This source accuracy estimate will be referred to as "objective recollection" throughout this paper. An identical method has been used to assess objective recollection in the past (Duarte et al., 2008; Duarte et al., 2006).

A limitation of the objective recollection estimate is that this measure does not account for response biases that participants may exhibit for one source over another. For example, a liberal response bias to choose the “self” source may lead to artificially high estimates for source memory accuracy. One method to assess potential response biases for source decisions is to model recognition data using a multinomial model. A multinomial model approach is useful because it can separately estimate memory accuracy and response biases for source decisions. In the present experiment, we modeled our data using the multinomial model approach of Batchelder and Riefer (1990) using the solver function in Excel (Dodson, Prinzmetal, & Shimamura, 1998) as others have done before (D'Argembeau & Van der Linden, 2004; Jacoby, Bishara, Hessels, & Toth, 2005). The full model we employed, which includes numerous parameters (e.g., item recognition accuracy, item guesses, source recognition accuracy, etc.), is shown in the **Supplemental** materials. Our focus in this paper is limited to estimates pertaining to source decisions: specifically source memory accuracy and source response bias. Fit of the model and parameter estimation was performed with the maximum likelihood approach using the log-likelihood statistic, G^2 (Batchelder & Riefer, 1990). To determine model fit, the G^2 statistic was compared against a chi-square distribution at an alpha of .05. For all model comparisons, post-hoc analyses revealed that power was greater than .95 to determine a medium effect size, w = .3 (Cohen, 1977).

Results

Participant based results

For the study decisions, young adults responded “yes” to the self and common tasks 46% (*SD* = 9%) and 76% (*SD* = 13%) of the time, respectively. Similarly, older adults responded “yes” 46% (*SD* = 8%) and 74% (*SD* = 17%) of the time. The mean proportions of memory judgments to studied (R hit, F hit, Miss) and unstudied adjectives (R false alarms, F false alarms, correct rejections) as a function of valence and study task (self, common) are presented in **Table 2**. The proportions of correct, incorrect and “don’t know” source judgments for R responses are also shown in that table.

(Table 2 about here.)

To examine potential age differences in item recognition, we entered Pr estimates of item recognition (**Table 3**) (see Methods for formula) into an Age (young, older) x Condition (self, common) x Valence (positive, negative) repeated measures analysis of variance (ANOVA). Results indicated main effects of Age, $F(1, 46) = 30.1$, $p < .001$, Condition, $F(1, 46) = 30.5$, $p < .001$, and Valence, $F(1, 46) = 10.44$, $p = .002$, without any significant interactions, *F*’s < 1. The Age effect resulted from better recognition memory in the young, while the Condition effect was driven by better performance in the self condition. The Valence effect was due to better recognition memory for the negative than the positive adjectives.

(Table 3 about here.)

We conducted Age (young, older) x Condition (self, common) x Valence (positive, negative) ANOVAs on estimates of familiarity and subjective recollection derived from the independence procedure (see methods). Starting first with the familiarity estimates (**Table 3**), ANOVA results indicated an Age effect, $F(1, 46) = 6.26$, $p < .05$, with no effects of Condition, Valence, nor any interactions, F's < 1. The Age effect was driven by higher familiarity estimates in the young relative to the older adults. Subjective recollection estimates are shown in **Figure 1**. ANOVA results for subjective recollection revealed main effects of Age, $F(1, 46) = 35.7$, $p < .001$, Condition $F(1, 46) = 74.1$, $p < .001$, and a Condition x Valence interaction, $F(1, 46) = 7.04$, $p = .01$. The main effect of Age resulted from higher recollection estimates in the young adults, while the Condition effect was due to increased recollection estimates for self items compared to common items in both groups. Critically, there was no significant interaction between Age and Condition, $F(1, 46) = 1.13$, $p = .29$, suggesting that recollection in the older adults benefited from self-referencing to a similar degree as the young. Subsidiary analyses showed that the Condition x Valence interaction was due to higher subjective recollection estimates for negative relative to positive adjectives encoded in the common condition, $t(47) = 1.99$, $p = .05$, , with no effect of valence for self-referentially encoded adjectives, $t(47) = 0.45$, $p = .65$.

(Figure 1 about here.)

We examined memory for the objective recollection estimates (see methods), which are shown in **Figure 1**. Results from the Age x Condition x Valence ANOVA for the objective recollection estimates indicated main effects of Age, $F(1, 46) = 45.5$, $p < .001$, and Condition, $F(1, 46) = 24.4$, $p < .001$, as well as Condition x Valence, $F(1, 46) = 39.7$, $p < .001$, and Age x Condition x Valence interactions, $F(1, 46) = 19.1$, $p < .001$. Young adults showed greater objective recollection than the older adults and both groups showed greater objective recollection estimates for self-referentially encoded items relative to those encoded in the common task. With respect to the three-way interaction, subsidiary analyses showed that for the common condition, negative items yielded higher objective recollection estimates in both age groups, *t*'s > 2.23, p < .05, whereas for the self condition, recollection for positive items was better than negative items in the old *t*(23) = 4.69, p < .01 and to a lesser degree the young *t*(23) = 2.01, p = .06. Thus, valence had a similar effect on objective recollection estimates in both age groups, with a somewhat more pronounced positivity effect for self-references items in the old than young.

Model based results

The full 32 parameter multinomial model (See **Supplemental materials**) fit the entire data, as measured by the log-likelihood statistic (G^2), G^2 (4) = 0.99, below the critical chi-square value of 9.48. Parameters estimating source accuracy (*d* parameters) and source response bias (*a/g* parameters) for each age group are presented in **Table 4**. For the older adults, model results showed better source memory accuracy for positive than negative items in the self condition, G^2 (1) = 20.81, p < .05. That is, the fit of the model was significantly worse when these two parameters were equated. In the common condition, the older group showed better memory for the negative relative to the positive items, G^2 (1) = 9.08, p < .05. This result is consistent with the objective recollection ANOVA results that showed a positivity effect for the self-referenced items and a negativity effect for items processed in the common condition. The young also demonstrated better source memory for the positive than negative items in the self condition, G^2 (1) = 20.21, p < .05, consistent with the ANOVA results. By contrast, the young showed equivalent source memory accuracy for negative and positive items encoded in the common condition, G^2 (1) = 1.93, p > .05. This is inconsistent with the ANOVA results which showed a negativity effect for the objective recollection estimates in the young adults, although, it should be noted that the multinomial model yielded a numerically higher estimate of memory for the negative items which is consistent with the ANOVA results.

(Table 4 about here.)

We examined response bias for the source decision in both age groups. Starting first with the older adults, the model indicated a bias to report that positive items, relative to negative, were encountered in the self condition, G^2 (1) = 500.06, $p < .05$. In contrast, the older adults showed a bias to say that negative items were encountered in the common condition, G^2 (1) = 613.51, $p < .05$. Like the older adults, the young participants showed a bias to report that positive items were encoded in the self condition compared to the negative items, G^2 (1) = 82.53, $p < .05$, and a bias to say that negative items were encoded in the common condition, G^2 (1) = 45.73, $p < .05$.

