A novel face-name mnemonic discrimination task with naturalistic stimuli

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ABSTRACT

Difficulty remembering faces and names is a common struggle for many people and gets more difficult as we age. Subtle changes in appearance from day to day, common facial characteristics across individuals, and overlap of names may contribute to the difficulty of learning face-name associations. Computational models suggest the hippocampus plays a key role in reducing interference across experiences with overlapping information by performing pattern separation, which enables us to encode similar experiences as distinct from one another. Thus, given the nature of overlapping features within face-name associative memory, hippocampal pattern separation may be an important underlying mechanism supporting this type of memory. Furthermore, cross-species approaches find that aging is associated with deficits in hippocampal pattern separation. Mnemonic discrimination tasks have been designed to tax hippocampal pattern separation and provide a more sensitive measure of age-related cognitive decline compared to traditional memory tasks. However, traditional face-name associative memory tasks do not parametrically vary overlapping features of faces and names to tax hippocampal pattern separation and often lack naturalistic facial features (e.g., hair, accessories, similarity of features, emotional expressions). Here, we developed a face-name mnemonic discrimination task where we varied face stimuli by similarity, race, sex, and emotional expression as well as the similarity of name stimuli. We tested a sample of healthy young and older adults on this task and found that both age groups showed worsening per-formance as face-name interference increased. Overall, older adults struggled to remember faces and face-name pairs more than young adults. However, while young adults remembered emotional faces better than neutral faces, older adults selectively remembered positive faces. Thus, the use of a face-name association memory task designed with varying levels of face-name interference as well as the inclusion of naturalistic face stimuli across race, sex, and emotional expressions provides a more nuanced approach relative to traditional face-name as-sociation tasks toward understanding age-related changes in memory.

1. Introduction

The ability to form face-name associations is an important requisite for having successful social interactions because it allows us to recognize and communicate effectively with others. Face-name associative mem-ory tends to decline with age (Sperling et al., 2003; Rentz et al., 2011) and has been proposed to be a sensitive measure for early diagnosis of Alzheimer's disease (AD; Rubiño and Andrés, 2018). Difficulty in forming face-name associations could be due to the high amount of overlap and interference across our experiences. Many people share similar facial characteristics (e.g., eye color, beard) or names (e.g., Lauren and Laurel). It is also common for a person's appearance to change slightly from day to day (e.g., different hairstyle, clothing, makeup, accessories, etc.). These discrepancies can lead people to

experience the "tip-of-the-tongue" phenomenon, in which you might remember the first letter of someone's name, or a name that sounds similar to the person's name but cannot recall their full name (Brown and McNeill, 1966). Thus, social interactions which interfere with our existing memory schemas may drive difficulties in forming face-name associations, especially as we age.

The formation of new face-name associative memories is supported by the medial temporal lobe (MTL), which includes the hippocampus and surrounding cortices (Squire et al., 2004). Pattern separation is a computation that allows for the disambiguation of similar experiences in a non-overlapping manner and is supported by the dentate gyrus (DG) subfield of the hippocampus (Yassa and Stark, 2011). Mnemonic discrimination tasks have been developed to tax hippocampal pattern separation in humans by including similar lure stimuli with overlapping

features to those shown during encoding (Stark et al., 2013). While the hippocampus is generally agnostic to the type of information processed (e.g., spatial, object, face-name associations) (Azab et al., 2014; Reagh and Yassa, 2014), remembering faces and names is somewhat unique due to the complexity and similarity among faces (e.g., overlap in facial features across individuals) and because of their arbitrary associations with names, which also tend to overlap (Tak and Hong, 2014). These features are not necessarily captured by traditional mnemonic discrimination tasks using object or scene stimuli.

Cross-species evidence shows that aging is associated with impaired hippocampal pattern separation (Leal and Yassa, 2015). Recent work has examined MTL structure and function with high-resolution fMRI in healthy older adults as well as in those with cognitive impairment during performance of a face-name associative memory task. The results showed that hippocampal activity during retrieval, particularly in the DG/CA3 subregions, was associated with worse face-name memory in older adults (Carr et al., 2017). Impaired face-name memory has also been associated with greater beta-amyloid deposition, a primary pathology of AD, in the frontal and posterior cortices in older adults (Rentz et al., 2011). It has been suggested that clinical assessment of face memory can usefully contribute to early detection of memory deficits in prodromal and initial stages of AD (Werheid and Clare, 2007). Additional advantages such as ecological validity (e.g., feature overlap of faces, varying race/sex, hair/accessories included), high task comprehensibility, and greater independence from education and intelligence level due to novel face-name learning render measures of face-name associative memory valuable for clinical assessment in early AD.

