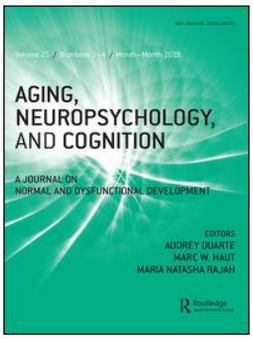

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ARTICLE

The effect of cognitive testing and feedback on older adults' subjective age

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ABSTRACT

Subjective age, or how old a person feels, is an important measure of self-perception that is associated with consequential cognitive and health outcomes. Recent research suggests that subjective age is affected by certain situations, including cognitive testing contexts. The current study examined whether cognitive testing and positive performance feedback affect subjective age and subsequent cognitive performance. Older adults took a series of neuropsychological and cognitive tests and subjective age was measured at various time points. Participants also either received positive or no feedback on an initial cognitive task, an analogies task. Results showed that participants felt older over the course of the testing session, particularly after taking a working memory test, relative to baseline. Positive feedback did not significantly mitigate this subjective aging effect. Results suggest that subjective age is malleable and that it can be affected by standard cognitive and neuropsychological test conditions.

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KEYWORDS
Memory; cognitive testing; subjective age; feedback; self-perception

The effect of cognitive testing and feedback on subjective age

When people think about aging, they often think about chronological age, but the number of years an individual has been alive is not a complete indication of how they are aging (Staudinger, 2015). Research shows that subjective age—the age one feels—is associated with important health outcomes for older adults, with benefits being linked to younger subjective ages (Infurna, Gerstorf, Robertson, Berg, & Zarit, 2010; Kotter-Grühn, Kleinspehn-Ammerlahn, Gerstorf, & Smith, 2009). Adults typically begin reporting subjective ages younger than their chronological ages starting at about 25 years of age, and this discrepancy grows until about the age of 40; afterwards, adults report subjective ages that are about 20% younger than their chronological age (Rubin & Berntsen, 2006). Since subjective age lags behind chronological age, it may sometimes take unexpected events or difficulties associated with being older to notably increase subjective age in the latter half of the life span (Settersten & Hagestad, 2015). Subjective age is often assessed using a single question; participants are sometimes asked if they feel younger, older, or the same as their chronological age (Infurna et al., 2010; Markides &

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Pappas, 1982), or they are asked how old they feel in years (Stephan, Caudroit, & Chalabaev, 2011; Stephan, Sutin, Caudroit, & Terracciano, 2015).

Although most older adults already report subjective ages that are younger than their chronological ages (Rubin & Berntsen, 2006), a relatively younger subjective age is associated with a number of desirable outcomes in old age. Older adults who report younger subjective ages relative to their peers use more beneficial coping strategies (Boehmer, 2007) and have better mental and physical functioning (Barak & Stern, 1986; Barrett, 2003; Kotter-Grühn et al., 2009; Stephan, Chalabaev, Kotter-Grühn, & Jaconelli, 2013) than those who report relatively older subjective ages. For people with negative attitudes toward aging, having a younger subjective age is associated with higher levels of well-being (Mock & Eibach, 2011). Further, studies show that people who feel subjectively younger have a reduced risk of mortality over the course of several years (Kotter-Grühn et al., 2009; Levy & Myers, 2005; Levy, Slade, Kunkel, & Kasl, 2002; Maier & Smith, 1999; Markides & Pappas, 1982; Uotinen, Rantanen, & Suutama, 2005) and fewer major depressive episodes compared to older adults who report higher subjective ages (Keyes & Westerhof, 2012). A meta-analysis of 19 longitudinal studies supports these general trends, showing that a younger subjective age is associated with positive health outcomes and longevity (Westerhof et al., 2014).

Subjective age is also a significant predictor of cognitive ability for older adults, with younger subjective ages being predictive of better cognitive functioning (Kotter-Grühn et al., 2009; but see Kerr & Castel, 2016). For example, older adults who report feeling relatively young show superior long-term memory performance and executive functioning 10 years later compared to older adults who report feeling relatively old (Stephan, Caudroit, Jaconelli, & Terracciano, 2014). Even after controlling for chronological age, diseases, and levels of physical activity, subjective age remained a significant predictor of memory performance and executive functioning in older adults (Stephan et al., 2014). Younger subjective ages are also linked to superior immediate and delayed recall and superior memory performance 4 years later, even after accounting for demographic and health variables (Stephan et al., 2015).

Given the associations between subjective age and later cognitive ability, health, and well-being, there is growing interest in determining whether subjective age is malleable. Recent experimental studies suggest that subjective age is affected by a variety of situations. For example, older adults who were exposed to negative aging stereotypes reported a younger subjective age compared to those not exposed to negative stereotypes, as if to distance themselves from this demographic (Kotter-Grühn & Hess, 2012; Weiss & Lang, 2012). Conversely, older adults who were presented with positive aging stereotypes reported feeling older, possibly reflecting motivation to affiliate with the older age-group (Kotter-Grühn & Hess, 2012). Subjective age has also been found to fluctuate from day to day due to daily changes in health, stress, and affect—older adults report higher subjective ages on days where they experience more health problems, stress, and negative affect compared to less difficult days (Kotter-Grühn, Neupert, & Stephan, 2015).