Overall, the multinomial model largely confirmed the source accuracy findings from the participant based analyses. While both groups showed response biases for the source decisions, analysis of source accuracy from the multinomial model (denoted by the *d* parameters) confirmed the results of the objective recollection ANOVA analysis: namely, that both groups showed a positivity effect for items processed in reference to the self and that the older adults showed a negativity effect for items processed semantically. Thus, while response bias undoubtedly affected the objective recollection estimates in both age groups, the underlying valence effects were confirmed.

Discussion Experiment 1

Two main findings were evident in Experiment 1. First, both young and older adults showed that self-referencing supports recollection, whether measured subjectively or objectively. Second, both young and older adults showed negativity effects in objective recollection estimates for semantically processed items, but both groups also showed positivity effects for items processed self-referentially. These results suggest that self-referential encoding, relative to semantic processing, enriches the episodic details associated with studied items. This is consistent with our prior work showing source memory benefits from self-referencing across age (Leshikar & Duarte, 2014). In that investigation, young and older adults showed better source memory (i.e., which background an object was presented with) for self-referencing relative to “other”-referencing. While Experiment 1 suggests that both age groups were able to retrieve more episodic details after self-referencing, it is unknown which *type* of details were facilitated, such as perceptual characteristics or internally-generated details such as thoughts or incidental feelings. To address this question, we conducted a second experiment to assess the quality and quantity of details participants reported for self-referenced and semantically encoded episodes.

Because the self-reference effect is robust and observed across many studies, it is likely that many types of episodic associations are enhanced by self-referential encoding. Previous evidence has demonstrated this with perceptual details (Leshikar & Duarte, 2012; Leshikar & Duarte, 2014), but internally generated details, such as thoughts and feelings experienced during encoding, may also be enhanced. One approach to measure such memory details is through a Memory Characteristics Questionnaire (MCQ) (Johnson et al., 1988) where participants self-report the various external perceptual details and internally generated thoughts and feelings they retrieved. Previous studies using the MCQ have found that, while young adults report more perceptual details associated with their recalled memories than the old, older adults report more thoughts and feelings (Hashtroudi, Johnson, & Chrosniak, 1990).

Experiment 2 Methods

Participants

An independent sample of 30 young (*m*: 20.87, *SD:* 2.30*,* 19 Females, range 18 – 27) and 31 older adults (*m*: 67.10, *SD:* 5.28*,* 17 Females, range 60 – 81) recruited from Georgia Tech and the surrounding community participated in Experiment 2. Participants were subjected to the same consenting procedures as in Experiment 1 with the additional exclusionary screening for red/green color blindness. Participants were paid $10 per hour or received course credit for their involvement. Participants were given the same standardized battery of neuropsychological tests as in Experiment 1. Neuropsychological characteristics of the young and older adults are presented in **Table 1**.

Stimuli

Given that the task required participants to recall multiple details for each item, only a subset of words from Experiment 1 was used in Experiment 2 in order to improve retrieval success for the various contextual details we measured. Thus, a total of 72 positive and 72 negative adjectives served as stimuli. All adjectives were presented in either a male or female voice. Word duration did not differ between the male or female voice ($t<1$). Across participants, words were counterbalanced to appear equally often in each study condition, male or female voice, red or green font, Comic Sans or Times New Roman, or as novel items at test. Words were further balanced to appear in red or green font, and in times new roman or comic sans font[1]. At study, words were presented in 24-point font on a black background and subtended a maximum horizontal visual angle of approximately 9 degrees. Participants were positioned three feet from the monitor, and given headphones (Sony Dynamic headphones) to hear the spoken adjectives. We instructed participants to adjust the volume to a comfortable, but audible level before the beginning of the experiment. This volume was fixed for the remainder of the experiment.

Procedure

Participants practiced the tasks for the study and test phases after receiving written and oral instructions. Practice contained 20 study and 30 test phase trials (20 old and 10 new). After practice, participants performed the experiment in three study-test blocks. At study, participants encoded 32 trials per block (half in each encoding condition) over 3 encoding blocks resulting in 96 studied items. Given that participants were tasked with encoding several contextual details, study trial durations were increased to 4250 ms (compared to 3000 in Experiment 1) and were separated by a 250 ms central fixation. There were two experimental conditions at study (self, common) identical to those of Experiment 1. Trials were presented in "mini-blocks" of 16 consecutive words for the same encoding condition (e.g. the *self* task). Before each mini-block, a prompt displayed for 6000 ms, cueing the participant to prepare for

[1] We varied font type and color to enrich the amount of visual details that participants could later recollect.

the upcoming task ("Get ready to do the Self task"). Trials with no response or more than one response as well as trials with response times less than 200 ms were excluded from analysis.

Recognition memory for 144 words (96 studied and 48 novel words) was tested over three experimental blocks. In each block 48 trials were presented (16 items studied under the self task, the common task, as well as 16 unstudied items). All test phase words were presented in 32 point arial font. For each trial, participants were given 5000 ms to make a remember/familiar/new judgment (Tulving, 1985). For trials judged as new, no further judgments were solicited. For trials given a remember or familiar response a series of 5 MCQ questions and then a voice source decision followed. In order, the 5 MCQ questions assessed amount of episodic details participants could retrieve for: visual details, auditory details, feelings, thoughts, and temporal order. These judgments were adapted from the MCQ (Johnson et al., 1988). Each MCQ decision was self-paced with a maximum allowable response time of 7000 ms. Participants rated their memory for each detail on a 3-point scale (1 = no detail, 2 = few details, and 3 = rich details) using their index, middle, or ring finger of their right hand. For the temporal order judgment, participants were asked to rate approximately when the item appeared in the encoding session. They were given 3 options (1 = beginning, 2 = middle, 3 = end), again using their index, middle, and ring finger, respectively, on their right hand. Finally, participants made a source decision deciding in which voice the word was spoken at study (1 = male | 2 = female | 3 = don't know). A fixation cross was presented for 250 ms separating trials. Trial types (e.g., self, common, unstudied items) were presented in a pseudorandom order with no more than 4 trials of the same type presented in a row. Trials with too many or too few responses were excluded from all analyses.

Results

Memory estimates

Mean proportions of memory judgments to studied (R hit, F hit, Miss) and unstudied adjectives (R false alarms, F false alarms, correct rejections) as a function of valence and study task (self, common) are presented in **Table 2**.

As in Experiment 1, we calculated Pr (Item recognition), subjective recollection, and familiarity estimates. Pr estimates (**Table 3**) of item memory were tested in an Age (young, older) x Condition (self, common) x Valence (positive, negative) repeated measures ANOVA. Results showed main effects of Age, $F(1, 59) = 28.74$, $p < .001$, $\eta^2 = .33$, and Condition, $F(1, 59) = 55.81$, $p < .001$, $\eta^2 = .33$, and a marginal effect of Valence, $F(1, 59) = 3.08$, $p = .09$, $\eta^2 = .05$, which was modified by an interaction with Condition, $F(1, 59) = 7.10$, $p = .01$, $\eta^2 = .11$. The Age effect resulted from better recognition memory in the young than older adults, while the Condition effect was driven by better performance in the self than common condition. The Condition by Valence interaction resulted from better recognition memory for the negative than positive adjectives in the common condition, $t(60) = 2.75$, $p = .01$. Valence did not differ for the self trials, $t(60) = 0.11$, $p = .92$.