Traditional face-name associative memory tasks involve testing participants' memory for repeated faces and names. While faces generally exhibit greater susceptibility to interference due to their inherent similarity across faces, traditional tasks do not include explicit manipulations of similarity that may drive face-name associative memory difficulties, such as the overlap across features of faces and names. In addition, while many of these tasks use real human faces, they often lack naturalistic features that may further contribute to face-name associative memory difficulty such as inclusion of hair and accessories (e.g., glasses, beard), racial diversity, and emotional expressions that mimic real-world experiences. Studies using naturalistic face stimuli with varied similarity levels have shown evidence of differential hippocampal activation for correct face lure discrimination (Kirwan and Stark, 2007; LaRocque et al., 2013) and selective impairment for face lure discrimination, but not recognition, following hippocampal damage (Kirwan et al., 2012). These findings support the utility of using mnemonic discrimination to tax pattern separation of face stimuli. However, the face stimuli used in these studies are outdated and do not often include varying types of face lure similarity, races, and names. Studies using computer generated faces have morphed faces to create lure faces with varied levels of similarity to the original faces and were divided across race (Black, White, East Asian, and South Asian). The results showed that White participants' mnemonic discrimination–generalization abilities were enhanced for White faces compared to East Asian and Black faces, suggesting that expertise plays an important role in resolving mnemonic discrimination (Chang et al., 2015). These findings are in line with the "other race effect" (ORE), which can be characterized as superior recognition for own-race faces relative to other-race faces (Yaros et al., 2019). While the faces used in this task had varied race and levels of similarity, they lacked naturalistic features, which may impact how participants remember face-name associations in real life.

In the current study, we developed a novel face-name mnemonic discrimination task including naturalistic face stimuli with varied emotional expressions (negative, neutral, and positive), face similarity levels (same person with a similar appearance and similar person lures), sex (male and female), and race (White, Black, Asian, and Multiracial), as well as similar name stimuli paired with faces (same name and similar names; e.g., Lauren and Laurel). One novel aspect of our similarity manipulation during the memory test was that we included some faces

that were similar to, but not the same as, the person shown during encoding (i.e.; similar person lures), and some faces that were of the same person, but with a changed appearance, such as gaze direction, pose, lighting, expression, accessories, clothing, or a combination of any of these (i.e.; same person lures) to more closely mimic memory errors associated with face-name processing. We also manipulated name similarity, which was additionally novel. This task provides an important contribution to the field by creating a face-name stimulus set that is systematically varied across several dimensions (e.g., similarity, race, emotional expressions), making this a more ecologically valid and generalizable task relative to existing face-name associative tasks. The task was applied to both young and older adults.

We hypothesized that as interference in faces and names increases, memory performance will decrease. Furthermore, we predicted that older adults would perform worse overall compared to young adults, especially on lure faces/names, but may show a preservation of memory for positive faces given the positivity effect previously reported in aging, in which older adults tend to remember more positive relative to negative stimuli compared to young adults (Mather and Carstensen, 2005). While we varied sex and race, these manipulations were primarily meant to increase the diversity and inclusion of the stimulus set, as we did not design our study to examine participants' race and sex interacting with face stimuli race and sex. However, if powered across our sample, we hypothesized we would find evidence for the ORE (Hugenberg et al., 2010; Chang et al., 2015; Yaros et al., 2019) in which participants would show enhanced memory for faces within their own race relative to other races. We hypothesized the same would be true for sex, in which participants would be better at discriminating faces within their own sex.

2. Materials & methods

2.1. Participants

Participants ages 18–35 (N = 25) and 60–85 (N = 29) were recruited from Rice University and the local Houston community through flyers and listserv postings. Participants were compensated with either an Amazon gift card ($15/hour) or Psychology course credit (1 credit/hour) upon completion of the study. Informed consent was obtained from all participants in accordance with the guidelines approved by the Rice University Institutional Review Board. Due to the COVID-19 pandemic, participants completed the study online via Zoom from July to October of 2021. Participants were pre-screened to ensure they had access to a computer with a camera and microphone, stable internet connection, and a quiet testing space. Older adults were cognitively normal based on a Medical Screening Questionnaire, and all participants were screened for major medical, psychiatric, or substance abuse history and had normal or corrected-to-normal vision. Data from eight older participants was excluded due to response errors or technical issues. Participant demographics are shown in Table 1.

Table 1
Participant demographic information.

Variable	Young	Old
N	25	21
Age[a] (Mean, ±SD)	22.96 (3.92)	72.67 (6.66)
Sex	Male:8 Female:17	Male:4 Female:17
Education (Years)[a] (Mean, ±SD)	14 (2.38)	17.43 (1.57)
Race/Ethnicity (%)		
White	44%	90%
Other:	56%	10%
Asian/Asian American	32%	5%
Black/African American	4%	0%
Native Hawaiian/Pacific Islander	0%	5%
Multiracial	20%	0%
Hispanic/Latino/a/x	12%	0%

[a] = significant group difference.