Certain testing conditions may also highlight an older adult identity and lead to increased subjective age. For example, when older adults were shown small and blurry text to read without any explanation for their reading difficulties, they reported feeling older than those who read the same text but were told that there was a printing

problem (Eibach, Mock, & Courtney, 2010). The authors suggested that when the older adults experienced difficulty reading the small text, they likely attributed their visual disfluency to deteriorating vision due to advanced age. This in turn led participants to feel significantly older than those who had been given an explanation for the visual disfluency, or those who had read clearly printed text. Similarly, there is evidence that simply placing older adults in a memory testing context can make them feel subjectively older, relative to baseline (Hughes, Geraci, & De Forrest, 2013; see also Kerr & Castel, 2016). In the Hughes et al.'s study, participants reported their subjective age before and after taking a memory test. Results showed that older adults' subjective ages increased after taking the memory test, whereas younger adults' subjective age was unaffected by taking a memory test. Also, it appeared that for older adults, simply being in a memory testing context also led them to report feeling older relative to baseline because they felt older after simply being told they would take a memory test. It is possible that being in a memory testing context made participants' older adult status particularly salient, making them feel older than they did at baseline. Given that stressors have been linked to daily fluctuations in subjective age (Kotter-Grühn et al., 2015), it is also possible that being in a memory test or memory testing context was stressful for older adults, which led to the subjective aging effect. Regardless of the exact mechanism or mechanisms of the subjective aging effect, it appears that subjective age can change in response to environmental conditions across a variety of situations.

Although certain contexts can increase older adults' subjective age, there is some evidence that when given positive performance feedback, older adults report feeling younger, relative to baseline (Stephan et al., 2013). After assessing grip strength, participants in the Stephan et al. study were either told that they performed better than 80% of their peers or they were given no performance feedback. Those who had been given positive performance feedback reported feeling significantly younger relative to baseline, whereas subjective age did not change for those in the no feedback condition. Further, when older adults were given an opportunity to perform the grip strength task again, participants in the positive feedback condition performed better on the task than those in the no feedback condition; the positive feedback both decreased subjective age and improved performance. Thus, there is evidence that being placed in certain contexts that highlight one's age identity or induce stress can increase subjective age. In particular, being in a standard memory testing context (Hughes et al., 2013) or a difficult reading context (Eibach et al., 2010) increased subjective age.

Although these studies demonstrate that subjective age can also be influenced by testing conditions, the exact underlying mechanism by which this occurs is unknown. But certainly, the idea that cognitive testing poses a unique stress to older adults is consistent with a stereotype threat interpretation of the effect of testing and testing contexts on subjective age (see Barber, 2017, for review). Research shows that both younger and older adults hold negative stereotypes about older adults' competence and overall cognitive abilities (Chasteen, 2000; Chasteen, Schwarz, & Park, 2002) and believe, in particular, that older adults have poor memory abilities (e.g., Ryan & See, 1993). These beliefs may arise from various sources including from societally based notions, or stereotypes, of older adults. Knowledge and activation of these stereotypes affects older adults' performance on cognitive tests—the stereotype threat effect (e.g., Barber & Mather, 2013; Eich, Murayama, Castel, & Knowlton, 2014; Hess, Auman, Colcombe, &

Rahhal, 2003; Hess & Hinson, 2006; Hess, Hinson, & Hodges, 2009; Hess, Hinson, & Stratham, 2004; Levy, 1996). Moreover, a recent meta-analysis concluded that age-based stereotype threat significantly influences performance in older adults, and that the effect is strongest when the performance measured is in the cognitive domain (Lamont, Swift, & Abrams, 2015). The idea is that the fear of confirming the stereotype (e.g., that older adults are forgetful) leads older adults to perform poorly on tests that index the stereotyped ability (e.g., a memory test). The threat of confirming the stereotype might lead older adults to perform poorly because distracting threat-related thoughts and worries take up much-needed controlled processes or working memory resources (Mazerolle, Regner, Morisset, Rigalleua, & Huguet, 2012; Schmader, Johns, & Forbes, 2008). Or, the threat might affect performance by causing older adults to focus on losses and adopt a more conservative approach to responding, an interpretation that is consistent with a regulatory focus theory (Higgins, 1997) explanation of the effect of stereotype threat on performance (Barber & Mather, 2013; Barber, Mather, & Gatz, 2015). Hughes et al. (2013) suggested that age-related stereotypes are likely activated by testing contexts, such as a memory testing context, because there are cues in the environment that remind older adults of their age identity and the expectation that they are not competent. If cognitive testing activates negative stereotypes and performance expectations, then it is logical to predict that cognitive testing will affect other aspects of older adults' self-perceptions, including their subjective age.