Subjective recollection estimates were entered into an Age (young, older) x Condition (self, common) x Valence (positive, negative) ANOVA. Results showed only a Condition effect, $F(1, 59) = 66.91$, $p < .001$, $\eta^2 = .53$, with no other effects or interactions, F's < 2.3, *p's* > .14. The Condition effect was driven by higher subjective recollection estimates in the self than the common condition. Subjective recollection estimates are shown in **Figure 2**. Familiarity estimates (**Table 3**) were entered into an Age X Condition X Valence ANOVA and resulted in a main effect of Age, $F(1, 59) = 10.59$, p = .003, $\eta^2 = .26$, and Condition $F(1, 59) = 18.15$, p < .001, $\eta^2 = .38$, without a Valence effect, $F(1, 59) = 0.96$, p = .33, $\eta^2 = .03$, or any interactions, *F's* < 1. The main effect of Age resulted from higher familiarity estimates in the young than the older adults, while the Condition effect resulted from higher familiarity estimates for the self than the common items. Objective recollection performance for the voice of speaker was at chance for the majority of the participants so we did not perform any additional analyses on those estimates.

(Figure 2 about here.)

Memory Characteristics Questionnaire

Mean MCQ ratings for the remember hit trials as a function of valence, study task and age are presented in **Figure 3.** Given that the purpose of assessing the MCQ ratings was to determine self-reported amount of episodic details accompanying recollected items, MCQ ratings are reported only for remembered items[2]. We performed a series of Age (young, older) x Condition (self, common) x Valence (positive, negative) ANOVAs— for each detail type (e.g., visual, auditory, etc.)[3]. Results for the visual details ANOVA showed a main effect of Age, $F(1, 59) = 13.25$, p = .001, $\eta^2 = .18$, and marginal Condition effect, $F(1, 59) = 3.50$, p = .07, $\eta^2 = .06$, but no Valence effect or any significant interactions, *F*'s < 1. The Age effect was driven by higher

[2]After making a "Familiar" response, participants reported retrieving details (e.g., providing a response of 2 or 3 for any of the MCQ questions) on fewer than 1% of trials, which we thinks limits the informativeness of those trials.

[3] There were occasions where participants made "Remember" judgments without reporting any MCQ details. These types of trials were also rare, but we included them in the analysis, since it is possible that participants were retrieving some episodic detail that did not neatly fit into any of the MCQ categories.

reported visual details for the young than older adults and the marginal Condition effect due to higher ratings for the self than common condition. The ANOVAs for both auditory details and feelings resulted in main effects of Condition, $F(1, 59)$'s > 5.91, p's < .02, $\eta^2 = .09$, with no other significant effects or interactions, F's < 2.0, p's > .16. As can be seen in the **Figure 3**, self-referenced items were associated with greater auditory detail and reported feelings than were items encoded in the common condition. ANOVA results from the thought details showed a main effect of Age, $F(1, 59) = 4.07$, $p = .05$, $\eta^2 = .07$, Condition, $F(1, 59) = 13.61$, $p < .001$, $\eta^2 = .19$, and Valence, $F(1, 59) = 4.77$, $p = .03$, $\eta^2 = .08$. Additionally, there were significant Condition X Valence, $F(1, 59) = 12.71$, $p = .001$, $\eta^2 = .18$, and Condition X Valence X Age interactions, $F(1, 59) = 5.1$, $p = .03$, $\eta^2 = .08$. The Age effect was due to higher reports of thought details for the young than the older adults while the Condition effect was due to more reported thought details in the self than common condition. The Valence effect was predominately driven by a large positivity effect in the common condition. To interrogate the 3- way interaction, we performed Condition (self, common) X Valence (positive, negative) ANOVAs for the young and older adults separately. The Valence effect was evident in the young, $F(1, 29) = 5.07$, $p = .03$, $\eta^2 = .15$ but not the older adults $F(1, 30) < 1$. Additionally, only the young adults showed a Condition X Valence interaction $F(1, 29) = 11.01$, $p = .002$, $\eta^2 = .28$. This interaction was driven by greater reported thoughts for positive than negative items in the common condition, $t(29) = 3.61$, $p < .01$. Valence did not differ for the self items, $t(29) = 1.00$, $p = .33$. Finally, the temporal details ANOVA showed a main effect of Age, $F(1, 59) = 15.55$, $p < .001$, $\eta^2 = .21$, with no other effects or any significant interactions, F's < 1[4].

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[4] The temporal details assessed whether an item appeared in the beginning, middle or end of the encoding session,

(Figure 3 about here.)

Discussion Experiment 2

There were two primary findings from Experiment 2. First, we replicated several findings from Experiment 1, namely memory estimates were higher in the self than the common condition across estimates of Pr (item recognition), subjective recollection, and familiarity; and a negativity effect was shown in both age groups for the common condition. Second, we showed a consistent pattern of higher reported details, as assessed by our MCQ ratings, for recollected items encoded self-referentially as opposed to semantically, suggesting that self-referencing facilitates memory for a variety of details including perceptual detail, but also internally generated thoughts and feelings. This provides evidence that the mechanisms behind the self-reference memory boost come from the facilitation of many types of episodic details. Importantly, these effects were evident in both age groups. This is consistent with our prior work showing that older and young adults show equivalent benefits from self-referencing when trying to retrieve episodic (source) details (Dulas et al., 2011; Leshikar & Duarte, 2012; Leshikar & Duarte, 2014).

General Discussion

Across two experiments, we examined the effects of self-referencing on recollection estimates as a function of age and valence. There are three principal findings from this experiment which supported our predictions. First, young and older adults experienced a

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and not the *amount* of temporal details they could retrieve, which is a qualitatively different type of measure than the other 4 MCQ ratings, hence these data will not be discussed further.

similar recollection benefit from self-referencing across both experiments. Although older adults' recollection estimates improved after self-referential encoding relative to semantic processing, age-deficits were not ameliorated by this manipulation. Second, we showed that the self-reference benefit in recollection was reflected in the enhancement of multiple types of episodic details, as self-reported by participants using our MCQ approach. Importantly, this is the first evidence examining the type of details that benefit from self-referential processing in young and older adults. These included perceptual and auditory details, but also details that participants internally generated, such as thoughts and feelings. Third, with respect to valence, Experiment 1 revealed negativity effects in recollection estimates for semantically processed items and positivity effects in source memory for the adjectives processed self-referentially across both age groups.

Self-referencing supports recollection in young and older adults.

