Self-projection in younger and older adults: A study of episodic memory, prospection, and
theory of mind

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Abstract

Self-projection is the ability to orient the self in different places in time and space. Episodic memory, prospection, and theory of mind (ToM) are all cognitive abilities that share an element of self-projection. Previous research has posited that each of these abilities stem from the same neural network (Buckner & Carroll, 2006). The current study compared performance of cognitively healthy older adults and younger adults on several self-projection tasks to examine the relatedness of these constructs behaviorally. Episodic memory and prospection were measured using an episodic interview task where the participants were asked to remember or imagine events that either had happened in the past or could happen in the future and then gave ratings describing the extent to which they were mentally experiencing the event and from what perspective they viewed it. ToM was measured by asking participants to make judgments regarding the intentions of characters described in stories that involved cognitive, affective, or ironic components. Our results demonstrate that aging influences episodic memory, prospection, and ToM similarly: older adult participants showed declines on each of these measures compared to younger adults. Further, we observed correlations between performance on the measures of episodic memory and prospection as well as between episodic memory and ToM, although no correlation between prospection and ToM was observed after controlling for chronological age. We discuss these results in the light of theories suggesting that each of these abilities is governed by a common brain system.

Keywords: Self-Projection, Prospection, Episodic Memory, Theory of Mind, Aging

Self-Projection in Younger and Older Adults: A Study of Episodic Memory, Prospection, and Theory of Mind

People have an awareness of the past and the future through a process described as “mental time travel,” a process reliant on autonoetic consciousness, or the ability to be self-aware (Tulving, 1985). The term autonoetic consciousness was originally used to describe remembering the past, but it has been expanded into a theoretical model called self-projection, encompassing the cognitive processes of episodic memory (reliving past memories), prospection (imagining future events), theory of mind (ToM; understanding the viewpoints of others), and navigation (directing oneself physically in the present), due to conceptual, developmental, and neurological similarities (Buckner & Carroll, 2007). These cognitive processes rely on autobiographical information and imagination-based processes in order to develop a perspective of oneself or of another person in various places in time and space (Buckner & Carroll, 2007; Mullally & Maguire, 2013). All of these processes begin to develop around the age of four (Perner, Kloo, & Rohwer, 2010; Perner & Ruffman, 1995). Further, all of these processes may use the same neural network in the frontal lobe and the medial temporal-parietal lobe (Buckner & Carroll, 2007; Okuda et al., 2003). Buckner & Carroll (2007) hypothesized that the behavioral and physiological similarities between this cluster of mental abilities reflect the workings of a single neurological system.

Similarities among the activation patterns associated with episodic memory, prospection, ToM, and navigation have led researchers to suggest that these cognitive systems are more than conceptually linked: they utilize the same neural network as well (Buckner & Carroll, 2007). If the cognitive abilities encompassed by the self-projection model utilize the same cognitive architecture, then the physiological process of aging may influence each of the components of

the self-projection model similarly. We will now briefly review previous literature that has focused on individual processes involved with the self-projection model with a special emphasis on the effects of aging on these systems.

Episodic Memory

Episodic memory is the ability to “mentally time-travel” to previous experiences – re-experiencing and reliving the event in the form of a mental simulation of that event (Tulving, 1985). This process requires more than calling to mind facts about a previously experienced event. Immersing oneself in the retrieved moment, including details and feelings associated with the event, are considered to be a critical component of episodic experience (Schwartz, 2011; Tulving, 1985). Episodic memory deficits among older adults have consistently been found and are well-documented (Addis et al., 2008; Head, Rodrigue, Kennedy, & Raz, 2008; Piolino, Desgranges, Benali, & Eutache, 2002). For example, when asked to describe an event from the past, in comparison to younger adults, older adults provide fewer internal details from the event, such as thoughts and feelings, and more external details like the location and scenery (Levine, Svoboda, Hay, Winocur & Moscovitch, 2002). This is an indication that they are not reliving their experiences but merely recalling semantic details (Addis et al., 2008; Levine et al., 2002). This recall pattern has been observed after the age of 60 for the memory of events, regardless of the emotional intensity of the event (Kinugawa et al., 2013; Piolino et al., 2002).

Prospection

The act of prospection involves mentally simulating future events. The cognitive processes associated with episodic memory are used when imagining future scenarios (Buckner & Carroll, 2007; D’Argembeau, & Mathy, 2011; Mullally & Maguire, 2013). For instance, imagine a scenario in which a person has been invited to a dinner party by a new friend. In order

to prepare for this new situation, one might remember events from their past that are similar to the anticipated event, such as attending a dinner party at another friends' house for the first time, or interacting with this friend at other parties. All of this information may be mobilized when they imagine what this future party is likely to be like. This mental simulation of the future party informs how one prepares for the event.

Studies on the influence of age on prospection tasks have documented reduced performance among older adults on prospection tasks when compared with younger adults (Gaesser, Saccetti, Addis & Schacter, 2011). Older adults produce fewer internal and more external details than younger adults when imagining future scenarios, suggesting they are unable to visualize the future with the same clarity and detail as younger adults (Addis, Musicaro, Pan, & Schacter, 2010; Addis et al., 2008). The consistency of the findings of effects of aging on prospection in addition to the relatedness of prospection with episodic memory has been interpreted as support for the self-projection model (Buckner & Carroll, 2007).