The current study was designed to test this hypothesis. To do so, we examined older adults' subjective age at multiple time points during a standing cognitive testing session. Participants completed a series of cognitive tests including the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975), a reasoning test, a free recall test, and a working memory test. We included the MMSE because it is a standard cognitive test that is often given to older adults at the start of a series of cognitive tests. We expected that because of the nature of the questions included in the MMSE (questions about orientation to time and place, questions about memory, etc.), the use of this measure would highlight older adults' identity. We used the analogies test because this is a challenging task and because we could provide false performance feedback on this task in a way that would be difficult for older adults to verify—unlike a memory test they would not know how many items they got correct. We also included a working memory test (operation span) and a free recall test because age effects are often obtained on these memory tests and because these tests assess abilities that are typically assumed to decline with age. We expected that taking these memory tests would subjectively age older adults. We measured subjective age at baseline and at various time points throughout the testing session. Based on the results of past studies (i.e., Hughes et al., 2013), we hypothesized that subjective age would increase over the course of the testing session, with punctuated increases occurring after memory testing.

We also investigated whether positive performance feedback would offset any observed subjective aging effect. To test this, some participants received fabricated positive feedback upon completion of the initial cognitive test (a reasoning test) while others did not. Similar to the results from Stephan et al. (2013), we predicted that participants who received positive performance feedback (now on a cognitive test instead of a physical test) would show less subjective aging than those who received no feedback. In the current study, participants in the positive feedback condition were

told that they had performed better than the majority of people who completed the task. We hypothesized that receiving positive performance feedback would lead participants to evaluate their cognitive abilities favorably compared to others, which might lead to a younger subjective age. There is evidence that people compare their aging process to their peers, or with previous generations (Staudinger, 2015) and that they use these social comparisons to inform their own subjective age (Hughes & Lachman, 2016). Using data from the Midlife in the Unites States longitudinal sample, Hughes and Lachman found that participants who performed better on measures of episodic memory and compared themselves favorably to their peers reported lower subjective ages than those who made less favorable comparisons. Thus, we expected that positive feedback would mitigate any subjective aging effect caused by cognitive testing. We expected that those in the control condition would report feeling older across the testing session, whereas those in the positive feedback condition would not.

We also predicted the false positive performance feedback might influence subsequent cognitive performance. Previous research has shown that older adults show superior memory performance if they have succeeded at a prior cognitive task (Geraci, Hughes, Miller, & De Forrest, 2016; Geraci & Miller, 2013). In these studies, older adults who successfully completed an initial cognitive test (by design) performed better on a subsequent memory test compared to those who failed at or did not complete a prior test. The hypothesis is that older adults perform better following a successful cognitive task experience because this experience provides direct evidence to counter any negative age-related stereotyped performance expectations. In the current study participants did not necessarily succeed at a prior test, but those in the positive feedback condition were led to believe that they were successful on the initial analogies test regardless of whether or not they actually performed well on the task. There is evidence that in addition to positive performance experience, positive feedback alone leads to subsequent memory benefits among older adults (West, Bagwell, & Dark-Freudeman, 2005; West, Dark-Freudeman, & Bagwell, 2009). Therefore, we predicted that older adults would feel subjectively older throughout the course of the testing session, that feedback would moderate the subjective aging effect such that those who received positive feedback would subjectively age less than those who received no feedback, and that task success may lead to better performance on subsequent cognitive tasks.

Method

Participants

Sixty-six older adults from the community surrounding Texas A&M University participated in this study and received an honorarium for their participation. Six participants were excluded from the analyses because they scored lower than a 27 on the MMSE (Folstein et al., 1975) resulting in 60 participants (ages 65–84, 38 females, 22 males), however degrees of freedom varied slightly on different analyses because one participant was unable to complete several questionnaires due to a scheduling conflict. Participants were on average 69.98 (SD = 4.91) years of age and had on average 17.68 (SD = 2.85) years of education. Participants reported themselves to be in good health (M = 4.37, SD = .61) on a self-rated health measure ranging from 1 ("poor" health) to 5

("excellent" health). There were no significant differences in age, education, or self-reported health for participants in the two feedback conditions.

Design

We used a 2 × 3 mixed design in which feedback condition was manipulated between subjects and time of assessment (baseline/time 1, time 2, and time 3) was manipulated within subjects during a single experimental session. All participants received the same tasks, but to manipulate feedback, half (N = 30) of the participants received positive feedback about their performance on an initial task (the analogies task) whereas the other half (N = 30) received no feedback about their performance. For all participants, we assessed subjective age at three time points: after the demographics questionnaire (baseline/time 1), after feedback on the analogies test (time 2), and after the working memory (OSPAN) test (time 3).

