Trends and Issues
June 2018

TIAA Institute

Effects of positive memory retrieval on intertemporal choice in older adults
First year report

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Overview

As older Americans enter retirement, they will face numerous financial decisions that involve a trade-off between a smaller payout that could be received immediately versus a larger total expected payout in the future. In intertemporal choices[1] such as these, individuals tend to prefer immediate payouts to those received after a delay, even when the delayed payout is much larger. This tendency is known as temporal discounting. While most individuals exhibit some degree of temporal discounting, the rate at which people discount future rewards varies widely among individuals, and may depend on context[2,3]. Beyond its direct relevance to financial decisions, steep temporal discounting (i.e., overvaluing the present and undervaluing the future) is also associated with smoking[4,5], alcohol use[6], obesity[7,8], gambling[9], drug addiction[10], and other risky behaviors, such as excessive credit card borrowing[11] and texting while driving[12]. Steep discounting can therefore have a substantial negative impact on older Americans' well-being. Thus, it is critical to understand the factors that influence intertemporal choices in older adults, especially as the population ages[13].

Although adults generally make more far-sighted choices than children and adolescents[14,15], the evidence in older adults is conflicting and inconclusive. Some studies have shown decreased temporal discounting[16], others increased temporal discounting[17], and yet others no differences between older and younger adults[18,19]. This inconsistency may emerge from variability in the age-related decline of neural regions associated with decision making[20–23]. Reduced neural activity in the ventromedial prefrontal cortex (vmPFC) and ventral striatum (VS) is associated with less optimal decision making in older adults[20], and variability in VS activity during a financial investment task has been linked to increased likelihood of suboptimal decisions in this group[22]. Furthermore, the extent of cognitive decline in older adults is associated with

This research was supported by the TIAA Institute and the Pension Research Council.

impatience[24]. However, the specific cognitive processes that decline in older adults, leading to steeper discounting, have not been elucidated.

Episodic memory abilities generally decline with age[25,26] and have been associated with more patient decision making[27]. Episodic memory relies on an intact medial temporal lobe (MTL). Damage to this region impairs both retrieval of past memories and the ability to imagine possible future events[28]. Imagining positive future events, and retrieving positive autobiographical memories has been shown to decrease temporal discounting in young adults[27,29–32]. There is also unpublished evidence from our lab from a large sample of younger adults showing that reduced white matter (WM) and gray matter (GM) volume in temporal lobe are associated with steeper discounting. This previous work suggests that the MTL is important for intertemporal choice, but it did not examine the role of specific temporal lobe subregions, nor did it focus on older adults, who show more variability in both WM and GM volume in this region[33,34].

In this project, we take advantage of a unique resource at the Penn Memory Center, a large cohort of older adults who are well characterized both cognitively and neurologically, to examine the relationship between episodic memory abilities and financial decision making in older adults. Over the two years of this project, we are testing whether decline in episodic memory abilities and structural changes in the MTL system that mediates episodic memory are associated with steeper discounting during healthy aging (data collection is ongoing). In addition, in the first year of this project, we tested whether a simple psychological manipulation—retrieving positive autobiographical memories—can reduce discounting in older adults and potentially compensate for age-related decline.

Here we report the findings of the first year. We did not find a significant effect of positive memory retrieval on temporal discounting in cognitively normal older adults, unlike previous results in younger adults. This finding may suggest that episodic memory decline in older adults could limit the utility of episodic memory-based interventions to change choice. Interestingly, individual differences in perspective-taking ability moderated the effect of positive memory recall on choice, with individuals who reported being more willing to take the perspective of others making more patient choices after recalling positive memories. This result, though preliminary and exploratory, suggests possible future research directions examining perspective-taking-based influences on intertemporal choices in older adults.

First year: Effects of positive memory retrieval on temporal discounting in older adults