Theory of Mind

Theory of Mind (ToM) is the ability to attribute mental states and processes to others. These mental states and processes might include desires, concepts, intentions, and emotions (Paal & Bereczkei, 2007). The effects of aging on ToM have been widely disputed among researchers, with some research groups arguing that ToM does not change or improves with age (Carstensen, Isaacowitz, & Charles, 1999; Happé, Winner, & Brownell, 1998; MacPherson, Phillips, & Della Sala, 2002) and others arguing that there are impairments in ability over time (Duval, Piolino, Bejanin, Eustache, & Desgranges, 2011; Maylor, Moulson, Muncer, & Taylor, 2002; Slessor, Phillips & Bull, 2007; Wang & Su, 2013). One reason for the discrepancies in the ToM literature may be the lack of a central operational definition of ToM and the disparity

amongst tasks used to assess it. ToM tasks have used stories (Maylor et al., 2002; Wang & Su, 2013), videos (Slessor et al., 2007), and eye gaze interpretation (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Slessor et al., 2007). Each of these operational definitions of ToM may utilize different aspects of ToM or require different supportive cognitive systems to ensure the successful completion of the task.

Recently, researchers have separated ToM into two subcategories: cognitive ToM and affective ToM. Cognitive ToM refers to the ability to understand cognitions, thoughts, or ideas of others (Duval et al., 2011; Shamay-Tsoory et al., 2007; Wang & Su, 2013). Affective ToM refers to the ability to understand emotions or feelings of others (Duval et al., 2011; Shamay-Tsoory et al., 2007; Wang & Su, 2013). Wang & Su (2013) also defined a third category, which they called “mixed” ToM. This category included various situations involving irony, which required understanding both cognitive and affective states of the actors involved. Previous literature on the effects of aging on these subcategories is mixed. Some research has found that aging affected these subcategories differently, with cognitive and mixed ToM showing performance decrements while affective remained unaffected (Wang & Su, 2013), while others found aging to affect both affective and cognitive ToM (Duval et al., 2011). Thus, effects of aging on the subcomponents of ToM remain unclear.

Navigation

The ability to navigate through space is the final component of the self-projection model. Mental simulation is thought to be a core component of the ability to navigate the environment, due to its proposed role in forming mental maps of the world (Buckner & Carroll, 2007). For example, an individual who is trying to find their way from their seat in a theater to the concession stand may mentally preplan the route that will disrupt the fewest fellow movie-goers.

In doing so, they may recall the layout of the theater and imagine themselves traveling along a number of routes until deciding upon the best one. Consistent with the other components of the self-projection model, healthy aging has been shown to negatively impact navigation ability (for a review see Moffat, 2009). In a study by Wilkniss, Jones, Korol, Gold & Manning (1997), younger and older adults were asked to navigate their way through a hospital. Wilkniss et al. found that older adults navigated through the hospital more slowly and made more frequent turning errors than younger participants. This pattern of results is broadly consistent with the idea that aging universally suppresses performance in self-projection related tasks.

The Current Study

The results of our literature review suggest that the components of the self-projection model are similarly affected by age. However, it is important to note that previous literature focusing on the influence of age in self-projection has focused on one specific component of the model at a time (episodic memory: Head, Rodrigue, Kennedy, & Raz, 2008, prospection: D'Argembeau, & Mathy, 2011, ToM: Wang & Su, 2013, navigation: Schallenberg, Lövdén, Verrel, Krüger, & Lindenberger, 2010). The current study aims to address this shortcoming of the currently available literature by using behavioral measures of multiple components – episodic memory, prospection, and ToM – with a group of younger participants and a group of older participants. The advantage of this design is the ability to observe the potential influence of aging in each of the selected components of the self-projection model within one sample. Our design also allows us to tie subjective experiences and qualia associated with episodic memory retrieval with a measure of the overall strength of recollective performance, allowing us to track the relationship between participant's introspections as they simulate the past and future events and their objective ability to recall recent events. Further, the current study attempted to replicate and

extend recent research examining the differences between affective and cognitive ToM (Wang & Su, 2013). We hypothesized that performance on the cognitive processes unified by the self-projection model would be correlated and that there would be corresponding negative effects of aging on episodic memory (Piolino et al., 2006), prospection (Addis et al., 2008), and ToM (Duval et al., 2011). Although navigation is a crucial component of the self-projection model described by Buckner & Carroll (2007), the current study will did not measure navigation due to a number practical and methodological of reasons. First, known paradigms for assessing navigation ability often require specialized equipment ranging from specialized navigation video games (Weisberg & Newcombe, 2015; Yassen, Raber, Miller, & Piper, 2015) to virtual reality treadmills (Shellenbach, Lövdén, Verrel, Krüger, and Lindenberger, 2010). Unfortunately, we did not have access to these materials for this study. Second, even naturalistic navigation paradigms tend to be time consuming, and we wanted to protect our participants from cognitive fatigue. Rather than risking cognitive fatigue in our participants from testing all four components of the model, we chose to exclude navigation from our design. Ultimately, understanding the age-related changes in the three components of the self-projection system we were able to measure may suggest pathways for better support of aging populations.

Method

Participants

We recruited a sample of 45 older adults ($M = 78.73$ years, $SD = 9.89$ years) from local senior centers¹ and 45 younger adults ranging in age from ($M = 20.36$ years, $SD = 0.93$ years) from Willamette University. To ensure that all participants were cognitively and psychologically

¹ Participants from the senior centers either lived offsite and visited the center as a means for social engagement or lived onsite in independent living.

healthy, we excluded 15 younger adults for mild-severe depression as indicated by the BDI (Beck, Ward, Mendelson, Mock & Erbaugh, 1961) and 14 older adults for mild-severe depression as indicated by the 15 item Geriatric Depression Scale (Sheikh & Yesavage, 1986) and/or scores indicating lower than high cognitive capacity on the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). We set a relatively stringent criterion for exclusion due to depressions' well-established relationship with the specificity and quality of episodic memory (Anderson, Goddard & Powell, 2010). The final sample included 31 older adults (24 female and 7 male) ranging in age from 58 to 92 ($M = 76.20$ years, $SD = 9.11$ years) and 30 younger adults (18 female and 12 male) ranging in age from 18 to 22 ($M = 20.30$ years, $SD = 0.88$ years). Although we were unable to recruit a sample balanced by gender, we did not anticipate effects to differ by gender. Consistent with this prediction, controlling for gender did not significantly influence any of our findings. Consequently, gender is not further discussed. Education levels did not differ between younger and older adults $t(58) = -1.21$, $p = 0.23$ (see Table 1). Older adults were compensated for their time with a \$10 gift certificate to local restaurants, and younger adults participated voluntarily without compensation.