Previous work has shown that young adults experience a subjective recollection boost from self-referential processing (Conway & Dewhurst, 1995). We hypothesized that older adults would show a similar benefit. Consistent with this prediction, self-referencing enhanced subjective (in both Experiments) and objective measures of recollection (in Experiment 1) in both young and older adults to a similar extent. These data are consistent with prior results showing that both young and older adults experience item (Gutchess et al., 2007) and source memory benefits (Dulas et al., 2011; Leshikar & Duarte, 2014) from self-referential encoding. Crucially, the results of Experiment 2 shed light on the quantity and quality of recollected information enhanced by self-referential encoding. Specifically, our results demonstrated that self-referencing leads to retrieval of greater quantities of several kinds of episodic details including visual and auditory associations as well as internally generated thoughts and feelings. Our prior work showed source memory improvement for perceptual details, as measured by source memory accuracy, under self-reference encoding instructions (Leshikar & Duarte, 2014). This is also consistent with evidence showing healthy older adults show a recollection memory benefit that is marked by improved memorability of contextual details such as the condition in which an item was studied (Genon et al., 2014). We provide converging evidence here, and extend this memory benefit to include additional types of episodic details, both external perceptual and internally generated associations.

Age-related differences in the self-reported vividness of recollected visual and self-generated thoughts persisted, however. These results fall in line with previous evidence (Glisky & Marquine, 2009; Gutchess et al., 2007) suggesting that, while self-referencing may be an effective strategy to improve memory in older adults, it is unable to “rescue” performance to the level of the young. The present results expand these findings, suggesting that while self-referencing may support the creation of rich episodic memories, the vividness of these memories may remain reduced in older adults.

In Experiment 1, our inclusion of an objective recollection measure allowed us to measure memory for an experimentally manipulated detail, i.e. source, for which older adults have notable impairments relative to the young (Spencer & Raz, 1995). We have previously suggested that aging may disproportionately affect objective estimates of recollection, leaving subjective estimates relatively intact, especially in high-functioning older adults (Duarte et al., 2006). In the current study, we found no evidence that aging produced a larger effect on objective than subjective estimates of recollection, given that both estimates were reduced in the older adults compared to the young. One likely explanation for this discrepancy between Experiment 1 and our prior work is that item memory discrimination was lower overall in this study than our prior work (Duarte et al., 2006; Newsome, Dulas, & Duarte, 2012). Thus, it is possible that subjective estimates of recollection may be preserved in the older adults only under conditions in which item recognition is also high. Consistent with this possibility, no group differences were observed in subjective recollection estimates in Experiment 2 in which the mnemonic load was reduced relative to Experiment 1. Collectively, results from both subjective and objective measures suggest that the mnemonic benefit often observed for recognition of self-referentially encoded items is supported by recollection of episodic information, for both young and older adults. Given the abundant evidence that older adults exhibit difficulty accurately binding and/or retrieving associated details of previously encountered events (Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995), these findings suggest that self-referential encoding is an effective strategy for improving memory for episodic details in older adults. This is further consistent with previous evidence suggesting that older adults show a source memory benefit when task demands emphasize processing of socio-emotional details (May, Rahhal, Berry, & Leighton, 2005; Rahhal, May, & Hasher, 2002).

In contrast to recollection, we make two observations with respect to familiarity. First, we observed an age group difference, with the young adults showing higher familiarity estimates than older adults. While at odds with the prevailing view that familiarity is relatively intact with age (Yonelinas, 2002), age-related decline in familiarity estimates have been previously reported for both words and objects (Duarte et al., 2008; Duarte et al., 2006; Light et al., 2000; Toth & Parks, 2006). Several other recent studies also suggest that familiarity may be more impaired than has previously been believed, particularly for remember-know and ROC methods (Prull et al., 2006). A review of numerous behavioral studies using multiple measurement methods found little support for intact familiarity in older adults (Light et al., 2000), suggesting that familiarity deficits may have been underestimated in previous studies. The current results add support to this idea. Second, we report mixed finding with respect to condition effects. Experiment 1 showed no evidence of familiarity ~~support from~~was increased by self-referencing, which we did see in Experiment 2. The one study that has examined the impact of self-referential encoding on familiarity also found no reliable difference between familiarity estimates for self-referenced and semantically processed materials (Conway & Dewhurst, 1995), consistent with Experiment 1. One possible reason for this finding may be that familiarity-based recognition memory does not depend upon the elaborative and organizational processes which may be enhanced by self-referencing. Indeed, numerous behavioral studies have shown that recollection is more sensitive than familiarity to various experimental manipulations, such as divided attention and depth of encoding (Yonelinas, 2002). One possible reason that we did see a self-reference benefit in Experiment 2, where it was not obvious in Experiment 1, is the addition of the MCQ task. It may be that while making the initial R/K judgments participants were already trying to retrieve the precise types of details associated with that trial, which may have influenced their “F” judgments to give rise to condition effect. Further work is needed to examine this possibility.

Valence effects on recollection memory

Overall, valence affected recollection memory similarly in both young and older adults in Experiment 1. Across both estimates, negativity effects were seen for the semantically processed adjectives. The negativity effects seen for the semantically encoded items replicate previous instances of negativity effects found in the young (Kensinger & Corkin, 2003; Mather & Carstensen, 2005; Ochsner, 2000). Previous work has shown that negative materials are processed with greater perceptual detail than are positive or neutral items (Kensinger, Garoff-Eaton, & Schacter, 2007a). Indeed neuroimaging evidence has shown that perceptual processing regions are recruited to a greater extent to support memory for negative than positive materials (Kensinger, Garoff-Eaton, & Schacter, 2007b). Thus richer processing of the specific perceptual details of negative information may serve to benefit recollection more so than positive materials. The fact that older adults also exhibit enhanced recollection for negative compared to positive adjectives encoded semantically suggest that negative emotional events may be encoded in the same manner for both young and older adults, at least under some circumstances. Emerging evidence suggests that when emotional items are encoded in a self-external manner, episodic memory for negative items is greater than positive or neutral items for both young and older adults (Kensinger, Garoff-Eaton, et al., 2007a; Kensinger, Gutchess, & Schacter, 2007). Collectively, these findings add support to data suggesting that the positivity bias sometimes observed in older adults is not always found (Murphy & Isaacowitz, 2008), thus, consistent with the many previous reports that have failed to find positivity effects in older adults (Comblain, D'Argembeau, Van der Linden, & Aldenhoff, 2004; Denburg, Buchanan, Tranel, & Adolphs, 2003; Grady, Hongwanishkul, Keightley, Lee, & Hasher, 2007; Kensinger, Garoff-Eaton, et al., 2007a).

In contrast to the negativity effects observed for subjective and objective estimates of recollection in Experiment 1 for semantically encoded adjectives, positivity effects were observed for objective estimates for self-referentially encoded items, in both age groups. A positivity effect in the older adults was consistent with our expectations, consistent with positivity effects reported for older adults elsewhere in the literature (Mather & Carstensen, 2005), and in line with our prior work showing that positive self-relevant information is remembered well in older adults (Leshikar et al., 2014). Interestingly, we found positivity effects in the young adults as well. This, however, is compatible with prior investigations that have found that positive materials are particularly well-remembered when self-relevant in samples of young adults (Denny & Hunt, 1992; Kuiper & Derry, 1982). Thus such an effect would explain the robust positivity effect observed in both age groups.