2.2. Questionnaires

Participants completed a demographics form to determine age, sex, race, and ethnicity, as well as a series of questionnaires after the initial encoding task, which took an average of 36 min to complete. Participants completed the Beck Depression Inventory-II (BDI-II) (Beck et al., 1996) to measure current depressive symptoms (past two weeks). For the BDI-II, if a participant indicated suicidal thoughts (>1 on Question 9), they were given the Suicidal Ideation Screening Questionnaire (SISQ) based on the Columbia-Suicide Severity Rating Scale (C-SSRS) (Posner et al., 2011) and were given resources to seek additional help. Four participants were administered the SISQ, but none indicated active suicidal thoughts. Young adults showed greater depressive symptoms compared to older adults [$t(44) = 2.63$, $p = .01$], but were still within the mild to minimal range (Beck et al., 1996). Participants also completed a Lifestyle & Exercise Questionnaire (LEQ), which we developed to measure healthy habits such as physical and social activity, mindfulness, and eating a well-balanced diet (see Supplementary Information S1), the Cambridge Face Memory Questionnaire (CFMQ) (Arizpe et al., 2019), the 20-item Prosopagnosia Index (PI20) (Shah et al., 2015) to measure self-reported face memory, the Race Conceptions Scale (RCS) (Williams and Eberhardt, 2008), and a modified version of the Social Contact Scale (SCS) (Wong et al., 2020) to measure participants' quantity and quality of contact with White and Other (Asian, Hispanic, Black, and Middle Eastern) races/ethnicities. Questionnaire results are listed in Table 2.

2.3. Development of face and name stimulus sets

We developed a novel face-name stimulus set to be included in the memory task that depicted real people with a range of characteristics, including sex (male, female), race (White, Black, Asian, Multiracial), and emotional expression (negative, neutral, positive). The number of stimuli with each of these characteristics across each phase of the task can be found in Table 3. Many of the faces also had facial hair and accessories (i.e., glasses, jewelry, or headscarves) and were positioned in front of naturalistic backgrounds. All images were acquired from photo databases, including Google Images and Shutterstock.

We assigned *a priori* categories of emotional valence (negative, neutral, positive) to the faces based on facial expression (e.g., positive =

Table 2
Questionnaire results across young and older participants.

Variable (Mean, ±SD)	Young	Old
Beck Depression Inventory (BDI-II)*	10.64 (6.43)	5.48 (6.87)
Race Conceptions Scale (RCS)	84.56 (20.40)	84.90 (19.79)
Cambridge Face Memory Questionnaire (CFMQ) *	67.48 (8.33)	72.76 (6.33)
20-item Prosopagnosia Index (PI20)	39.68 (8.27)	40 (7.79)
Social Contact Scale (SCS)		
White – Quality	*W*: 4.50 (1.17)	*W*: 4.57 (0.90)
	O: 3.69 (0.99)	*O*: 3.55 (1.48)
White – Quantity	*W*: 4.51 (1.19)	*W*: 4.51 (0.98)
	O: 3.69 (0.56)	*O*: 4.20 (1.13)
Other – Quality	*W*: 2.73 (0.99)	*W*: 2.25 (1.07)
	O: 2.73 (1.39)	*O*: 2.23 (1)
Other – Quantity	*W*: 3.08 (1.04)	*W*: 2.74 (0.87)
	O: 2.98 (1.26)	*O*: 2.80 (1.40)