Materials and procedure

After giving consent, participants completed a demographic questionnaire that assessed chronological age, education, ethnicity, and self-reported health. Next, participants were asked to indicate their subjective age (baseline subjective age); in response to the question "How old do you feel at this moment?", participants were asked to draw a tick mark along a line segment that was 120 mm in length The line was labeled "0 years old" and "120 years old" on the left and right ends respectively. Subjective age was determined by measuring the distance between the left end of the line and the participant's tick mark in millimeters (1 mm = 1 year). We assessed subjective age using this scale (rather than asking participants to write down a number) to prevent them from responding to subsequent subjective age questions using previous responses (see Hughes et al., 2013 for a similar method and rationale).

Participants were then given the MMSE. Afterwards, they were given a computerized analogies test. Participants were given instructions and practice problems to ensure that participants understood the task. The analogies exam consisted of 25 multiple choice questions in which participants were asked to select the answer choice (out of 4 possible solutions) that completed each analogy (given "water:pipe", participants should respond by clicking the answer choice "blood:vein").

Upon completion of the analogies task, participants were told that the experimenter was going to check their test results. The experimenter left the room for a few minutes before returning. Participants were then either given no feedback and simply told "your data were entered correctly", or they were given positive feedback and told that "based on your response times and accuracy, you did better than 80% of the participants that have completed this task in our laboratory." This marks the only between-subjects manipulation, with 30 participants in the positive feedback condition and 30 in the no feedback condition.

After receiving positive feedback or no feedback, participants again indicated their subjective age (subjective age time 2) in a similar manner as before. Then, they were given a working memory test, the OSPAN (adapted from Foster et al., 2015). On this test, participants were asked to remember a series of letters while completing math

problems. Participants were first shown a math problem followed by a screen with a number on it and were asked to indicate with a key press whether or not the number was the correct answer to the previous math problem. After responding, participants were presented with a fixation screen for 1 s and then a letter appeared on the screen for 2 s, followed by a screen prompting the participant to press a key to continue. This process was repeated for each of the letters in the target string. After all the letters have been presented, participants were presented with a grid that included 12 possible letters and they verbally indicated which letters, in order, they had seen earlier. Each "span" consisted of one iteration of the previous process, and all participants completed the same 15 fixed spans of variable letter string length (ranging from 3 to 7 letters, in a fixed order with mixed question difficulty over the course of the test). Before beginning the OSPAN, all participants received instructions and practice on the math and letter portions of the test individually and jointly. The OSPAN was scored by giving participants credit only for spans where they recalled all letters in the order they appeared. If a participant did not recall all letters, or recalled them in a different order, they did not receive credit for this block. When a participant received credit for a block, a point value was assigned to that block equal to the number of letters in it. The point values for each credited block were then totaled. Upon completion of the OSPAN, participants indicated their subjective age (subjective age time 3) in the same manner as before.

Participants then took part in a standard free recall test. They studied a list of 30 unrelated words for 2 min, and then took a recall test in which they had 3 min to recall as many words as they could, in any order. Participants were then given several questionnaires. All of the following questionnaires used a 7-point answer scale, but scale measurements varied by question. The first questionnaire served as a check on the false feedback manipulation. Participants were asked to rate how well they thought they performed on the analogies test (ranging from 1: I think I got none of the analogies correct to 7: I think I got all of the analogies correct), and how their performance on the analogies task compared to their expectations of the tasks in the lab (ranging from 1: My performance on the analogies task was much worse than I expected to perform on tasks in the lab, to 7: My performance on the analogies task was much better than I expected to perform on tasks in the lab). To assess whether a subjective aging effect would be associated with anxiety, worry, or negative stereotypes participants experienced during testing, participants were asked to indicate how worried they are about their memory, how anxious they felt about taking a memory test, and how much they believe that age-related memory changes are inevitable, all using scales from 1 to 7.

We also assessed whether subjective age was associated with stereotype threat activation. To do this, we used a lexical decision task that we modeled after the one used by Chasteen, Bhattacharyya, Horhota, Tam, and Hasher (2005), which consisted of 150 letter strings (99 formed words and 51 formed nonwords). Participants had to decide whether each string was a word or a nonword (e.g., skrures). Each string was presented for 2 s or until the participant responded. The 99 words were divided into three categories of 33 words each consisting of positive (wise), negative (frail), or neutral (purple) aging stereotypes. Participants were told to respond as rapidly as possible, and were given instructions and practice before beginning the task. Stereotype activation would be evident on this task if participants were faster to read negative age-related words or slower to read positive age-related words, relative to control. We predicted that

more negative stereotype activation (faster reading times to negative age-related words) would be associated with more subjective aging.