One potential caveat to address given prior reports of older adult response bias in recognition memory paradigms (Spaniol, Voss, & Grady, 2008), is the possibility that the robust valence effects we observed in the objective recollection estimates in Experiment 1 might have been due to response bias. That is, both age groups, but particularly the old, may have exhibited a bias to endorse positive adjectives as having been encoded in the self-referential condition. Results from the multinomial model, however, argue against this prospect. The multinomial model analysis showed that both the positivity and negativity effects were driven only *partially* by response bias in both age groups (see the *a/g* parameters from the model).

The model further indicated that the valence effects seen in the objective recollection analysis were robust, suggesting that these valence effects were not simply artifacts of response bias. One result accounted for by response bias was the below chance performance for objective recollection of semantically-encoded positive items in the older adults in Experiment 1. Bias estimates obtained from the model showed that older adults, but not the young, were more likely to respond “self” than “common” for the source decision to correctly recognized positive adjectives. Thus, this strong bias caused the below chance performance on this measure. It is notable that the response bias was of a larger magnitude in the older than young adults. Work from personality psychology suggests that older adults, in comparison to young, show a more positive self-concept (Lodi-Smith & Roberts, 2010; Terracciano, McCrae, Brant, & Costa, 2005; Terracciano, McCrae, & Costa, 2010). Thus, older adults may have been more likely to respond “self” to positive items that were consistent with their more positive self-schema, regardless of the condition in which the item was originally encountered, explaining the larger positivity response bias to the source decision in the older adults than young. Indeed, older adults gave more “remember” responses to positive than negative materials consistent this possibility. Additional work will be necessary to clarify the cause of the response bias in the older adults. To our knowledge, this is the first evidence of a response bias for source decisions in a self-reference task.

There are a few limitations to this study we should note. First, our self-referencing task might have induced a deeper level of processing than the commonness task, leading to better overall memory for the self-reference condition. That said, previous evidence has shown that, when compared to a task where participants had to decide if a word described someone else (other-referencing), participants also showed improved source memory under self-referential conditions. We would note that our prior work has shown that memory for details (source memory) is improved under self-referencing conditions when compared to either semantic tasks (Dulas et al., 2011) or compared against "other-referencing" tasks (Leshikar & Duarte, 2014). We argue this suggests that even if there is a depth of processing difference, this does not fully account for the memory benefit we observed in this study. Another limitation is that our commonness task might have been less of a semantic task than in prior self-reference investigations, because participants might have been basing their commonness decision on linguistic fluency and not on the semantic content of the studied words. We would point out, however, that a range of semantic tasks have been used in prior work including "meaningful" tasks (Baron & Moore, 1987; Breck & Smith, 1983; Davis, 1979, and many others), "desirability" tasks (Ferguson, Rule, & Carlson, 1983; Halpin, Puff, Mason, & Marston, 1984; McCaul & Maki, 1984) as well as "commonness" tasks (Dulas et al., 2011). While it is true that our task is less standard than a semantic task such as judging synonomity (Rogers et al., 1977), we explicitly chose a task that required a subjective choice, so that we could match the self-reference judgment, which is by definition subjective. A further limitation is the high False alarm rates in experiment 1, which would suggest that some of the trials included in our R hits might have included guesses. We would note, however, that our primary finding—that self-reference leads to recollection memory improvement relative to control—is replicated in Experiment 2, where false alarms are much lower. This replication, we argue, allows us to confidently state that recollection memory is improved via self-referencing. High False alarms were evident, no doubt, to the higher memory burden in Experiment 1 than in Experiment 2. The higher memory load in Experiment 1 is especially important because of our use of adjectives; there was likely some false recollection of semantically related adjectives even though we did not explicitly include lures that were semantically related. It is important to note that R hits were much higher than R false alarms, which, suggests that our recollection memory effects were robust.

Conclusions

Overall the findings from this experimental set show that self-referencing supports objective and subjective estimates of recollection memory in both young and older adults, a novel extension of the self-reference effect. Further, we provide a more nuanced look at the type of details that self-referencing supports, and found that it improves memory for perceptual features as well as for internally-generated details such as thoughts and feelings. These data indicate that self-referential processing is an effective strategy for improving recollection in young and older adults through facilitation of many episodic details. Our evidence for task-dependent valence effects within the same individuals suggest that neither age group can be characterized by a generalized “positivity” or “negativity” effect in memory, but rather that members of both age groups exhibit valence memory effects dependent on the types of cognitive processes engaged at the time of study. These findings offer a more nuanced perspective of valence effects on memory with age.

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Tables and Figures

Table 1. Group characteristics of the young and older adults in Experiment 1 and 2.

	Experiment 1		Experiment 2	
	Young adults	Older adults±	Young adults	Older adults
Characteristic	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Education	15.2 (1.8)	15.9 (2.1)	14.9 (1.9)	15.9 (2.2)
Letter Fluency	53.2 (16.3)	47.8 (13.8)	54.8 (13.2)	47.0 (12.9)
Immediate List Free Recall	11.0 (0.7)	10.7 (1.6)	11.3 (0.8)	9.9 (2.1)*
Immediate Cued List Recall	11.3 (0.9)	11.1 (1.1)	11.4 (0.9)	10.4 (1.8)*
Delayed List Free Recall	11.6 (0.7)	11.3 (1.2)	11.7 (0.7)	10.7 (1.8)*
Delayed Cued List Recall	11.8 (0.4)	11.4 (1.0)	11.7 (0.6)	11.0 (1.6)*
List Recognition	11.9 (0.3)	11.4 (2.5)	11.8 (0.8)	11.9 (0.3)
Trails A (seconds)	20.3 (6.4)	29.9 (6.8)*	25.0 (9.4)	39.5 (9.4)*
Trails B (seconds)	42.1 (13.4)	74.5 (29.2)*	44.3 (13.9)	83.6 (33.0)*
Verbal Span Forward	6.9 (1.4)	6.7 (1.1)	7.4 (1.3)	6.6 (1.2)*
Verbal Span Backward	5.5 (1.4)	4.7 (1.4)*	5.5 (1.3)	4.3 (1.2)*
Immediate Visual Recognition	19.2 (1.2)	17.0 (1.8)*	19.0 (1.5)	15.7 (2.7)*
Delayed Visual Recognition	19.5 (0.8)	17.4 (2.0)*	19.5 (1.2)	17.5 (2.2)*
Visual Reproduction	9.0 (1.0)	6.1 (2.3)*	9.6 (1.3)	5.9 (2.3)*

±Neuropsych data from one older adults was not available.
*Measures showing significant age differences at $p < .05$. Statistical tests performed within experiment.

Table 2. Proportions of remember, familiar, and new judgments made to *studied* and *unstudied* items in Experiments 1 and 2 (A) as well as the proportions of recollected studied item associated with correct, incorrect, and "don't know" objective source decisions shown as a function of age, condition, and valence in Experiment 1 (B).