Measures

Episodic Memory and Prospection Episodic interview task

Episodic memory and prospection were measured using an episodic interview task (Lind & Bowler, 2010). Participants were asked to produce personal memories from each of several periods of their past and to imagine events that could happen in the future. Participants were presented with the prompt, "Try to remember an event that happened to you [specific time period]," in the episodic memory task and, "Try to imagine an event that could happen to you [specific time period]," in the prospection task. Participants generated a response for each of the

following seven time periods: today, yesterday/tomorrow, a week ago/in a week, a month ago/in a month, a year ago/in a year, five years ago/in five years, and ten years ago/in ten years. The prompts were presented in a randomly generated sequence and a reverse counterbalanced version of this sequence was presented to half of the participants. Participants first completed all seven episodic memory trials, and then completed the seven prospection trials. Before beginning the interview, participants were given an example of an appropriate response (“Last weekend I went bowling with my friends. I had a lot of fun because I got my highest score in years. We were hungry so we decided to eat nachos at the alley”) and an inappropriate response (“Yesterday, I went to work”). It was explained that responses that were overly general or that relied on semantic rather than episodic information were inappropriate. Participants gave their responses verbally. These verbal responses were recorded and later transcribed by our experimenters. All participants completed the same two practice trials to ensure comprehension of the instructions: they were asked to try to remember an event involving a television and to try to imagine an event that could happen involving a car. Participants were prompted with objects rather than time points in order to avoid prompts to be used in the experimental portion. If participants did not provide episodic examples, the experimenter informed the participant about why their practice example did not meet the requirements in order to confirm understanding of the task before the start of the experimental trials.

The episodic interview task was scored on a binary scale with each response given either a 1 to denote a description of an episodic event or a 0 to denote either an error response or an omitted response (Lind & Bowler, 2010). Scores for each response were added such that participants could receive up to a total score of 7 if episodic events were recalled for each time point or as low as 0 for no episodic events were recalled. This score was calculated separately for

episodic memory and prospection. Events were considered episodic if they included descriptions of events that happened or would happen in a particular time at a particular place, lasted or would last for less than a day, and occurred or would occur only that one specific instance. Events were considered errors if the participants failed to provide a memory for the time prompt, or the memory was an error response including general memories, meaning memories that either took place over a long period of time (for example, “going to high school”) or similar events that were condensed into one singular memory (for example, “eating lunch”). Upon completion of transcription, one interviewer coded the responses of the participants run by the other interviewer. Coding was completed from the transcriptions to remove the participant’s voice as a cue to the age of the participant. Two trained research assistants independently coded each event. These research assistants were blind to the identity and age group of the participant. Cohen’s *kappa* was computed to test interrater reliability. There was high agreement between raters (episodic: $k = 0.82$, $p < 0.001$; prospection: $k = 0.89$, $p < 0.001$).

After each prompt, participants were asked to rate the extent to which they felt as if they were reliving/experiencing the event while they were remembering/imagining the event in order to gauge the extent to which they were engaging in an experience of mental time travel (Lind & Bower, 2010). The extent of experiencing or reliving was verbally self-reported on a likert scale of 1-7 with a score of 1 representing not at all experiencing/reliving and 7 representing completely experiencing/reliving.

Participants were also asked to reflect on the perspective from which they relived/imagined their memory/representation. They were asked to choose between three options, either as a participant in the event (participation), a third party observing the event (observation), or another perspective (Lind & Bower, 2010). The prompt read:

“When you remember/imagine this event, how do you see it? From the following three options, choose the one that corresponds to your memory/representation. (a) In your memory/ representation, you see the scene in the same way as an external observer would see it. In other words, you can see yourself in your memory/representation as well as other aspects of the situation. (b) In your memory/representation you see the scene from your own point of view and not from that of an external observer. In other words, you see the scene through your own eyes. (c) Neither of these above mentioned perspectives corresponds to your memory/representation of the event. If this is the case, how would you describe your memory/representation?”

Perspective was recorded as their self-reported answer.

Episodic Recall

A list of eighteen words with an average frequency of usage in the English language between 35-55 (mean frequency of usage= 40.22) was selected using MRC Psycholinguistic DataSource (Wilson, 1988). All words were 7-8 letters long and two or three syllables. Participants were asked to try to remember as many of the words as possible while the list was slowly read aloud (one word every 5 seconds). They were asked to immediately record the words they could remember after the list was read and were not warned that there would be a second recall test later in the experiment. At the end of the experiment, they were again asked to recall as many of the words as possible. The goal of the word recall task was to objectively measure the accuracy of non-autobiographical episodic memories.

Theory of Mind

To measure ToM, we used a story task adapted from previous research in order to assess each subtype of ToM (Wang & Su, 2013). The stories were presented in a booklet that consisted

of anecdotes that required participants to make judgments on the thoughts and emotions behind the character's actions in a variety of scenarios (Happé et al., 1998; Maylor et al., 2002; Wang & Su, 2013). Participants were allowed to refer back to the story booklet while answering the corresponding questions to ensure a reduced cognitive load and to focus the task on ToM rather than working memory (Wang & Su, 2013). Participants read 14 stories and answered up to 4 questions that corresponded to each story: 12 stories required ToM skills to answer the questions correctly and 2 control stories did not require understanding another person's perspective (Apperly, Samson, Carroll, Hussain & Humphreys, 2006; Stone, Baron-Cohen & Knight, 1998; Wang & Su, 2013; see Appendix). Participants answered each of the questions by writing their answer on a response sheet.