One way to examine the role of episodic memory in intertemporal choices is to manipulate episodic memory prior to choice. In a previous experiment[35], young adult participants (n = 35; ages 18-30) completed an intertemporal choice task under two conditions. In one condition, they were asked to recall positive autobiographical memories and rate them prior to making a series of choices (Memory condition). In the other, they were asked to relax and answer questions about their current state prior to making a series of choices (Control condition). They showed significantly lower discount rates in the Memory condition compared to the Control condition ($t_{34} = 2.81$; $p = 0.008$; Cohen's $d = 0.48$). In a follow-up experiment with negative memories, instead of positive memories, there were no significant differences in discount rate between conditions ($t_{33} = -0.36$; $p > 0.25$), showing that positive affect is important for the manipulation to be effective. In a third experiment, individuals were more impulsive after imagining novel positive scenes unrelated to their memories ($t_{28} = -2.83$; $p = 0.009$; Cohen's $d = 0.52$), demonstrating that positive affect alone does not underlie this effect. In a neuroimaging version of the positive memory experiment, activity in the right temporo-parietal junction (rTPJ) and the ventral striatum (VS) predicted whether participants became more patient after recalling their positive memories. This suggests that the precise neural mechanisms by which memory retrieval alters choice may involve the reward processing system of the brain (including VS) as well as regions involved in perspective taking (such as rTPJ).

Here we conducted a similar experiment in older adults to see if the effect of positive autobiographical memory retrieval replicates in an older population. We expected that the results could go in one of two ways. One possibility was that episodic memory retrieval would compensate for age-related decline in this population, leading to more patient intertemporal choice. If this were the case, then this manipulation would hold promise as an intervention for promoting patient financial decision making in older adults. Given the episodic memory decline in this population, however, it was also possible that the manipulation would not have an effect at all. A previous study found that episodic future thinking (which also relies on the episodic memory system) prior to intertemporal choice was not effective in changing choice in older adults[36]. There were individual differences in the size of this effect, however, which were accounted for by differences in cognitive decline. In the case of a null effect, we decided to conduct a series of correlations to see if any individual difference measures could predict the effect size of this manipulation.

Methods

Participants

Thirty-eight participants (ages 65-90; mean age = 74; SD = 6.9; 24 F, 14 M; 31 White, 6 Black, 1 Asian) completed this experiment. These participants had undergone the National Alzheimer's Coordinating Center's Uniform Data Set battery (https://www.alz.washington.edu/WEB/data_descript.html), and had been discussed at the Penn Memory Center consensus conference to ensure they were cognitively normal. Three were excluded from the final sample because their discount rates could not be estimated in one or both experimental conditions. Of these three, two chose all delayed rewards, and one chose all immediate rewards. Thus, thirty-five participants were included in final analyses.

Procedure

Participants completed a two-day study. On Day 1, they described positive memories prompted by each of 12 life event cues (e.g., "being in a wedding," "winning an award"). The cues were a compilation of cues from prior studies[37,38] and were designed to probe for positive memories. For each cue, participants selected a memory in which they had been personally involved and that had occurred at a specific place and time. For each memory, participants had four minutes to provide a brief verbal description, and their response was audio recorded for later scoring with the Autobiographical Interview Protocol[39]. They were prompted when there was one minute left. Each memory cue was allotted four minutes, even if participants did not speak through the whole four minutes. An interviewer was present throughout this task in order to prompt the participant for more detail if necessary. After each memory description, they provided the location and date of the memory. Then, they gave subjective ratings for valence (1 = neutral; 2 = positive), emotional intensity (1-4: 1 = not intense; 4 = very intense), feeling now (i.e., how they felt when recalling the memory; 1-4: 1 = neutral; 4 = very good), feeling at the time of the memory (1-4: 1 = neutral; 4 = very good), personal importance of the memory (1-4: 1 = not important; 4 = extremely important), similarity between current self and self in the memory (1-4: 1 = very different; 4 = exactly the same) and vividness (1-4: 1 = not vivid; 4 = very vivid). Participants were instructed to select memories that were positive but not negative. If they could not think of a specific memory for a cue, or if the cue was only associated with negative memories, they could skip the cue and receive another. There were 30 possible cues, but the experiment terminated after twelve memories had been described.

In preparation for the second session, nine of each participant's positive memories were selected. These nine had been rated as positive (i.e., valence = 2), and had the highest combined intensity and feeling ratings. They were summarized in subject-specific event cues that the participants reviewed at the beginning of the second session, to ensure that they could bring to mind the memory associated with each cue.

Participants returned for the second session about one week later to perform an intertemporal choice task. On each trial of this task, they were presented with a screen showing two options: "$10 today" and a monetary reward of larger magnitude available after a delay (e.g., "$20 in 30 days"; amounts varied from $11 to $40; delays from 4 days to 180 days. All delayed reward amounts were paired with all delays). They made a button press, indicating which option they preferred. The order of the trials was randomized, and the immediate and delayed reward options switched sides of the screen randomly. After participants responded, they were shown the option they had just chosen for 1 second. After a 2-second inter-trial interval, the next choice screen appeared. There were 54 distinct trial types, shown once in each condition, for a total of 108 trials.