Following the lexical decision task, participants completed four additional questionnaires, the order of which was randomized across participants. To further examine whether stereotype activation or beliefs were associated with a subjective aging effect, we assessed perceived stereotype threat using a questionnaire that was taken from Chasteen et al. (2005). This questionnaire includes five statements about memory ability and age, and participants were asked to indicate their level of agreement with each statement on a 5-point scale (1 = strongly disagree; 5 = strongly agree). The questions include: (1) Some people feel I have less memory ability because of my age. (2) Based on my age, people often underestimate my memory ability. (3) I often feel I have to prove to others that their perceptions of my memory ability are wrong. (4) The experimenter expected me to do poorly because of my age. (5) In memory experiments people of my age often face biased evaluations. Cronbach's alpha for the questionnaire was .687 in our sample. Participants also completed a measure of positive and negative affect schedule (PANAS; Watson, Clark, & Tellegen, 1988). Participants were asked to rate the extent to which they were feeling 20 (10 positive, 10 negative) feelings and emotions (made up of the general dimension scales of the PANAS-X) on a 5-point scale (1 = very slightly or not at all; 5 = extremely). Participants also completed the Morningness-Eveningness Questionnaire, which established their time of day preference (Horne & Ostberg, 1976), and the Memory Self-Efficacy Questionnaire, which assessed their everyday memory performance (Berry, West, & Dennehy, 1989). To anticipate, we did not find any time-of-day effects on any measures and so we do not discuss this questionnaire further.

Results

Significance for all analyses set α = .05. Table 1 shows the means and standard deviations for chronological and subjective age for each condition and time point.

The effect of testing and feedback on subjective age

As a manipulation check, we first examined whether feedback influenced participants' beliefs about how well they had performed on the analogies task. Participants were asked to indicate how well they thought they performed relative to their expectations. Participants in the positive feedback condition indicated they believed they performed

Table 1. Mean chronological age and subjective age across each time point by condition.

	Condition	
	Feedback	No feedback
Age measure		
Chronological age	69.76 (4.48)	70.30 (5.36)
Subjective age (time 1)	51.40 (11.00)	50.70 (12.45)
Subjective age (time 2)	50.23 (11.38)	51.77 (11.47)
Subjective age (time 3)	53.67 (11.19)	54.27 (12.03)

Standard deviations are in parentheses.

better than expected on the analogies task compared to participants in the no feedback condition, $t(57) = 2.64$, $p = .011$ (feedback $M = 4.17$, $SD = 1.21$; no feedback $M = 3.38$, $SD = 1.08$). Participants were also asked to indicate how well they thought they had performed. There was no difference in how well participants in either condition believed they performed, $t(57) < 1.00$, $p = .964$ (feedback $M = 4.63$, $SD = 0.76$; no feedback $M = 4.62$, $SD = 1.29$). Taken together, responses to these two questions provide some evidence that participants believed the feedback, but only when making a judgment relative to expectations and not when making an absolute post-diction about performance.

Next, we examined our central question regarding whether there was an effect of testing and feedback on change in subjective age. For these analyses, we used subjective age discrepancy scores (calculated by subtracting chronological age from subjective age) for each measurement point. Positive scores indicate that people feel older than their chronological age and negative scores indicate that they feel younger than their chronological age. A 2 (feedback condition) by 3 (testing time) Mixed ANOVA showed that there was no interaction between condition and time of subjective age measurement, $F < 1$. There was no effect of condition on subjective age discrepancy, $F < 1$. However, there was a main effect of testing on subjective age discrepancy scores, $F(2, 116) = 4.61$, $p = .012$, $\eta^2 = .074$, showing that scores became more positive (participants felt older) in a linear fashion from times 1 to 3, $F(1, 58) = 5.10$, $p = .028$ (see Figure 1). We note that the main effect of testing on subjective age discrepancy is present when baseline subjective age is used as a covariate ($F(2, 114) = 10.68$, $p < .001$, $\eta^2 = .158$).

The effect of feedback on performance

We also examined whether there was an effect of feedback on performance on the OSPAN or the free recall test (see Table 2). An independent *t*-test revealed that there were no significant differences in performance between the positive and no feedback

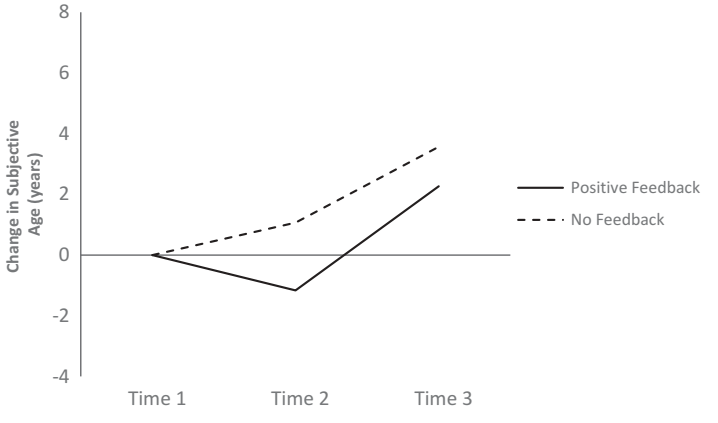

Figure 1. Change in subjective age relative to baseline for both conditions.
Positive changes in subjective age indicate participants felt older. Differences between conditions were not significant.

Table 2. Average performance on memory measures by condition.