The experimental stories consisted of three subcategories: cognitive, affective, and mixed. The cognitive ToM stories required participants to understand characters' thought processes in order to grasp the events of the story (Shamay-Tsoory et al., 2007; Wang & Su, 2013). These stories included components concerned with first-order or second-order false belief understanding and bluff or double bluff understanding (Apperly et al., 2006; Wang & Su, 2013). The affective ToM stories required participants to understand characters' emotions and feelings in order to understand the stories (Shamay-Tsoory et al., 2007; Wang & Su, 2013). These stories included components concerned with faux pas stories and white lies (Stone et al., 1998). Mixed ToM had stories that included irony and sarcasm, which include a mix of cognitive and affective components (Wang & Su, 2013). There were two examples of each component of each subcategory in the booklets: false belief, bluff or double bluff, white lies, faux pas, cognitive irony, affective irony, and two control stories placed in a randomized order.

ToM responses were coded based upon the extent to which they demonstrated an understanding of the perspectives of the actors in the scenarios. Responses were given a score of 2 if the responses included the explicit use of mental state words such as know, think, forget, remember, believe, understand, sarcasm, etc. (Nielsen & Dissanayake, 2000). Responses were given a score of 1 if the response did not include an explicit use of mental state words but had partially or implicitly correct answers. Responses were given a score of 0 if it was an incorrect or incomplete answer (Happé et al., 1998; Wang & Su, 2013). The task was double coded by research assistants blind to the identity or age of the participant. Cohen's *kappa* was run to test interrater reliability. There was high agreement between raters ($k = 0.93, p < 0.001$).

Procedure

The experiment was conducted with participants individually and took approximately an hour to complete. Participants first completed a questionnaire designed to provide the researchers with relevant demographic information. A depression screening was included as part of this questionnaire (Geriatric Depression Scale for the older adults and Beck Depression Index for the younger adults). Participants then completed a forward digit span test using PEBL software (Mueller, 2012). The digit span test assessed working memory capacity, a common index of cognitive performance (Schwartz, 2011). Older adults then completed the MMSE. Following the MMSE, participants listened to the study list for the episodic recall task and immediately participated in the first recall test in which they were asked to write down as many words from the list as they could remember. They then participated in the episodic interview task, which was audio recorded and subsequently transcribed. They next completed the verbal fluency task (Turner, 1999). Including the verbal fluency task allowed us to measure cognitive performance in a cognitive system that is theoretically distinct from the self-projection system. The

participants then received the ToM story packet and answered the accompanying questions. The participants were then instructed by the experimenter to complete a second surprise recall test for the words from the episodic recall task at the beginning of the experiment (average delay $M = 57$ minutes, $SD = 9.85$ minutes). Participants completed this task by writing down as many words as they could remember from the list. Finally, participants were thanked, debriefed, and compensated.

Results

Preliminary Analyses

A significance criterion of .05 was adopted for all analyses, unless explicitly noted. Some demographic characteristics of the recruited participants (age, years of education, digit span, and verbal fluency) are reported in Table 1. In order to determine whether testing fatigue influenced results, we conducted a correlational analysis relating time to complete the test battery to performance. Time to complete the experimental protocol ($M = 57.61$ minutes, $SD = 9.85$ minutes) correlated with measures at the beginning of the experimental sequence (the episodic interview task episodic memory ($r = -0.33$, $p < 0.05$) episodic interview task prospection ($r = -0.35$, $p < 0.05$) and the initial episodic recall session ($r = -0.36$, $p < 0.05$), but not for measures at the end of the experiment $r_s < 0.25$ (ToM and episodic recall at the end of the experiment). This suggests that the length of time it took to learn instructions, think about memories, and/or talk about memories was greatly related to the time it took to complete the entire experiment. However, since this measure was at the beginning of the experiment, it is unlikely that this relationship suggests an influence of fatigue. Overall, these results suggest that testing fatigue did not significantly affect the results presented here.

Episodic Memory and Prospection in the Episodic interview task

Quantity of Events Recalled/Imagined

A one-way ANOVA was conducted to test for differences between the older and younger adults on number of events recalled or imagined. As expected, older adults (OA) recalled fewer episodic events than younger adults (YA), $M_{oa} = 4.06$, $SD = 1.26$; $M_{ya} = 6.07$, $SD = 1.31$; $F(1, 60) = 34.55$, $p < 0.001$, $\eta^2 = 0.39$. Older adults also imagined fewer future events than younger adults, $M_{oi} = 2.90$, $SD = 1.54$; $M_{yi} = 4.83$, $SD = 1.39$; $F(1, 60) = 24.92$, $p < 0.001$, $\eta^2 = 0.31$. These data are summarized in Figure 1.

Effects of Temporal Distance

The proportion of participants who were able to recall an episodic memory for each time period is reported in the top portion of Figure 2. In order to examine the influence of temporal distance on episodic memories for younger and older participants, a 2 (age group: younger, older) $\times$ 7 (time period: earlier today, yesterday, a week ago, a month ago, a year ago, five years ago, and ten years ago) mixed factorial ANOVA was conducted. We observed a significant main effect of time period ($F(6,54) = 14.63$, $p < 0.001$, $\eta^2 = 0.62$): generally, participants reported fewer memories as temporal distance from the present moment grew. We also observed an effect of aging $F(1,59) = 36.89$, $p < 0.001$, $\eta^2 = 0.38$. Younger adults generally provided more memories than older adults. Critically, the interaction between time period and aging was also significant, $F(6, 54) = 5.12$, $p < 0.001$, $\eta^2 = 0.36$, suggesting that the negative influence of aging is greater when participants try to retrieve memories that are more temporally distant from the present moment.