Participants made these choices in blocks ("Memory" and "Control" blocks). In Memory blocks, participants re-accessed the nine positive memories triggered by cues from their questionnaire on Day 1 before making choices. At the beginning of each memory trial, a fixation point appeared for 3 seconds. Then, a memory cue was displayed for 20 seconds. Participants were asked to recall the memory described by this cue and to elaborate on it for as long as they could or until 20 seconds expired. After a 3 s inter-stimulus interval, participants rated the memory on valence, emotional intensity, and feeling (allotted 4 s for each). Following this, participants made six intertemporal choices before the next memory cue appeared on the screen. The first memory block consisted of 5 memories and 30 intertemporal choices, and the second memory block consisted of 4 memories and 24 intertemporal choices (Fig. 1).

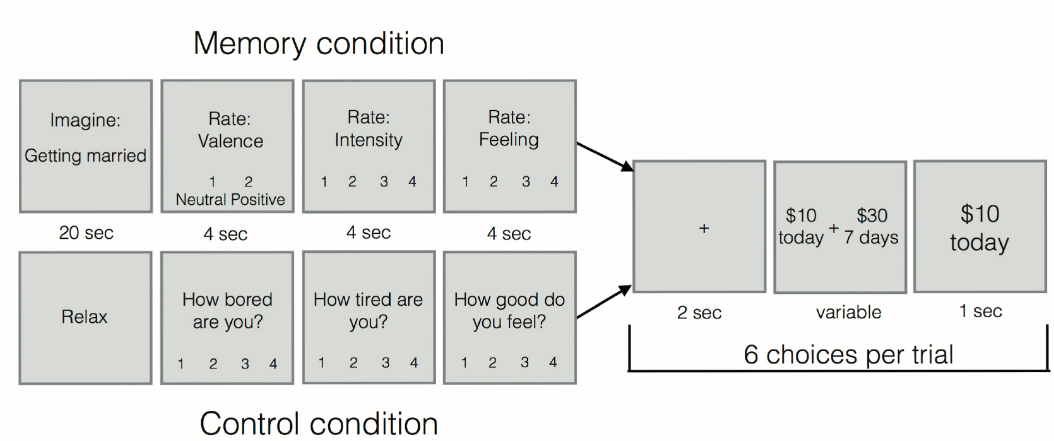
In Control blocks, participants first saw the word "relax" on the screen for 20 seconds. They were instructed to rest during this time. Then, they rated how tired they were (1-4; 1 = very awake; 4 = very tired), how bored they were (1-4; 1 = not bored; 4 = very bored), and how good they felt (1-4; 1 = neither good nor bad; 4 = very good; 4 seconds for each rating). Following this, they made six intertemporal choices before the next "relax" screen appeared. The first Control block consisted of 5 "relax" screens and 30 intertemporal choices, and the second Control block consisted of 4 "relax" screens and 24 intertemporal choices. There were two Control blocks and two Memory blocks, and the order was counterbalanced across subjects. The same choices were presented in both conditions.

Participants were told at the outset of the Day 2 session that one of the intertemporal choice trials would be randomly selected and they would receive the amount they chose on that trial, at the delay specified. They were paid via a prepaid debit card (Greenphire Clincard system). If they chose the immediate reward on that trial, they would receive the money on their card that day. If they chose the delayed reward, they would receive the money after the delay had elapsed. This task was programmed using E-Prime 2.0 Stimulus Presentation Software (Psychology Software Tools).

After the decision-making task was completed, participants filled out four questionnaires on a computer: the Interpersonal Reactivity Index (IRI[40]), the Life Orientation Test-Revised (LOT-R[41]), the Geriatric Depression Scale (GDS[42]), and the Vividness of Visual Imagery questionnaire (VVIQ[43]). The IRI assesses perspective taking and empathy abilities, abilities that have recently been shown to be associated with temporal discounting[44]. The four subscales of the IRI (Perspective Taking, Empathic Concern, Personal Distress, and Fantasy) were separately assessed. The LOT-R tests for optimism, which tends to be elevated in older adults[45], and may be related to future-oriented decision making. The GDS was included because symptoms of depression are associated with deficits in positive memory recall[46]. Finally, the VVIQ instructs participants to imagine different scenarios in order to measure individual differences in self-reported imagery vividness. VVIQ scores have been shown to be correlated with temporal discounting[47]. We examined correlations between scores on these questionnaires and age, as well as with the size of the effect in our study. Outliers (scores that were more than 2.5 SD from the mean) were removed.