	Positive feedback	No feedback
Total letters recalled on OSPAN	21.14 (19.43)	21.40 (18.65)
Free recall	8.67 (3.35)	8.17 (3.77)

Standard deviations are in parentheses.

conditions on total number of letters correctly remembered for the OSPAN or on number of words recalled on the free recall test, p's > .450.

Additionally, we investigated whether feedback influenced reports of worry or anxiety during the OSPAN, beliefs about inevitable age-related memory changes, memory self-efficacy, affect, endorsement of aging stereotypes, and priming of stereotypes on a lexical decision task[1]. In brief, we did not find any evidence that feedback influenced any of these variables.

Accounting for changes in subjective age

To examine which factors were associated with the observed subjective aging effect, we first calculated a difference score for each participant by subtracting subjective age at baseline from subjective age at time 3 (after the OSPAN task). Positive values indicated that participants felt older compared to baseline, whereas negative values indicated participants felt younger compared to baseline. Because there was no significant effect of feedback condition on either the memory measures or subjective age at times 1, 2, and 3, we collapsed across conditions for the following analyses. We then correlated the subjective age difference scores with memory performance and with responses on the attitude and mood measures. Results showed that participants who believed that age-related memory changes were inevitable ($r(59) = .280$, $p = .032$) and those who endorsed more aging stereotypes ($r(59) = .325$, $p = .012$) subjectively aged to a greater extent from times 1 to 3 than participants who felt otherwise. No other measures were significantly correlated with subjective age change, p's > .110. Self-rated health was not related to baseline subjective age, $r(59) = -.169$, $p = .200$, and was not associated with change in subjective age across the testing session, $r(59) = -.015$, $p = .908$. Additionally, subjective aging over the course of the experimental session (time 3 minus time 1) was not correlated with performance on any of the cognitive tests (p's > .334).

We also examined whether performance on the implicit measure of stereotype threat was correlated with change in subjective age. We were interested in whether subjective aging was correlated with reaction times to the negative words—specifically, would increases in subjective aging be associated with speeded judgments to negative words, which would indicate more negative stereotype activation? However, we did not find an association between median RT's on the lexical decision task for neutral, positive, and negative age-related words and subjective age differences, p's > .272.

Lastly, we used the variables discovered to be associated with subjective aging from time 1 to time 3 to determine which of these factors best predicted the subjective aging effect. We entered inevitable memory changes, stereotype threat endorsement, and negative lexical decision RTs (an implicit measure of stereotype threat) into a multiple regression simultaneously with subjective age difference score as the dependent variable. We found that the model with the three variables accounted for a significant

amount of variance in the subjective age difference scores, $F(3,52) = 5.28$, $p = .003$, $R^2 = .23$, $R^2_{adjusted} = .19$. Coefficients tests showed that the extent to which participants believed that memory changes are inevitable was a significant predictor in this model ($\beta = .32$, $t(52) = 2.58$, $p = .013$). Participants who believed age-related memory changes were inevitable felt older across the testing session. Explicit stereotype threat endorsement was also a significant predictor of subjective aging ($\beta = .36$, $t(52) = 2.92$, $p = .005$), but negative stereotype lexical decision times did not account for a significant amount of unique variance in the subjective aging effect, $p = .605$. Table 3 presents standardized β coefficients from the previous regression model.

Using discrepancy scores to investigate change is a controversial topic (see Edwards, 2001) so we ran a repeated measures linear mixed model analysis as a supplementary examination of our results. This analysis examined the subjective aging effect in reference to baseline subjective age for each participant. Variance between participants was accounted for by using a random effects model, with subjective age times 1–3 as a fixed factor. A number of potentially predictive variables were entered as main effect fixed factor covariates. The most predictive model was identified by removing nonsignificant factors individually under the condition that their removal did not negatively affect the Bayesian Information Criterion by more than 5 points. The resulting model contained six substantial predictors, in three distinct groups for subjective age across the study.

First, as expected, there was a significant main effect of time of test on subjective age ($F(53.13) = 3.37$, $p = .042$). Second, two variables measuring performance on cognitive tasks were substantial, though nonsignificant, main effects: total letters recalled on OSPAN ($F(47.65) = 2.44$, $p = .125$ and Analogies ($F(47.65) = 1.42$, $p = .239$). Third, three variables measuring self-perceptions were substantial, though nonsignificant predictors: how well participants thought they would perform on the analogies task ($F(47.65) = 2.10$, $p = .154$), how well participants expected to perform on the analogies task ($F(47.65) = 3.15$, $p = .082$), and median negative age-related word reaction time on the lexical decision task ($F(47.65) = .51$, $p = .479$). Together, these results indicate that there was significant change in subjective age across our repeated measures condition, but that no recorded variables were able to predict both the level and change in subjective age together. The finding showing that no variables predicted both level and change in subjective age is inconsistent with the finding from the regression analyses showing that belief in inevitable age-related memory changes and explicit stereotype threat endorsement were significant predictors of subjective aging. We cannot say for sure why these results differed across analysis approaches. Future research will be needed to clarify which factors predict subjective aging.