A similar analysis was performed for the prospection data. The percent of participants who were able to imagine a scene for each time period is reported in the bottom portion of Figure 2. In order to examine the influence of temporal distance on prospective simulations for younger

and older participants, a 2 (age group: younger, older) x 7 (time period: later today, tomorrow, a week from now, a month from now, a year from now, five years from now, and ten years from now) mixed factorial ANOVA was conducted. We observed a significant main effect of time period ($F(6,54) = 24.90, p < 0.001, \eta^2 = 0.74$): generally, participants reported fewer prospective simulations as temporal distance from the present moment grew. We also observed an effect of aging $F(1,59) = 26.41, p < 0.001, \eta^2 = 0.31$. Younger adults generally provided more prospectations than older adults. The interaction between time period and aging was not significant, $F(6,54) = 1.40, p = 0.23, \eta^2 = 0.14$.

Vividness and Perspective

A one-way ANOVA was conducted to test for differences between the older and younger adults on how vividly they reported reliving or imagining their memories. Older adults did not differ from younger adults on the extent to which they reported “reliving” their memories, $M_{oa} = 5.02, SD = 1.65; M_{ya} = 4.68, SD = 1.22; F(1, 58) = 0.83, p = 0.37, \eta^2 = 0.01$. Contrary to our predictions, older adults reported experiencing their future events to a greater extent than the younger adults, $M_{oa} = 5.29, SD = 1.11; M_{ya} = 4.02, SD = 1.23; F(1, 56) = 16.53, p < 0.001, \eta^2 = 0.23$.

To calculate perspective taking, reported third-person perspective taking was coded as a 0 and reported first-person taking was coded as a 1. Any other response was left as a missing value. Scores were averaged across temporal periods for a composite perspective taking score. A one-way ANOVA was conducted to test for differences between the older and younger adults on the perspective they took when recalling or imagining events. There was a marginally significant trend such that older adults reported reliving memories from a first-person perspective more than younger adults did, $F(1, 59) = 3.29, p = 0.08$, and reported imagining future events from a first-

person perspective more than younger adults, $F(1, 58) = 4.57, p = 0.04$. While older adults did not produce as many episodic events, their self-reports indicate that the memories they did retrieve were more auto-noetic than those of younger adults.

Episodic Recall of the Word List Task

Separate one-way ANOVAs were conducted to test for differences between the older and younger adults on the number of events recalled immediately, at the end of the experiment, and the change in recall performance between the first test and the second test. Older adults recalled fewer words initially than younger adults, $M_{oa} = 3.74, SD = 1.81; M_{ya} = 6.97, SD = 1.69; F(1, 60) = 51.14, p < 0.001, \eta^2 = 0.46$. Older adults also recalled fewer words at the end of the experiment when controlling for the number of words recalled initially, $M_{oa} = 1.23, SD = 1.21; M_{ya} = 4.07, SD = 1.89; F(1, 60) = 6.59, p = 0.01, \eta^2 = 0.10$. An intrusion is a word falsely remembered as being on the initial list of words. The greater quantity of intrusions recalled, the less accurate the participant's memory was of an event. Older adults and younger adults had similar numbers of intrusions at the initial time point [$M_{oa} = 0.61, SD = 1.09; M_{ya} = 0.4, SD = 0.62; F(1, 60) = 0.88, p = 0.35, \eta^2 = 0.02$] and at the end of the experiment [$M_{oa} = 0.45, SD = 0.89; M_{ya} = 0.63, SD = 1.25; F(1, 60) = 0.43, p = 0.51, \eta^2 = 0.01$]. Older adults and younger adults had relatively few intrusions over the course of the experiment. This finding is consistent with previous research demonstrating a decrease in recollection performance associated with aging.

Theory of Mind

The average rating of the participant responses on the ToM task (2 = correct answer with explicit mental state terms; 1 = partial and implicit correct answer without explicit mental state terms; 0 = incorrect answer) grouped by task type and age data are summarized in Figure 3. A 2 (age group: older, younger) X 4 (task type: cognitive ToM, affective ToM, mixed ToM, control

ToM) repeated measures ANOVA was conducted to investigate the age differences among ToM tasks. There was a significant main effect of age, $F(1, 59) = 6.90, p = 0.01, \eta^2 = 0.11$, a significant main effect of task type [$F(3, 57) = 10.97, p < 0.001, \eta^2 = 0.16$], but no interaction between age and task type [$F(3, 57) = 0.65, p = 0.59, \eta^2 = 0.01$]. In order to further investigate the main effect of task type, we performed a series post-hoc contrasts (Bonferroni corrected $\alpha = .008$). Cognitive ToM was significantly different from affective ToM [$t(60) = 3.63, p = 0.001$], mixed ToM [$t(60) = -5.89, p = 0.0001$], and control ToM [$t(60) = -3.94, p = 0.001$]. Affective ToM was significantly different from mixed ToM [$t(60) = -2.8, p = 0.007$] but not control ToM [$t(60) = -2.01, p = 0.049$]. Mixed ToM did not differ from control ToM, [$t(60) = 0.176, p = 0.86$].

Correlational Analysis

In order to assess the relatedness of the hypothesized components of the self-projection model, we tested the correlations between the facets of the self-projection measures. Scores from the two episodic memory tasks were converted into Z-scores and combined. The scores on all of the ToM tasks were also combined into one composite score. All correlations reported are Pearson product moment correlations unless otherwise indicated. Episodic memory was highly related to prospection ($r = 0.58, p < 0.001$) and the composite ToM scores ($r = 0.51, p < 0.001$). Prospection and the composite ToM scores were moderately correlated ($r = 0.29, p = 0.03$). Scatterplots for each of the reported correlations can be found in Figure 4.