Values are Mean (Standard Deviation); **BDI** = scores range from 0 to 50 points, where scores >16 indicate symptoms of depression; **RCS** = scores range from 22 to 154 points, where lower scores indicate a more biological conception of race and higher scores indicate a more physical conception of race; **CFMQ** = scores range from 17 to 85 points, where lower scores indicate perceived face memory impairment; **PI20** = scores range from 20 to 100 points, where higher scores indicate perceived face memory impairment; **SCS** = scores range from 1 to 5 points, where 1 = no or low degree of interaction and 5 = high degree of interaction; **W** = White participants; **O** = Other race/ethnicity (Asian/Indian, Latinx, Black, Middle Eastern) participants; * = significant group difference.
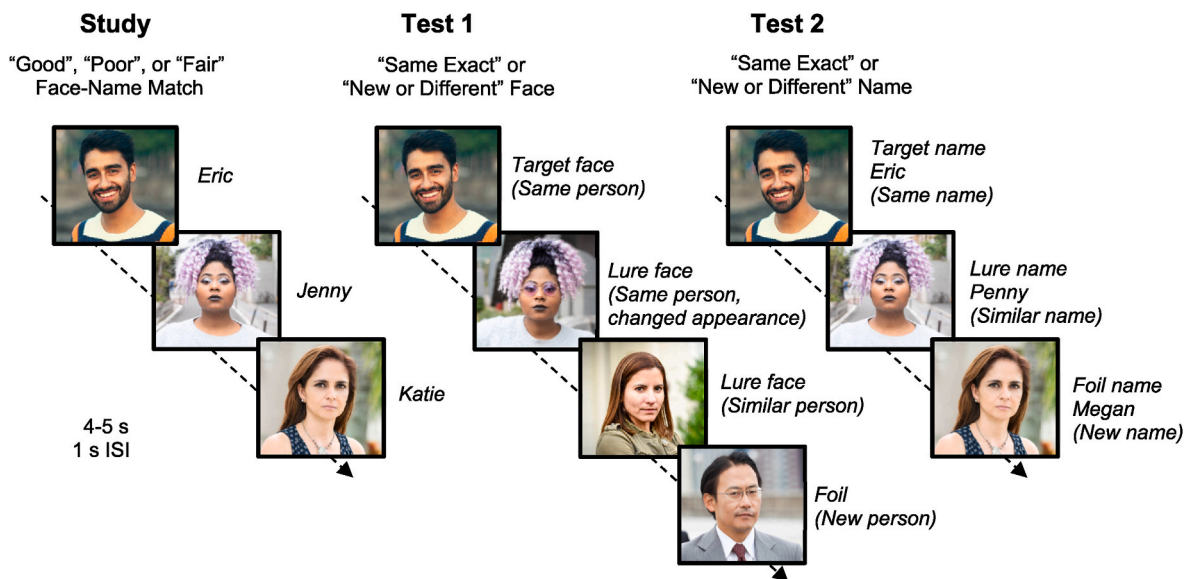
Table 3
Number of face stimuli across sex, race, and emotional expression.

Variable	Study/Test 2 (Face-Name)	Test 1 (Faces)
N	90	120
Sex	Male: 45 Female: 45	Male: 60
		Female: 60
Race		
White	32	40
Other:	58	80
Asian	14	21
Black	21	28
Multiracial	23	31
Emotional expression		
Negative	30	40
Neutral	30	40
Positive	30	40

smiling; negative = frowning; neutral = blank expression). After completing the mnemonic discrimination task, participants were shown side-by-side pairs of face images and provided ratings on a 7-point scale of the face pairs' similarity (1 = Not at all Similar, 7 = Exactly the Same), emotional valence (1 = Most Negative, 4 = Neutral, 7 = Most Positive), and emotional arousal (1 = Low Arousal, 7 = High Arousal). These images included pairs of faces which were identical (same person), very similar (same person, changed appearance), somewhat similar (similar person), or completely different (new person). These ratings were used to confirm whether face stimuli differed across emotional valence, arousal, and similarity.

The name stimuli were conceived by our lab members or selected from lists of popular baby names (in English). The names were assigned to faces largely based on sex norms. Lure names were created by altering the baseline names to have either similar beginnings (e.g., Jeffery and Jefferson), similar endings (e.g., Alissa and Melissa), or similar sounds (e.g., Simone and Sloane). Foil names were created to be fully distinct from baseline names (e.g., Norman and Walter).

2.4. Face-name mnemonic discrimination task

We developed a novel face-name mnemonic discrimination task that included a Study phase and two Test phases (Fig. 1). An Apple iMac equipped with PsychoPy (version 3.2.4) (Peirce, 2007) was used to present stimuli. Participant responses were recorded using the remote-control feature on Zoom via mouse click. Each trial consisted of two displays: an image display and an inter-stimulus interval (ISI) display (black screen). All images were sized to a width of 600 pixels and presented in a randomized order.

During the Study phase, 90 face-name pairs were presented for 4s with an ISI of 1s. Response options appeared on the screen beneath the face-name pairs where participants were asked to rate how well the name matched the face (1 = Poor Match, 2 = Fair Match, 3 = Good Match) to ensure they were paying attention to the face-name pairs during encoding. Face images were split across race (White, Black, Asian, Multiracial), sex (male, female), and emotional valence of expression (positive, negative, neutral). After encoding, participants completed the series of questionnaires discussed above followed by two surprise memory tests.