Table 3. Multiple regression analysis where *SE* is coefficient standard errors and β is standardized coefficients predicting change in subjective age from time 1 to 3.

	β	Coefficients	*SE*	*T*	*p*
Memory changes	0.32	2.17	0.84	2.56	.013
Stereotype threat	0.36	1.08	0.37	2.92	.005
Neg. word RT	0.06	0.01	0.01	0.52	.605

General discussion

The present study investigated whether cognitive testing would be associated with increasing subjective age, measured at several time points across a single experimental session. As expected, the results supported our hypothesis and showed that subjective age increased across the laboratory testing session. This finding is consistent with prior research that suggests that memory and reading tests can influence older adults' subjective age (Eibach et al., 2010; Hughes et al., 2013). In addition to finding that subjective age increased across the testing session, there was some evidence that endorsement of stereotyped beliefs and the belief that age-related memory changes are inevitable predicted the subjective aging effect. This finding may suggest that cognitive testing activates these negative stereotypes and that certain older adults are particularly vulnerable to these contexts. Interestingly, the extent to which people subjectively aged was not related to how they actually performed on the cognitive tests. Note, however, that conclusions regarding which factors are associated with subjective aging are tentative given the disparate results that were obtained using the random effects analysis.

The present study also investigated the influence of positive feedback on subjective age and performance. Previous research shows that older adults who successfully completed a cognitive task prior to taking a memory test showed better memory performance than those who had not successfully completed a prior task or who had failed at the test (Geraci et al., 2016; Geraci & Miller, 2013). Also, previous research shows that after receiving positive feedback on a task (a physical, hand-grip task), older adults reported feeling younger and showed subsequent performance enhancements relative to baseline (Stephan et al., 2013). However, contrary to predictions, in the current study participants in the positive feedback group did not perform better on the subsequent OSPAN test or the free recall test, compared to those in the no feedback group. Further, positive feedback did not mitigate the subjective aging that occurred across the testing session. There are a variety of differences between the current paradigm and previous ones. In the Geraci and Miller study, for example, older adults experienced real task success, having performed the initial cognitive task at close to 100% accuracy. Thus, it is possible that participants will only show a task success effect if they actually experience task success, rather than simply believe that they performed successfully on a task. Yet, there is evidence that false positive feedback can decrease subjective age and, in turn, improve performance on a physical task (Stephan et al., 2013). One primary difference stands out between the current study and the Stephan et al. study that may explain the divergent results. In the Stephan et al. study participants were given positive feedback on the same (hand-grip) task that they were later asked to perform; whereas in the current study, participants were given positive feedback on one cognitive task (an analogies task) and then performed a different cognitive task (the OSPAN task). Thus, it may be that positive feedback influences subjective age, but that it only influences subsequent performance if the later task is the same as the task for which people received positive feedback. Future research should examine this hypothesis.

In addition to the lack of an effect of false feedback on performance, there was also no effect of feedback on subjective age. We expected that false positive feedback would have a protective effect on subjective aging due to cognitive testing. Yet, contrary to our

hypothesis, we did not find an effect of feedback on subjective age. It is possible that we did not find this effect because we assessed subjective age in general. Although subjective age is most often assessed by having people report a single number to reflect their subjective age, in reality, subjective age is a multidimensional construct. According to Barak and Stern's (1986) review of the literature, there are five types of subjective age scales (see also Cutler, 1982; Hoffman, Shrira, Cohen-Fridel, Grossman, & Bodner, 2016; Kornadt, Hess, Voss, & Rothermund, 2016): "identity age" (Markides & Boldt, 1983), in which people report how old they feel in general terms (i.e., young, middle aged, old, or very old), "comparative age" (Baum & Boxley, 1983), in which participants report how old they feel relative to their chronological age (i.e., older, younger, or the same as chronological age), "felt age" in which people report how old they feel (Underhill & Cadwell, 1984), "cognitive age" (Kastenbaum, Derbin, Sabatini, & Artt, 1972) in which people report how old they feel in terms of their cognitive abilities, and "stereotype age" in which people identify descriptors that signify their age when compared to an older person or a middle-age person (e.g., a participant might rate himself as active or inactive in comparison with an older adult; George, Mutran, & Pennybacker, 1980). Thus, it is possible that the feedback used in the current study would affect cognitive or comparative age in particular, but not overall subjective or felt age. Future research might examine this hypothesis. It is also possible, given the lack of an effect of feedback on performance and subjective age, that the feedback manipulation was not a strong enough manipulation and that other types of performance feedback would be more effective. Lastly, it is possible that feedback was ineffective due to a kind of subjective age floor effect (see Kotter-Grühn, Kornadt, & Stephan, 2016). The idea is that older adults already feel approximately 10 years younger than they are, so it might have been relatively easy to increase subjective age with cognitive testing, but more difficult to decrease it following positive feedback because older adults are already feeling much younger than they are. We did not predict a *decrease* in subjective age relative to baseline—rather we predicted that giving feedback would mitigate any observed subjective aging effect due to testing—but nonetheless it could be that the effect of feedback was simply not effective because of a kind of floor effect in subjective age for older adults. Kotter-Grühn and colleagues (2016) note that given a possible floor effect, it is important to find manipulations and interventions that focus on preventing older adults from feeling older than their age, rather than helping them to feel younger. Although we did not find that positive feedback prevented older adults from feeling older during cognitive testing, future research should examine other methods of using feedback or other approaches to mitigate the detrimental effects of some experiences on subjective age in older adults.