One concern arising from the previous analysis might be that the correlations may be driven by changes in performance due to aging. Indeed, the difference between younger and older participants on baseline measures of cognitive ability like the Digit span ($t(59) = 5.40, p < .001$) and the verbal fluency task ($t(59) = 6.21, p < .001$) (See Table 1) suggests that cognitive

impairment due to aging was not isolated to the self-projection system. In order to control for the possibility that the relationships we observed between the components of the self-projection model were driven primarily by shared variability due to aging, we ran partial correlations examining the relationship between each component of the model partialing out the variance associated with chronological age. The results of this analysis revealed that the relationship between the combined episodic measures and the ToM measures was somewhat weakened but still significant ($r = 0.28, p = 0.03$). Similarly, the relationship between episodic memory and prospection remained significant ($r = 0.27, p = 0.04$). However, the relationship between prospection and ToM was no longer significant when chronological age was controlled for ($r = .08, p = .66$).

Discussion

We observed consistent age-related changes across each of the self-projection related cognitive abilities that we measured including episodic memory tasks, prospection and ToM. Importantly, our results replicate the results of several studies which have observed age related declines in episodic memory, prospection, and ToM individually (Head, Rodrigue, Kennedy, & Raz, 2008; D'Argembeau, & Mathy, 2011; Wang & Su, 2013; for a discussion of the importance of reproducibility in psychological research, see Open Science Collaboration, 2015). Further, our findings extend this literature by demonstrating relatively consistent age-related changes in cognition across all three subdomains in the same sample. In addition, we observed correlations between episodic memory and prospection as well as episodic memory and ToM, although no correlation between prospection and ToM was observed after controlling for the influence of chronological age. The fact that episodic memory is related to prospection and ToM, but ToM and prospection do not correlate with each other after controlling for age may suggest that

episodic memory may serve as a lynchpin in the self-projection model. That is, both ToM and prospection may draw on episodic memory in order to accomplish their respective goals. In our sample, ToM and prospection were only linked through their mutual relationship with episodic memory. Broadly, our findings provide preliminary evidence demonstrating that episodic memory, prospection and ToM are linked in a manner similar to that predicted by the self-projection model and are consistent with the previous literature examining the self-projection model (Addis et al., 2009; Buckner & Carroll, 2007; Gamboz et al., 2010; Okuda et al., 2003; Spreng & Grady, 2010). However, more research is necessary. Specifically, future research should expand on the foundation laid down by the present research by adding navigation tasks to the experimental test battery. We now turn to a discussion of each of the subdomains of the self-projection model in order to place our findings in an appropriate theoretical context for each.

Episodic Memory

Episodic memory is a complex cognitive function that relies on various different cognitive systems. Various tasks that have been used to test episodic memory have been found to be significantly different from each other and thus all test slightly different aspects of episodic memory (Cheke & Clayton, 2013). One strength of the current design was that we used two different measures to test episodic memory (one autobiographical and one focusing on simple recollection). The immediate and delayed episodic recall tasks do not test episodic memory using autobiographical cues but instead tested participants' ability to encode a controlled event at the beginning of the experiment and retrieve it at two points throughout the experiment. This measure is beneficial because the accuracy of the memory can be evaluated (which is not the case in the episodic interview task). Older adults remembered fewer words than younger adults at both time points, which denotes a reduced ability to encode and retrieve new memories.

Further, performance at the first recall time was correlated with performance on the episodic interview task. Moreover, older and younger adults forgot at similar rates when differences in initial memory performance were controlled for. This collection of findings is consistent with the idea that the episodic word recall task and episodic interview task tapped into similar memory processes and were similarly influenced by healthy aging.

Younger adults provided more episodic memories than older adults during the episodic interview task. This supported our hypothesis of a decline in performance for older adults when compared with younger adults in line with the self-projection model. As adults age, the cognitive systems required to recall events become less reliable and are less able to produce episodic memories (Abu-Akel et al., 2011; Berna, Schönknecht, Seidl, Toro, & Schröder, 2012; Kinugawa et al., 2013; Piolino et al., 2006; Piolino et al., 2002). The finding that older adults provided fewer episodic memories than the younger adults is consistent with previous research demonstrating deficits in episodic memory associated with age (Addis et al., 2008; Kinugawa et al., 2013; Levine et al., 2002; Piolino et al., 2002). Older adults and younger adults also described similar levels of feeling as though they were reliving their memories. However, it is important to keep in mind one caution when interpreting the episodic data: our cross-sectional design may have led to meaningful differences between the baseline memorability of the events that our participants were asked to retrieve. The “reminiscence effect” refers to the well established finding that it is generally easier to remember events from the ages of 16-25 than other periods of life (Kawasaki, Janssen, & Inoue, 2011; Leist, Ferring, & Filipp, 2010; Piolino et al., 2006; Thomsen, Pillemer, Ivcevic, 2011; Rybash, 1999). Several factors unrelated to changes in the self-projection system may contribute to the higher memorability observed during this time, with explanations ranging from the number of “firsts” during the 16-25 year old time

period, and the prevalence of changes in identity formation (Schwartz, 2011). The reminiscence effect has been observed in older adults when remembering episodic events. The younger adults in our sample were in the midst of living this time period and this may have made it easier for them to identify episodes than for older adults remembering events in their immediate past. In addition, previous research has found younger adults also have a reminiscence bump for events between the ages of 5 and 13 (Kawasaki et al., 2011). When younger participants were remembering events for our task, some of the cues fell within this time frame. Future research should concentrate on the prevalence of transition events and their reminiscence bump in order to develop a more comparable comparison task.