During Test 1, participants were tested on their memory of the face images alone. Participants were shown 120 face images (4s, 1s ISI) with an even distribution of targets (repeated faces), similar person lures, same person lures (changed appearance), or foils (new faces), relative to faces shown during the Study phase. Response options appeared on the screen beneath the faces, in which participants were asked to indicate whether the face was *exactly* the same as a face shown during encoding or if it was new or different in any way (1 = 'Same Exact Face', 2 = 'New or Different Face'). Participants were explicitly told that in order for a face image to be called the 'Same Exact Face', it had to be the same *exact* face they saw before, rather than a similar or new face, or the same

Fig. 1. Face-name mnemonic discrimination task. Participants were shown a series of faces paired with names during the Study phase and were asked to determine if each face-name pair was a "Good", "Poor", or "Fair" match. After a short delay, participants were first tested on their memory in Test 1 for the face stimuli alone and were shown either a repeated face (target), new face (foil), or a similar but not identical face (lure). Lure faces varied by similarity level, such that same person lures were the same person's face, but their appearance changed in some way (high similarity) whereas similar person lures were not the same person, but resembled each other (low similarity). During Test 2, participants were shown faces from the Study phase only, but the names paired with the faces were either the same (target), new (foil), or similar (lure) names.

person with changed appearance.

During Test 2, participants were presented with the 90 faces that were shown during the Study phase (5s, 1s ISI) paired with name stimuli, which included targets (repeated names), lures (similar, but not identical names), and foils (new names). Response options appeared on the screen beneath the face-name pairs where participants were asked to indicate whether the name paired with the face was *exactly* the same name paired during the Study phase or if it was new or different in any way (1 = 'Same Exact Name', 2 = 'New or Different Name'). Participants were explicitly told that for an item to be called the 'Same Exact Name', it had to be the same *exact* name they saw before, rather than a similar or new name.

2.5. Memory measures of interest

A discriminability index was used to evaluate two key outcome measures: target recognition and lure discrimination. Target recognition (d') is a standard memory measure for repeated items (targets), calculated as d' = z(Hits) − z(False Alarms). Hits and false alarms refer to correct recognition of repeated items and false recognition of new items (foils), respectively. Lure discrimination (lure d') measures the ability to discriminate similar, but not identical items (lures) from targets, calculated as lure d' = z(Hits) − z(Lure False Alarms), where lure false alarms refer to the false recognition of lures and accounts for the relative overlap between lure and old memory strengths. We calculated both target recognition and lure discrimination using d' measures to directly compare them (Loiotile and Courtney, 2015). We also calculated positivity and negativity bias scores on an individual participant basis, where Bias Score = (Emotional − Neutral)/(Emotional + Neutral).

2.6. Statistical analysis & data availability

Statistical analyses were conducted in SPSS v. 28 (IBM Corp., Armonk, NY). Planned comparisons were conducted using repeated-measures ANOVAs and t-tests. Scheffé's *post-hoc* contrasts and Pearson correlations were conducted where appropriate. Effects sizes are reported as η_p^2 or Cohen's d where appropriate. To compare correlation coefficients, Fisher's r to z transform was conducted to calculate a value of z that can be applied to assess the significance of the difference between two correlation coefficients, r_a and r_b, found in two independent samples (http://vassarstats.net/rdiff.html). Statistical values were considered significant at a final corrected alpha level of 0.05, which controlled for Type I error. Repeated-measures tests were corrected for error non-sphericity using Greenhouse–Geisser correction. The data generated in the current study are available in a GitHub repository (https://github.com/lealmemorylab/facename).

3. Results

3.1. Valence, arousal, and similarity ratings

To establish normative baseline ratings for the stimuli, we examined young adult ratings. We also collected ratings in older adults (see Table 1 for demographics) and compared young and older adult ratings to determine if there were any age effects across valence, arousal, and similarity ratings.

We examined young adult participant ratings for emotional valence of the face stimuli (Fig. 2A) by conducting a repeated-measures ANOVA with emotional valence (negative, neutral, positive) as the within-subject factor. There was a significant main effect of emotional valence [$F(2,48)$ = 343.12, $p < .001$, $\eta_p^2 = 0.94$], where a linear relationship was evident, in which negative stimuli received the lowest valence ratings, followed by neutral stimuli, and finally positive stimuli, which received the highest valence ratings [post-hoc Scheffé: $F(1,24)$ = 363.53, $p < .001$, $\eta_p^2 = 0.94$]. This aligns with our *a priori* emotional valence categorization. When we compared young versus older adult ratings using a mixed repeated-measures ANOVA with emotional valence (negative, neutral, positive) as the within-subject factor and age group (young, old) as the between-subjects factor, there were no interactions with age, but the main effect of emotional valence remained [$F(2,88)$ = 521.14, $p < .001$, $\eta_p^2 = 0.92$; see Supplementary Fig. S2A].