	Young				Older			
	Self		Common		Self		Common	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
A. Studied Items: Experiment 1								
Remember (R)	0.76 (0.18)	0.70 (0.21)	0.58 (0.24)	0.59 (0.24)	0.60 (0.23)	0.49 (0.21)	0.48 (0.23)	0.38 (0.23)
Familiar (F)	0.14 (0.12)	0.19 (0.14)	0.25 (0.15)	0.24 (0.16)	0.22 (0.20)	0.23 (0.18)	0.27 (0.18)	0.27 (0.19)
New (Miss)	0.10 (0.10)	0.11 (0.10)	0.17 (0.16)	0.17 (0.12)	0.18 (0.14)	0.28 (0.16)	0.25 (0.18)	0.35 (0.19)
Studied Items: Experiment 2								
Remember (R)	0.66 (0.24)	0.64 (0.22)	0.51 (0.27)	0.52 (0.29)	0.76 (0.21)	0.68 (0.22)	0.60 (0.18)	0.56 (0.21)
Familiar (F)	0.26 (0.22)	0.26 (0.23)	0.27 (0.28)	0.31 (0.24)	0.10 (0.14)	0.10 (0.14)	0.09 (0.15)	0.10 (0.14)
New (Miss)	0.08 (0.08)	0.10 (0.07)	0.22 (0.18)	0.17 (0.14)	0.14 (0.17)	0.22 (0.19)	0.31 (0.18)	0.34 (0.18)
		Novel				Novel		
		Positive	Negative			Positive	Negative	
Unstudied Items: Experiment 1								
Remember (FA)		0.15 (0.11)	0.10 (0.08)			0.28 (0.20)	0.17 (0.13)	
Familiar (FA)		0.20 (0.12)	0.19 (0.11)			0.21 (0.17)	0.18 (0.16)	
New (CR)		0.65 (0.16)	0.71 (0.15)			0.51 (0.1)	0.65 (0.19)	
Unstudied Items: Experiment 2								
Remember (FA)		0.03 (0.04)	0.04 (0.04)			0.15 (0.16)	0.12 (0.12)	
Familiar (FA)		0.08 (0.08)	0.05 (0.06)			0.07 (0.11)	0.03 (0.07)	
New (CR)		0.89 (0.11)	0.91 (0.08)			0.78 (0.18)	0.85 (0.14)	

	Young				Older			
	Self		Common		Self		Common	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
B. Source Memory: Experiment 1								
Remember + source correct	0.89 (0.10)	0.86 (0.09)	0.70 (0.18)	0.73 (0.16)	0.78 (0.19)	0.55 (0.28)	0.36 (0.19)	0.62 (0.24)
Remember + source incorrect	0.07 (0.07)	0.09 (0.07)	0.24 (0.17)	0.19 (0.15)	0.12 (0.12)	0.32 (0.29)	0.50 (0.23)	0.25 (0.21)
Remember + source DK	0.04 (0.06)	0.05 (0.05)	0.06 (0.08)	0.08 (0.12)	0.10 (0.18)	0.13 (0.21)	0.14 (0.21)	0.13 (0.23)

Note: FA = False Alarm; CR = Correct Rejection; DK = don't know.

Table 3. Estimates of Pr (Item recognition) and familiarity from experiment 1 (A) and experiment 2 (B) are presented as a function of age, condition, and valence.

	Young				Older			
	Self		Common		Self		Common	
A. Experiment 1	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Pr estimates	0.55 (0.18)	0.60 (0.15)	0.49 (0.18)	0.54 (0.16)	0.33 (0.15)	0.37 (0.16)	0.26 (0.16)	0.29 (0.16)
Familiarity estimates	0.27 (0.24)	0.32 (0.27)	0.34 (0.120	0.32 (0.17)	0.22 (0.20)	0.21 (0.17)	0.22 (0.19)	0.19 (0.17)
B. Experiment 2								
Pr estimates	0.81 (0.14)	0.81 (0.09)	0.67 (0.21)	0.74 (0.17)	0.65 (0.18)	0.64 (0.19)	0.48 (0.14)	0.51 (0.16)
Familiarity estimates	0.70 (0.21)	0.73 (0.19)	0.52 (0.27)	0.61 (0.25)	0.52 (0.24)	0.53 (0.19)	0.34 (0.25)	0.39 (0.22)

Table 4. Multinomial model parameters of accuracy and response bias for the source decision, separated by condition and valence, are reported as a function of age for Experiment 1.

	Source Accuracy (*d* parameter)				Source Response Bias (*a*/*g* parameter)			
	Self		Common		Self		Common	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Young	0.79	0.69	0.51	0.55	0.26	0.22	0.28	0.30
Older	0.49	0.35	0.16	0.26	0.42	0.20	0.27	0.43

Note: Details of parameter estimation can be found in the Supplemental materials.

Figure 1.

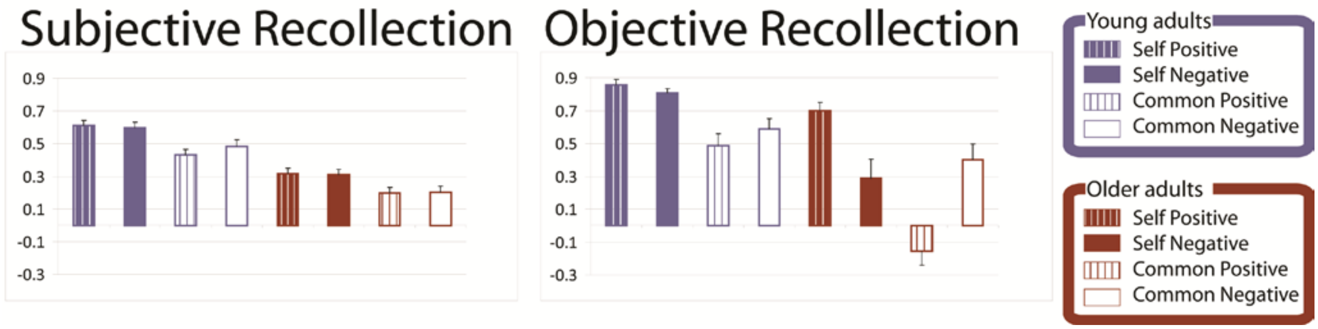


Figure 1. Behavioral effects are depicted for each age group for Experiment 1. Subjective and objective recollection estimates are plotted on the Y-Axis as a function of age, condition, and valence. Error bars represent the standard error of the mean.

Figure 2.