In addition, we had access to episodic memory measures from the neuropsychological battery that was completed by all participants within a year of their participation in this study. We selected the Craft Story Recall (immediate recall) measure, because this measure shows significant individual variability even within a cognitively normal sample. In this test, participants are read a short story and asked to recall it immediately, as well as 15 minutes later. The score is the tally of the number of story elements correctly recalled by the participant. We explored whether individual differences in effect size in this study might be related to episodic memory ability.

Figure 1. Task layout



Each trial contained six intertemporal choices. Each memory trial began with a memory cue, describing an autobiographical memory specific to the participant. The participant was asked to think about that positive memory for 20 seconds. Then they rated the valence (1 = neutral; 2 = positive), intensity (1-4; 1 = not intense; 4 = very intense) and feeling (1-4; 1 = neutral; 4 = very good) of the memory. Finally, they made six choices between $10 today and a larger amount of money in the future. The participant made a button press while the options were on the screen, and then was shown what they chose for 1 second before the next trial began. In the Control trials, participants were told to "relax" for 20 seconds and then to answer questions about how bored and tired they were and how good they felt (1-4 scale for each). They then made the same intertemporal choices in this condition.

Analyses

Participants' individual intertemporal choice data were fit separately for choices in the Memory blocks and Control blocks with the following logistic function using maximum likelihood estimation:

$$P_1 = \frac{1}{1+e^{-\beta(SV1-SV2)}}, \; P_2 = 1 - P_1$$

Here P_1 and P_2 refer to the probability of choosing the delayed and immediate options, respectively, $SV1$ and $SV2$ are the subjective values of the delayed and immediate options, respectively, and β is the fit slope of the logistic function. The subjective value of the options was estimated using a hyperbolic model[48,49]:

$$SV = \frac{A}{(1 + kD)}$$

Where SV is the subjective value, A is the amount, D is the delay to receiving the reward, and k is the parameter that represents the participant's discount rate (higher k values correspond to more impatience). The discount rate parameters were log-transformed before statistical analyses were performed, since they are non-normally distributed. We conducted a two-tailed paired t-test to compare discount rates between conditions for each participant.

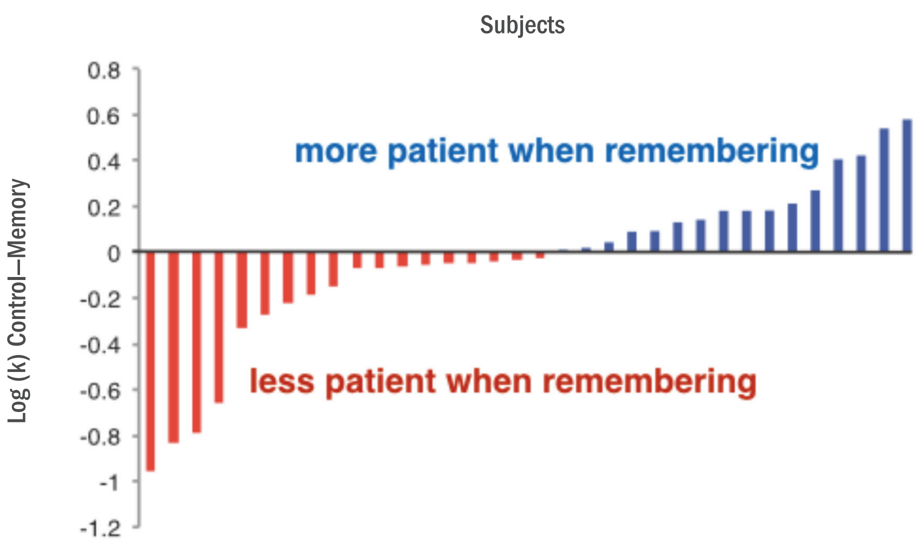
Results

Participants (N = 35; 24 F; mean age = 74; SD = 6.9) made a series of intertemporal choices either after retrieving positive autobiographical memories for 20 seconds (Memory blocks) or after relaxing for the same amount of time (Control blocks). The positive memory manipulation had no significant effect on temporal discounting (t_{34} = -0.65; p = 0.74; Fig. 2).