When analyzing ratings for emotional arousal of the face stimuli in young adults (Fig. 2B), we found a significant effect of emotion [$F(2,48)$ = 26.55, $p < .001$, $\eta_p^2 = 0.53$], in which both negative and positive faces
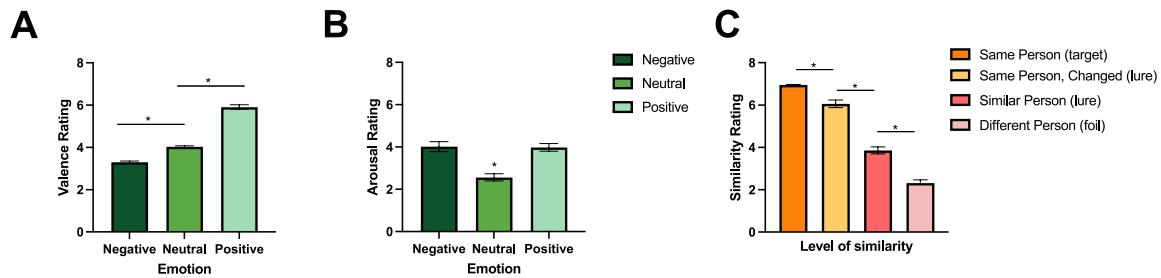
Fig. 2. Emotional valence, emotional arousal, and face similarity ratings in young adults. A) Faces with negative expressions (i.e., anger, disgust) were rated as most negative, those with neutral (i.e., non-emotive) expressions received neutral ratings (~4), and those with positive expressions (i.e., happy, joyful) received positive ratings, B) Positive and negative faces were rated as being very arousing compared to neutral faces, which were significantly less arousing, C) Same person pairs (repeats) received the highest similarity rating (7 = Exactly the same), followed by same person, changed appearance lure pairs, similar person lure pairs, and different person pairs (1 = Not at all similar). Error bars represent standard error or the mean (SEM).

received higher arousal ratings compared to neutral faces [post-hoc Scheffé: $F(1,24) = 56.37$, $p < .001$, $\eta_p^2 = 0.70$]. When we compared young versus older adult ratings using a mixed repeated-measures ANOVA with emotional valence (negative, neutral, positive) as the within-subject factor and age group (young, old) as the between-subjects factor, there was a main effect of emotional valence [$F(2,88) = 31.02$, $p < .001$, $\eta_p^2 = 0.92$; see Supplementary Fig. S2B]. There was also a significant interaction between emotional valence and age [$F(2,88) = 5.54$, $p = .01$, $\eta_p^2 = .11$], where older adults rated neutral and positive faces as more arousing than young adults relative to negative faces [post-hoc Scheffé: $F(1,44) = 6.69$, $p = .01$, $\eta_p^2 = 0.13$].

When analyzing ratings for similarity of the face stimuli, a repeated-measures ANOVA was conducted across levels of similarity (same person, same person changed appearance, similar person, different person) to assess participant ratings of similarity of the face pairs. In young adults, the analysis revealed a main effect of similarity [$F(3,72) = 297.66$, $p < .001$, $\eta_p^2 = 0.93$], where pairs of images with the same exact person received the highest similarity rating (7 = Identical face) and successively lower ratings were given same person (changed appearance) pairs, similar person pairs, and different person pairs [post-hoc Scheffé: $F(1,24) = 736.77$, $p = .001$, $\eta_p^2 = 0.97$]. This confirmed that lure images of the same person but with a changed appearance were quantified as having greater interference (high similarity) compared to lure images of a similar-looking person (low similarity). When we compared young versus older adult similarity ratings using a mixed repeated-measures ANOVA, there was a main effect of similarity [$F(3,132) = 392.92$, $p < .001$, $\eta_p^2 = 0.90$; see Supplementary Fig. S2C], as expected. However, there was also a main effect of age group [$F(1,44) = 6.37$, $p = .02$, $\eta_p^2 = 0.13$], where older adults rated face pairs as less similar to one another compared to young adults, and an interaction between similarity and age [$F(3,132) = 5.78$, $p = .01$, $\eta_p^2 = 0.12$], where older adults rated lure face pairs, relative to repeated and different face pairs, as less similar to one another than young adults [post-hoc Scheffé: $F(1,44) = 11.01$, $p = .002$, $\eta_p^2 = 0.20$].

3.2. Face memory and face-name associative memory performance in young adults

The primary goal of this study was to develop a novel face-name association memory task to include naturalistic stimuli varied by similarity, emotion, race, and sex. To determine whether our manipulations were successful, we analyzed data from a sample of young adults. A secondary goal of this study was to then apply this task in a sample of older adults to examine age-related changes in face-name association memory. Thus, we performed these analyses separately as our goals were two-fold, first to establish a baseline of task performance in young adults alone and then to compare performance with that of an older adult sample who may exhibit age-related memory impairment. Raw

behavioral results for all conditions can be found in Table 4.