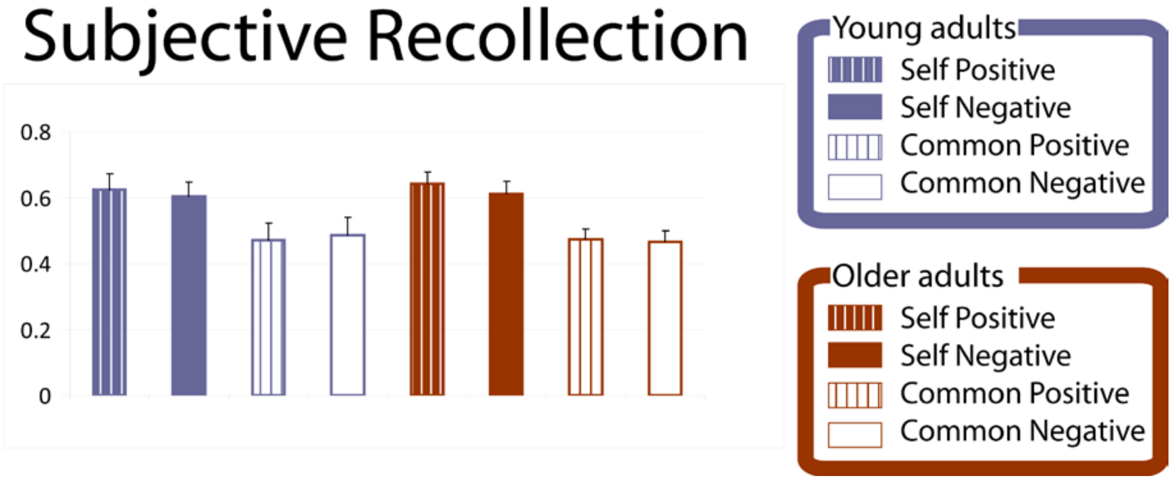


Figure 2. Behavioral effects are depicted for each age group for subjective recollection estimates in Experiment 2, as a function of age, condition, and valence. Subjective recollection estimates are plotted on the Y-Axis. Error bars represent the standard error of the mean.

Figure 3.

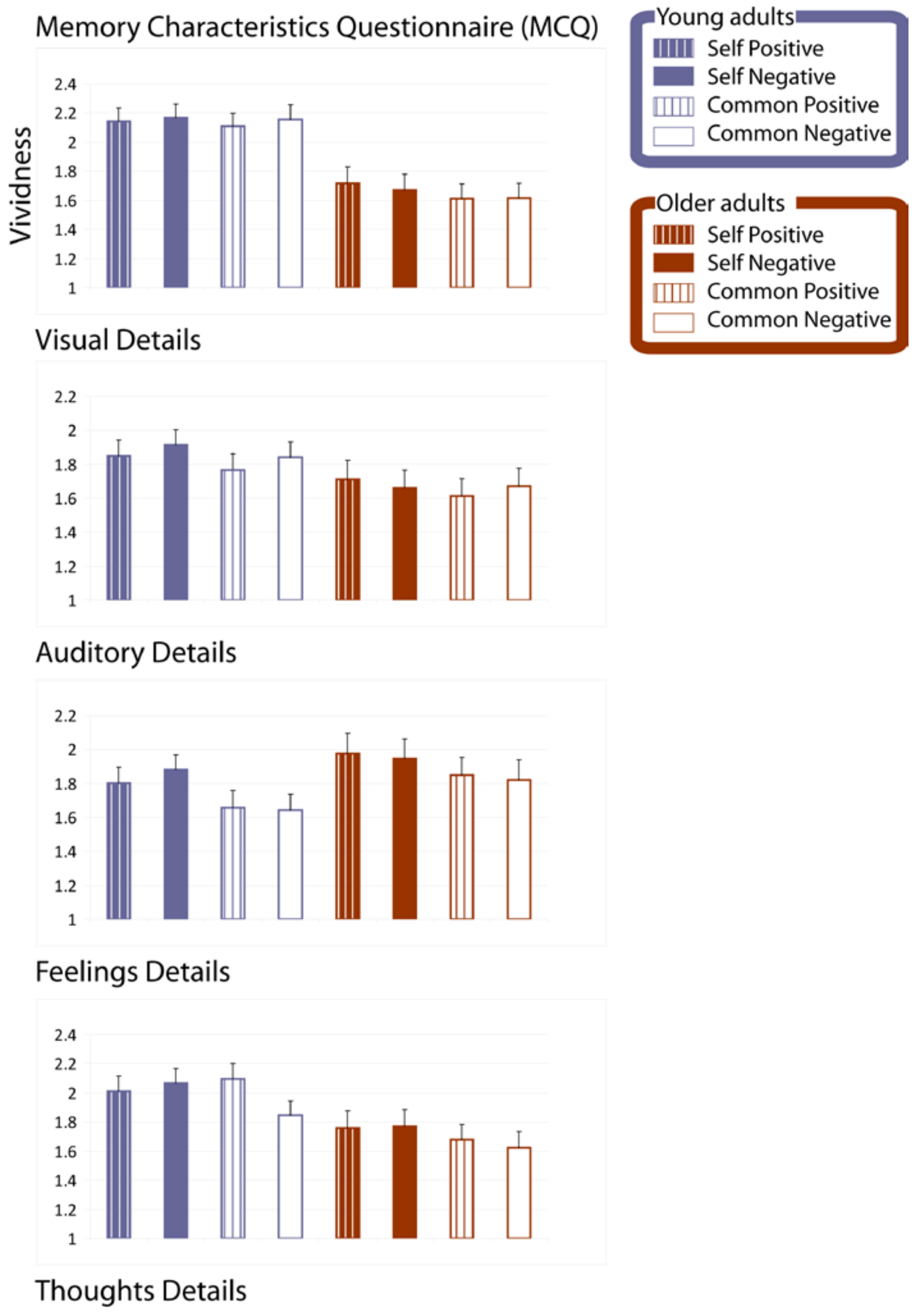


Figure 3. Mean rating for the MCQ judgments from Experiment 2 are shown as a function of age, condition, and valence. Error bars represent the standard error of the mean.

Supplemental material

Multinomial Model based analysis.

Data from this experiment were modeled using the two high threshold multinomial model of Batchelder and Riefer (1990). This model estimates parameters representing item memory, source memory, response bias for source memory along with guessing parameters. **Supplemental Figure 1** depicts a tree diagram representing the various cognitive processes associated with making item and source recognition judgments to studied (i.e., Self condition, Common condition) and unstudied items in this experiment. The model shows that, with probability D_s, participants recognize that a studied item from the self condition is old (and by analogy, recognizes with probability D_c that a studied item from the common condition is old). Then, with probability d_s, participants recognize that the studied item was presented in the self condition. If, however, they fail to recognize the source they may guess, with probability a_s, that the item was from the self condition, or they may guess, with probability a_c, that the item was from the common condition, or they may report, with probability a_{dk}, that they do not know the source. Hence, the *a* parameter estimates response bias for the source decision. Participants failing to recognize a studied item from the self condition as old (1 – D_s) may instead guess that the item is old with a probability of *b*. They then may further guess, with a probability of g_s, that the unrecognized item was seen in the self condition, or they may guess that the item was seen in common condition with probability, g_c, or they may report, with probability g~~a~~$_{dk}$~~$_{s}$~~ that they do not know the source. Finally, participants may correctly identify novel items as new with a probability of 1-b (see the bottom of **Supplemental Figure 1**), or they may incorrectly guess that the item is old with a probability of b, and then guess the source of the item with probability g (e.g., g_s, g_c, and g_{dk}). Thus in this model, memory performance is captured by an 11 parameter model space which consists of the following parameters: D_s, D_c, d_s, d_c, a_s, a_c, a_{dk}, g~~a~~$_s$, g~~a~~$_c$, g~~a~~$_{dk}$, and b.