We conducted post-hoc analyses to examine if individual differences related to the size of the effect. Our six variables of interest were age, episodic memory ability (as measured by the Craft Story Recall measure), all four subscales of the IRI (perspective taking, empathic concern, fantasy, and personal distress), LOT-R optimism score, GDS depression score, and VVIQ visual imagery score (see Table 1 for all pairwise correlations).

Of note, scores on the IRI-perspective-taking scale (example item: "I sometimes try to understand my friends better by imagining how things look from their perspective") were significantly positively correlated with the difference in discount rate between the Control and Memory conditions ($N = 34$; $r = 0.57$; $p < 0.001$), suggesting that people who are more inclined toward perspective taking are more likely to show reduced discounting following positive memory recall (Fig. 3). Optimism scores (LOT-R) and depression scores (GDS) were also significantly correlated with the size of the effect, in that people with higher optimism ($N = 34$; $r = 0.42$; $p = 0.01$) and less self-reported depression ($N = 34$; $r = -0.43l$; $p = 0.01$) were more likely to show a shift toward more patient choice after the manipulation. Perspective-taking was also correlated with optimism ($N = 34$; $r = 0.51$; $p = 0.002$) and depression ($N = 33$; $r = -0.39$; $p = 0.03$), inviting the question of which of these individual difference variables was driving the effect. When entering perspective taking, optimism, and depression in the same regression model predicting the difference in discount rate between conditions, only perspective taking remained significant ($\beta = 0.045$; $p = 0.002$; depression $\beta = -0.045$; $p = 0.18$; optimism $\beta = -0.001$; $p = 0.93$; R^2 for full model = 0.46; $p = 0.0005$). Notably, episodic memory recall ability was not significantly related to the size of the behavioral effect ($N = 35$; $r = 0.07$; $p = 0.70$).

Figure 2. Positive memory retrieval does not significantly affect choice in older adults



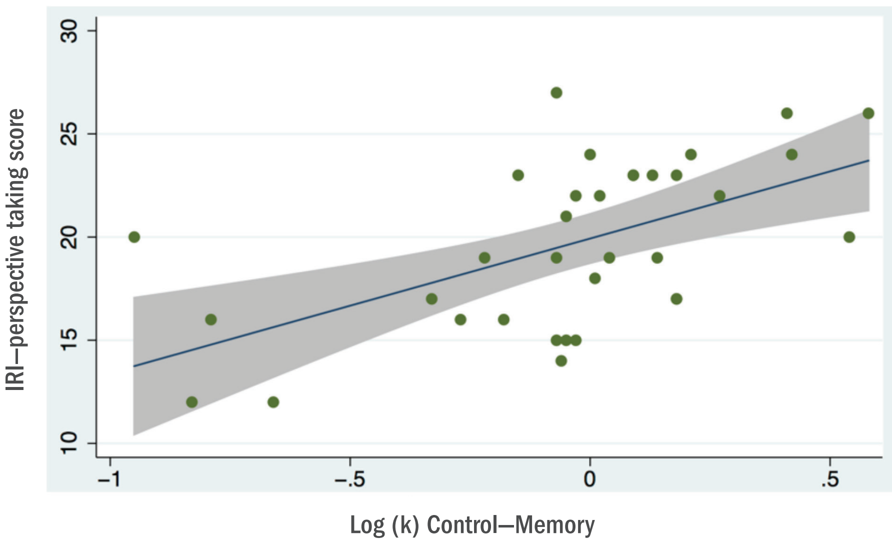
The difference in log-transformed discount rate between the control and memory condition is plotted for each subject. Positive difference (blue) indicates more patience in positive memory condition. Negative difference (red) indicates more impulsivity in positive memory condition. ($t_{34} = -0.65$; $p = 0.74$; $N = 34$; $N = 1$ not shown because difference in discount rate was equal to 0).