In young adults, we conducted a repeated-measures ANOVA across face similarity (same person, same person changed appearance, similar person) to examine memory for faces (Test 1). There was a significant effect of face similarity [$F(2,48) = 99.34$, $p < .001$, $\eta_p^2 = 0.81$], where participants remembered repeated faces best, followed by faces of a similar person (low similarity) and faces of the same person but with changed appearance (high similarity) [post-hoc Scheffé: $F(1,24) = 148.91$, $p < .001$, $\eta_p^2 = 0.87$; Fig. 3A]. Next, we conducted a *t*-test across name similarity (same name, similar name) to examine memory for face-name association memory (Test 2). There was a significant difference across name similarity, where participants remembered face-name pairs with the same name better than face-name pairs with a similar name (e.

Table 4
Behavioral response by trial type.

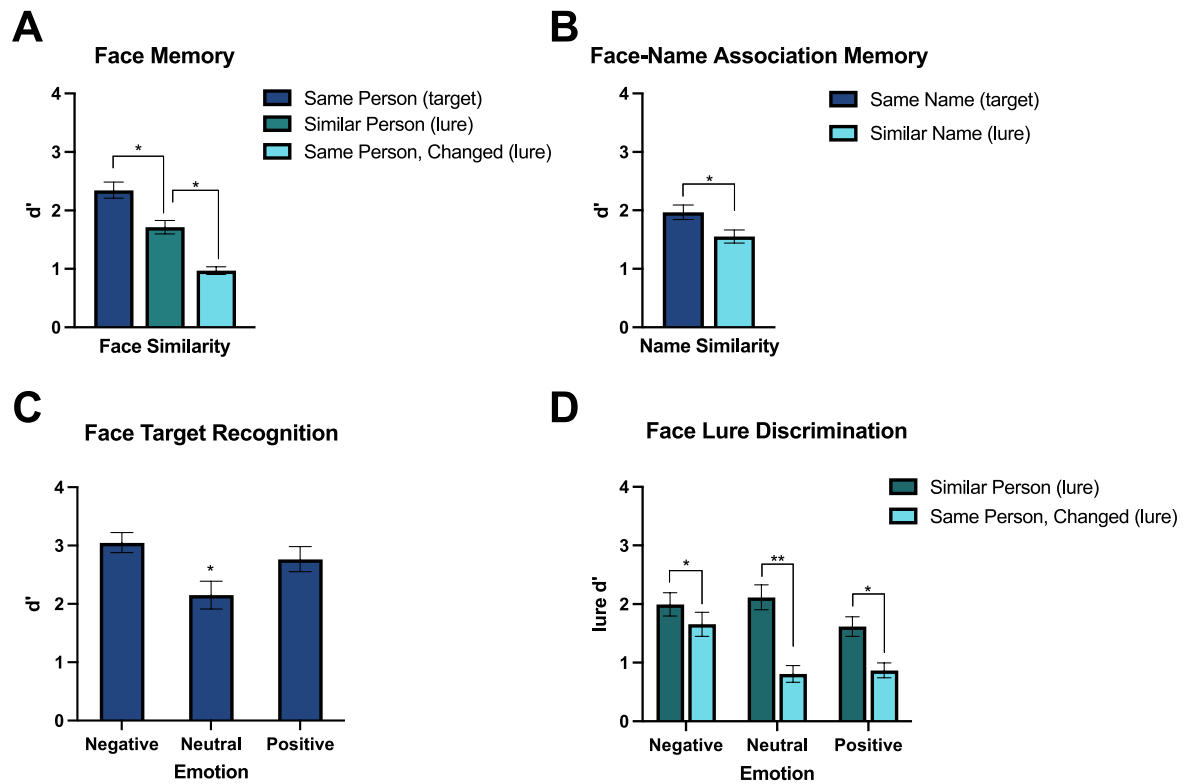| Emotion	Stimuli Type	"Same Exact Face"		"New or Different Face"	
		Young	Old	Young	Old
Overall	Foils	0.10	0.21	0.90	0.79
		(0.02)	(0.03)	(0.02)	(0.03)
	Targets	0.80	0.65	0.20	0.35
		(0.02)	(0.04)	(0.02)	(0.04)
	Similar Person Lures	0.23	0.31	0.77	0.69
		(0.03)	(0.05)	(0.03)	(0.05)
	Same Person Lures	0.47	0.43	0.53	0.57
		(0.03)	(0.05)	(0.03)	(0.05)
Negative	Foils	0.05	0.15	0.95	0.85
		(0.02)	(0.04)	(0.02)	(0.04)
	Targets	0.82	0.55	0.18	0.45
		(0.02)	(0.06)	(0.02)	(0.06)
	Similar Person Lures	0.24	0.28	0.76	0.72
		(0.03)	(0.05)	(0.03)	(0.05)
	Same Person Lures	0.33	0.32	0.67	0.68
		(0.04)	(0.05)	(0.04)	(0.05)
Neutral	Foils	0.18	0.27	0.82	0.73
		(0.03)	(0.05)	(0.03)	(0.05)
	Targets	0.78	0.63	0.22	0.37
		(0.04)	(0.05)	(0.04)	(0.05)
	Similar Person Lures	0.18	0.32	0.82	0.68
		(0.03)	(0.06)	(0.03)	(0.06)
	Same Person Lures	0.56	0.53	0.44	0.47
		(0.03)	(0.07)	(0.03)	(0.07)
Positive	Foils	0.07	0.18	0.93	0.77
		(0.02)	(0.03)	(0.02)	(0.05)
	Targets	0.78	0.75	0.22	0.25
		(0.03)	(0.05)	(0.03)	(0.05)
	Similar Person Lures	0.27	0.34	0.73	0.66
		(0.04)	(0.05)	(0.04)	(0.05)
	Same Person Lures	0.52	0.47	0.48	0.53
		(0.04)	(0.06)	(0.04)	(0.06)