Prospection

For the prospection task, our results were consistent with past research showing reduced performance levels for older adults with no relation to the temporal distance from the present (Addis et al., 2010; Rendell et al., 2012). Similar to performance on the episodic component of the episodic interview task, older adults also produced more general events and fewer events total when compared with younger adults, which is consistent with the idea that prospective performance is meaningfully linked with episodic performance (Addis, Wong, & Schacter, 2007) and replicates previous work examining the influence of aging on prospection (Addis, Musicaro, Pan, & Schacter, 2010). However, one surprising result was the finding that despite that fact that older adults produced less specific and fewer total events during the prospective interview, their ratings of the subjective vividness of their prospectations were significantly higher than those of their younger peers. The gap between the objective performance on the task and ratings of subjective experiences during the task may suggest a deficit in older adults' metacognitions about their prospectations. In contrast with past literature demonstrating that older adult

evaluations of their own prospective performance are reliable predictors of prospective performance when variables like depression are controlled for (Zeintl, Kliegel, Rast & Zimprich, 2006), our data suggest that older adult reports regarding their metacognitions about their projections may not accurately reflect performance. Another possible explanation of this data pattern might be that older adults may have felt pressure to demonstrate cognitive competency when being interviewed by a younger experimenter and subsequently overestimated the richness of their simulations. However, it is more difficult to explain why older adults might have felt social pressure to rate their prospective simulations as more first person.

When interpreting the data from the projection task, it is also important to consider some important situational differences between younger and older adults. As people age, thoughts about their eventual mortality become more salient and the type of planning that is feasible is different because their perceptions of their futures may be limited due to declining health (Kotter-Grühn & Smith, 2011). Indeed, when asked to imagine a relatively distant future, older adults may have been less likely to engage in effortful mental simulation if thoughts of mortality became salient. Further, as people age, they make fewer future plans in general (Kotter-Grühn & Smith, 2011), which suggests that older adults in the sample may have had less frequent practice at this type of task in their recent history (although it is also safe to assume they would have had more net practice over the course of their lifespan). These differences in the situational cognitive demands of older and younger adults may have contributed to the age differences we observed in projection beyond any changes associated with deterioration of the self-projection network.

We also found that the negative influence of aging is greater when participants try to retrieve memories or imagine future events that are more temporally distant from the

present moment. Using a similar methodology, D'Argembeau & Van Der Linden (2004) found that remote memories were less likely to contain sensory details and were less likely to be accompanied by a strong feeling of re-experiencing. One potential explanation for this pattern of results is that more temporally distant memories require more effortful mental simulation as participants attempt to recall details from more remote time periods- consequently they may be more likely to rely on semantic knowledge in their responses. However, it is also possible that thinking about temporally distant events leads participants to adopt holistic processing strategies that may deemphasize detail oriented sensory processing. This change in processing strategy has been documented in younger participants (e.g. Wyer, Perfect & Paul, 2010), but future research may want to examine whether older adults are particularly prone to this strategy change.

Theory of Mind

In contrast with some past literature (Happé, Winner, & Brownell, 1998), we observed effects of aging on ToM. In the ToM task, we found significant decreases on ToM task performance associated with age for all types of ToM, replicating the pattern observed by Duval et al. (2011). Wang & Su (2013) observed similar performance on cognitive and affective ToM for younger adults, but significantly impaired performance of cognitive ToM tasks compared with affective tasks in older adults. Unlike the results of Wang & Su, age did not interact with type of ToM task in our study. The negative influence of aging on performance in the ToM task extended to the control portion of the task, suggesting that age related cognitive changes beyond those associated with self projection may have influenced performance on the task. Consequently, the data from the ToM task should be interpreted cautiously. Although our sample size was comparable to that collected by Wang & Su (2013), given that the pattern of

performance across ToM measures was consistent with the pattern observed by Wang & Su, it is possible that with increased power we may have replicated the age dependent differences between cognitive and affective theory of mind. Future research should continue to investigate the potential differences of cognitive and affective ToM, particularly as they relate to aging.

While ToM clearly shares important similarities with episodic memory and prospection, it is also true that ToM differs from these other constructs in important ways. Studies of amnesic patients have found that despite their inability to remember their past or imagine a future, they were still able to perform well on ToM tasks (Rabin et al., 2012; Rosenbaum et al., 2007). While it is true that neuroimaging studies reveal significant overlap between the neural activity associated with engagement in ToM and the areas associated with episodic memory and prospection, it has been demonstrated that when the MTL has suffered significant damage, ToM can rely on other brain areas in order to continue to be able to function successfully. These data suggest ToM may not be as reliant on the MTL in comparison to episodic memory and prospection processes. Although the current data are consistent with the idea that ToM is a part of the self-projection system, these data must be interpreted carefully in light of these challenges.

Implications and Conclusions

The finding that older adults were less able to remember their past, imagine their future, or consider the thoughts and emotions of others in our sample suggests a need for greater sensitivity when interacting with older adults, especially for healthcare professionals. Increased understanding regarding the difficulties that older adults may face with self-projection may ultimately lead to better care for older adults. A deeper understanding of older adults self-projection deficits may also help to explain why older adults are more susceptible to scams (Conrad, Ridings, Iris, Langley, & Wilber, 2010); the inability to engage with self-projection

means they may not be able to easily imagine the perspectives of others, remember past events that could provide context for the scam or imagine how the scam would affect them in the future. Due to the variability of performance on these tasks by older adults, it can be concluded that these effects are not seen in older adults unilaterally and can affect older adults at different ages during development. Older adults may want to consider cognitive testing so they can assess their risk level for scams or other mishaps due to the effects of normal aging.