To summarize, various memory phenomenon for this experiment can be modeled using a multinomial approach: Detection that a studied item is old is estimated by the D parameter, while accurately recognizing the source is estimated by the d parameter. Further, when item recognition does not occur, participants may guess that an unrecognized item is old which is represented by the b parameter. When source recognition does not occur, participants may show a response bias while making source decisions which is represented by the a and g parameters, respectively. More explicitly, we estimated item recognition for the self and common conditions with the parameters D_s and D_c; we estimated source recognition for the two conditions with the parameters d_s and d_c; we represented response bias for the source decision with the parameters a_s, a_c, a_{dk}, g_s, g_c, and g_{dk}, and we represented item guesses with the parameter b. To model valence effects in our paradigm, we took the 11 parameter model and created parameters for each valence: we represented memory effects for the negative items with the following parameters D_{sp} D_{cp} d_{sp} d_{cp} a_{sp} a_{cp} a_{dkp} g_{sp} g_{cp} g_{dkp} and b_p. Similarly, we represented memory effects for the positive items with the parameters D_{sn} D_{cn} d_{sn} d_{cn} a_{sn} a_{cn} a_{dkn} g_{sn} g_{cn} g_{dkn} and b_n.

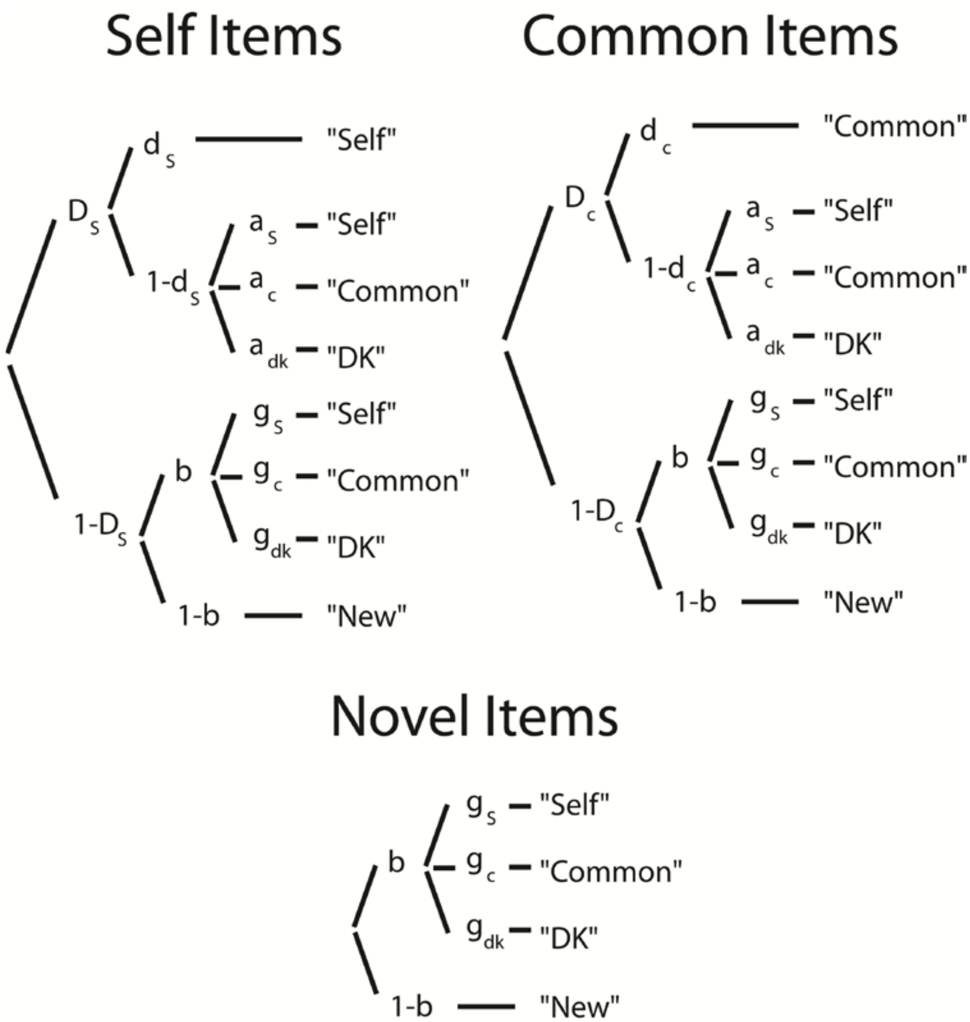
Thus, the full multinomial model space was made up of a total of 44 parameters (11 parameters for each of the age by valence sets; e.g., young-positive set, young-negative set, old-positive set, old-negative set) with an accompanying 36 degrees of freedom (9 degrees of freedom for each age by valence set). The case of more free parameters than degrees of freedom renders the model overdetermined; thus we moved to reduce the parameter space, by setting some parameters equal to one another (see Batchelder and Riefer, 1990). In trying to free up the parameter space, our aim was to find the model with the fewest parameters that fit the data. Because we had no theoretical reason to believe that estimates across the two response bias parameters (a and g) would be meaningfully different, we set the a and g parameters equal to one another. Thus, a_{sp} was set to equal g_{sp}, a_{cn} was set equal to g_{cn}, and so forth. This reduction yielded the best fitting model and contained a total of 32 free parameters with an accompanying 36 degrees of freedom. Supplemental Table 1 shows results of the full 32 parameter model for the *D* and *b* parameters which were not included in Table 43 of the main text.

Supplemental Table and Figures

Supplemental Table 1. Multinomial model estimates of item accuracy and item guessing separated by condition and valence are reported as a function of age.

	Item Accuracy (*D* parameter)				Item Guessing (*b* parameter)	
	Self		Common			
	Positive	Negative	Positive	Negative	Positive	Negative
Young	0.84	0.84	0.74	0.76	0.34	0.29
Older	0.65	0.57	0.51	0.46	0.48	0.35

Supplemental Figure 1.



Supplemental Figure 1. Tree diagram of the multinomial model used to estimate memory effects in this experiment, with separate branches representing decision for items from the self and common conditions, respectively. D_s: the probability of detecting an item from the self condition as old; D_c: the probability of detecting an item from the common condition as old; d_s: the probability of correctly detecting the source of a self item; d_c: the probability of correctly detecting the source of a common item; a_s = response bias to guess that a recognized item was from the self condition; a_c = response bias to guess that a recognized item was from the common condition; a_{dk} = response bias to respond "don't know" to a recognized item; g_s = response bias to guess that a unrecognized item was from self condition; g_c = response bias to guess that a unrecognized item was from common condition; g_{dk} = response bias to respond "don't know" to an unrecognized item; b = the probability of guessing that an item is old.