Table 1. Correlations among individual difference variables

Age	Memory (Story recall)	IRI—perspective taking	IRI—empathic concern	IRI—fantasy	IRI—personal distress	LOT-R	GDS	VVIQ	
r=0.09 p=0.62 N=35	r=0.07 p=0.70 N=35	r=0.57*** p=0.0005 N=34	r=0.28 p=0.10 N=34	r=-0.03 p=0.86 N=35	r=-0.20 p=0.26 N=35	r=0.42* p=0.01 N=35	r=-0.43* p=0.01 N=34	r=0.05 p=0.79 N=34	Log (k) Control-Memory
	r=-0.36* p=0.03 N=35	r=-0.08 p=0.66 N=34	r=-0.31 p=0.07 N=34	r=-0.28 p=0.10 N=35	r=-0.04 p=0.82 N=35	r=0.02 p=0.91 N=35	r=0.20 p=0.25 N=34	r=-0.64*** p< 0.0001 N=34	Age
		r=0.19 p=0.28 N=34	r=0.21 p=0.25 N=34	r=0.38* p=0.03 N=35	r=-0.25 p=0.14 N=35	r=0.32 p=0.06 N=35	r=-0.01 p=0.95 N=34	r=0.43* p=0.01 N=34	Memory (story recall)
			r=0.31 p=0.07 N=34	r=0.11 p=0.54 N=34	r=-0.40* p=0.02 N=34	r=0.51** p=0.002 N=34	r=-0.39* p=0.03 N=33	r=0.13 p=0.47 N=33	IRI-perspective taking
				r=0.22 p=0.21 N=34	r=-0.09 p=0.63 N=34	r=0.05 p=0.76 N=34	r=0.34 p=0.05 N=33	r=0.59*** p=0.0003 N=33	IRI-empathic concern
					r=0.05 p=0.79 N=35	r=0.05 p=0.80 N=35	r=-0.03 p=0.86 N=34	r=0.36* p=0.04 N=34	IRI—fantasy
						r=-0.45** p=0.007 N=35	r=0.09 p=0.57 N=34	r=-0.08 p=0.67 N=34	IRI—personal distress
							r=-0.50** p=0.003 N=34	r=-0.03 p=0.89 N=34	LOT-R
								r=-0.09 p=0.63 N=33	GDS
									VVIQ

*p < 0.05; **p<0.01; ***p<0.001. Outliers removed for IRI-perspective taking and IRI-empathic concern (N = 1), GDS (N = 1), and VVIQ (N = 1).

Figure 3. Self-reported perspective taking is correlated with the difference in discount rate between Control and Memory conditions



Older adults who report a greater propensity to take the perspective of others are more likely to become more patient following positive autobiographical memory retrieval (N = 34; $r = 0.57$; $p < 0.001$).

Summary and discussion

Our project focuses on the connection between episodic memory and intertemporal decision making in cognitively normal older adults. Our investigation of behavioral and neural correlates of episodic memory and how they relate to temporal discounting is ongoing. In this first year, we attempted to manipulate the episodic memory system in older adults, using a positive memory retrieval manipulation previously shown to reduce temporal discounting in young adults. We found that this manipulation had no significant effect on choice in this population, but that individual differences in perspective-taking ability correlated with the size of the effect.

Our results are consistent with previous research showing that episodic memory-based manipulations of intertemporal choice are not effective in older adults[36]. This suggests that efforts to intervene in choice behavior in healthy aging should be focused on manipulations of other neural systems. This null result does not contradict our overall thesis that episodic memory is related to temporal discounting. In fact, older adults with better episodic memory ability may already have low discount rates, and may therefore be less likely to benefit from such an intervention.

At first glance, our finding that perspective-taking ability relates to the extent to which positive memory recall promotes patient choice seems unexpected. How does a self-report questionnaire that mostly captures taking the perspective of other people relate to intertemporal choice? One possibility is that people who engage in perspective taking in social settings are also more inclined to take the perspective of their future self or their past self when making decisions. This may increase their feeling of self-continuity[50,51], which would, in turn, decrease their discount rate. Some evidence for this idea comes from recent work showing that the temporo-parietal junction (TPJ), an area typically associated with perspective taking of social others, plays a causal role in patient decision making[44]. Moreover, the original study of positive memory recall in young adults[35] showed that it was actually neural activity in the TPJ that predicted whether positive memory recall reduced discounting. It could be that older adults who engaged in perspective taking of their past selves while recalling positive memories were the ones who made more patient intertemporal choices. This is an open research question. We plan to run additional studies to see if explicitly encouraging perspective taking of the past self in the context of memory retrieval will be more likely to lead to more patient intertemporal choice.

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Dr. Wolk completed his medical training at Johns Hopkins University, a Neurology residency at the University of Pennsylvania, and clinical Fellowship training in Cognitive and Behavioral Neurology at Brigham and Women's Hospital/Harvard Medical School; where he also completed a post-doctoral research fellowship studying memory in Alzheimer's Disease. Amongst a number of honors, he is the recipient of the American Academy of Neurology's Norman Geschwind Prize in Behavioral Neurology.