We found consistent effects of aging for our measures of two distinct measures of episodic memory performance, prospective performance on the episodic interview task, and ToM. We also found that performance on the episodic memory tasks was correlated with performance on the TOM and prospection tasks, but that TOM and prospection were not correlated with each other when chronological age was controlled for. These data are generally consistent with past research examining the subcomponents of the self-projection model (D'Armentau, & Mathy, 2011; Head, Rodrigue, Kennedy, & Raz, 2008; Wang & Su, 2013) in that they demonstrate a link between episodic memory, prospection, and TOM and extend this literature by demonstrating age related changes in cognition across all three subdomains in the same sample. Our data are generally consistent with the model of self-projection proposed by Buckner & Carroll (2007) that ties these measures to the shared use of the MTL. Previous work has suggested that lower volumes of MTL associated with aging may result in poor performance across all self-projection related measures (Preussner, Collins, Preussner, & Evans, 2001). However our findings also help to clarify the types of mental processes that neatly fit within the framework of the self-projection network: consistent with some (Henry et al., 2013), but not all of the literature on examining differences between affective and cognitive ToM (Wang & Su, 2013), the current data suggest that affective ToM may operate somewhat independently from

the other proposed components of the model. Future research should continue to explore the influence of aging on the elements of self-projection.

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Table 1. Demographic characteristics of the older and younger adult samples.

	Age	Education	Digit Span	Verbal Fluency
Older Adults	76.20	15.87	5.32	10.78
Younger Adults	20.30	15.08	7.00	15.17

Figure 1. Total number of events generated for the prospective and episodic tasks during the episodic interview task, across each temporal distance.

Figure 2. Proportion of events recalled/imagined by time period for older and younger participants.

Figure 3. Average rating of participant responses on the theory of mind task (2 = correct answer with explicit mental state terms; 1 = appropriate answer without explicit mental state terms; 0 = incorrect answer) grouped by task type and age.

Figure 4. Correlations between the facets of the combined self-projection measures. The upper section displays the correlations between items. The diagonal displays the distribution of the values. The lower section displays the correlation plots of the items.

Supplementary Materials

Sample Theory of Mind Scenarios:

Affective Theory of Mind

Faux Pas story

Barbara and Karen are good friends. On Barbara's wedding, Karen bought Barbara a crystal vase as a wedding gift. Barbara had a big wedding and there were lots of presents to keep track of. About a year later, Karen went to Barbara's home for dinner. Karen was so happy to see her vase placed on the table by her best friend. Karen accidentally dropped a wine bottle on the crystal vase, and broke it. "I'm really sorry that I broke the vase," Karen said. "Don't worry," said Barbara, "I never liked it anyway. Someone gave it to me as a wedding present." Karen was very sad and cried.

- Test Questions: Did anyone say something they shouldn't have said in the story? Who said something they should not have said in the story? Why shouldn't the individual in the story say what they did? Why do you think they did say it?

White Lies story

Elizabeth likes her aunt very much. One day, her aunt wore a new hat to dinner with Elizabeth. Elizabeth doesn't think the new hat fits well and does not look good on her aunt. At dinner, her aunt asks Elizabeth, "I bought this new hat from Nordstrom's. Do you think it looks good on me?" Elizabeth says, "It's pretty."

- Test Question: Why did Elizabeth say "It's pretty"?

Affective Irony story

On a rainy Sunday afternoon, Jimmy's father drove him to his basketball game at the YMCA and promised to pick him up at 6:00 PM, after the game had ended. Jimmy's father became so busy at work that he lost track of time. By the time he remembered that he needed to pick up Jimmy, it was already 7:00 PM! when Jimmy's father arrived at the YMCA, Jimmy was scared from being alone and cold from waiting in the rain. When they arrived home, Jimmy cried and told his mother what happened. His mother said to his father, "You are such a good father!"

- Test question: Does Jimmy's mom think that her husband is a good father? Why does she say that?

Cognitive Theory of Mind

Bluff Story

Christopher is a naughty boy who always lies. One day, Christopher took grandma's camera and went to play with his friends, Doug and Peter. The next morning, Grandma was getting ready to go on a scenic hike with friends when she could not find her camera! Grandpa told Grandma that Christopher might have lent the camera to one of his friends. Grandma anxiously asked Christopher, "Please tell me, did you lend my camera to Doug or Peter?" Christopher said he lent it to Peter. However Grandma directly went to Doug's home to fetch her camera.

- Test Question: Why did Grandma go to Doug's home to fetch her camera?

First Order or Second Order story

Jeremy is eating out at a restaurant. Inside the restaurant, Jeremy hangs his coat on the stand by the door, and leaves his bag underneath. The waitress shows Jeremy to his table and tells him about today's specials dishes. When she comes back, the waitress notices Jeremy's bag beneath the coat stand by the door. She decides that it is unsafe for the bag to stay there, as it would be easy for someone to steal. Leaving the coat on the coat stand, she locks the bag in the store cupboard.

· Test Questions: Where does Jeremy think the bag is? If the waitress had not noticed the bag, where would the bag be?

Cognitive Irony Story

Mr. Smith and Mr. Johnson are good friends. One day, Mr. Smith went to Mr. Johnson's office. Mr. Johnson enthusiastically said, "Have a seat!" But, Mr. Smith could not find anywhere to sit because all of the chairs were filled with papers. Piles of disorganized documents and mail were scattered around the room. Mr. Smith said with a smile, "Your office is so tidy!"

· Test Questions: Did Mr. Smith think the office was tidy? Why did Mr. Smith say that?

Control Story

A thief was trying to break into a jewelry shop. If he triggered any of the scanning beams, all of the alarms in the jewelry shop would sound. The thief skillfully unlocked the door. He carefully crept along the floor and bypassed the scanning beam. Finally, the thief opened the safe with the jewels shining inside. While he reached in the safe to grab the jewels, the thief felt something soft on his feet. Something furry ran along his side toward the door. Then, all the alarms sounded.

· Test question: Why did the alarms sound?