There are limitations to the current study. For example, the older adults who participated were sampled from the local community and were generally well educated and healthy, so future studies would need to investigate whether our results generalize to other populations of older adults. Also, we investigated the immediate effect of testing on subjective age and don't know how long the effects of testing on subjective age last. We speculate that older adults encounter several short "tests" every day that might have a cumulative effect on their self-perception and subjective age. For example, common events such as trying to remember where you parked the car or straining to read a road sign while driving may have cumulative effects on subjective age that might be

relatively long-lasting. Future research could investigate the effects of repeated age-relevant encounters on subjective age. In addition, although we found that people reported feeling subjectively older after participating in several cognitive tests, compared to baseline, the design of the current study does not allow us to pinpoint the specific nature of the effect. Future work might compare the effects of various activities on subjective aging to determine the key factors that lead to the effect. For example, future studies could compare engaging in cognitive tasks to engaging in noncognitive tasks (perhaps of equal difficulty) to determine the role of cognitive testing in particular. Or, future studies could compare engaging in difficult cognitive tasks to engaging in easier ones to determine the role of difficulty of testing on subjective age. Finally, future studies might compare engaging in short versus long cognitive testing sessions on subjective age to, perhaps, determine the role of fatigue on subjective aging.

Across the testing session, we found that older adults subjectively aged about 4 years. Given the nature of the subjective age measure we used, some may wonder if it occurred by chance. We think that there is good evidence that this scale accurately measures subjective age and subjective age change. For one, chance movement would likely be in either direction (some people getting younger and some getting older, which would lead to an average of no change). But more importantly, there is evidence that using this measurement scale, change in subjective age is systematic and occurs or does not occur in response to theoretically meaningful manipulations. For example, Hughes et al. (2013) showed that using this measurement scale, older adults reported older subjective age after taking a memory test. However, younger adults did not. Furthermore, older adults' subjective age was affected only by taking a memory test, which indexes an ability that is stereotypically assumed to be poor in older adults. However, there was no movement on the scale—older adults did not indicate that they felt older—after taking a vocabulary test, which indexes an ability that is not associated with negative age-related stereotypes. If people marked an older subjective age on the scale simply by chance, then we might expect a chance finding for both younger and older adults. Rather, the fact that the results are quite systematic and theoretically consistent suggests that subjective age changed in response to the memory test (for older only) because participating in a memory test included self-perceptions by highlighting an older age, rather than by chance movement on the scale. Further, responding in general on this scale does not appear to reflect chance responding as people report the same subjective age using this scale as they do when asked to report it by writing down a number (see Hughes et al., 2013). Thus, we think that the weight of the evidence suggests that responding in general and after a manipulation on this scale reflects participants assessment of their subjective age rather than chance responding.

Results showed that, on average, participants reported feeling approximately 4 years older after participating in a series of difficult cognitive tests. Although the effect size for this result was medium, the simple fact that participants subjectively aged only a few years (rather than 10 or 20) might lead readers to wonder whether this finding is meaningful. The design of the current study doesn't allow us to answer that question, but we hypothesize that the result may be meaningful because often older adults encounter situations that highlight their age identify. It may be that these repeated experiences accumulate and lead to relatively large, and possibly long-lasting, effects on subjective age and self-perception more generally. Certainly, there is evidence that

many small effects can accumulate to lead to large meaningful effects for other stereotyped and marginalized groups. We know that even small daily stressors can affect older adults' subjective age, and one can imagine that experiencing these stressors on a regular basis would lead to a fairly permanent older subjective age. Given that having a relatively older subjective age predicts later poor psychological and health outcomes, we speculate that many small increases in subjective age can have a significant outcome for older adults. Future research might directly examine the effect various age-related contexts and threats on older adults' subjective age and how these effects relate to important outcomes.

This study demonstrates that subjective age increases for older adults following standard neuropsychological and cognitive testing. We did not find that positive feedback significantly blunted this effect, but future research might investigate other interventions that could reduce subjective aging.

Note

1. As expected, participants performed near ceiling on the lexical decision task. Accuracy on word and nonword trials did not vary across conditions (p's > .300). Average accuracy collapsed across the two conditions was 0.97 for word trials and 0.94 for nonword trials.

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