*Mean, SEM.

Fig. 3. Face-name association mnemonic discrimination performance in young adults. A) Young adults remembered repeated, same person faces best, followed by similar person lure faces (low similarity) and same person but with a changed appearance lure faces (high similarity), B) Young adults showed better target recognition compared to lure discrimination measures for face-name associations, C) Young adults recalled emotional face stimuli better than neutral stimuli, D) Young adults differentially discriminated similar and same person lures depending on the emotional expression of the faces. Error bars represent SEM. Asterisks highlight a subset of significant findings. See text for full set of significant results. Single versus double asterisks indicate the presence of an interaction.

g., Laura vs Laurel) [$t(24) = 5.91$, $p < .001$, d = 1.18; Fig. 3B].

Next, we examined the effect of emotional expression on face memory, in which we varied emotional valence of the expression of the faces (Test 1). For target recognition, we conducted a repeated-measures ANOVA across emotional expression (negative, neutral, positive) and found a significant main effect of emotional expression [$F(2,48) = 5.78$, $p = .006$, $\eta_p^2 = 0.19$], where young adults remembered emotional (both positive and negative) faces better than neutral faces [post-hoc Scheffé: $F(1,24) = 11.73$, $p = .002$, $\eta_p^2 = 0.33$; Fig. 3C]. For lure discrimination, we conducted a repeated-measures ANOVA across emotional expression (positive, negative, neutral) and face similarity (similar person, same person changed appearance). There was a significant main effect of emotional expression [$F(2,48) = 3.53$, $p = .039$, $\eta_p^2 = 0.13$; Fig. 3D], where young adults discriminated negative lure faces best, followed by neutral, and positive faces [post-hoc Scheffé: $F(1,24) = 6.33$, $p = .019$, $\eta_p^2 = 0.21$]. There was also a significant main effect of face similarity [$F(1,24) = 67.26$, $p < .001$, $\eta_p^2 = 0.74$], where young adults better discriminated similar person lure faces (low similarity) compared to same person lure faces with a changed appearance (high similarity). Finally, a significant interaction was found between emotional expression and face similarity [$F(2,48) = 10.90$, $p < .001$, $\eta_p^2 = 0.31$], where there was similar performance across all lure faces with emotional expressions (negative and positive) compared to neutral lure faces, which showed the largest difference in lure discrimination across similarity [post-hoc Scheffé: $F(1,24) = 24.14$, $p < .001$, $\eta_p^2 = 0.50$].

3.3. The impact of aging on face memory and face-name association memory

Next, we aimed to examine whether the task was sensitive to age-

related memory impairment in a sample of cognitively normal older adults. We conducted a mixed repeated-measures ANOVA across face similarity (same person, same person changed appearance, similar person) as the within-subject factor and age group (young, old) as the between-subjects factor to examine memory for faces (Test 1). There was a significant main effect of face similarity [$F(2,88) = 108.73$, $p < .001$, $\eta_p^2 = 0.71$; Fig. 4A], where participants showed a greater ability to recognize repeated faces than to discriminate lure faces with low similarity (similar person lures) or high similarity (same person changed appearance lures) [post-hoc Scheffé: $F(1,44) = 180.07$, $p < .001$, $\eta_p^2 = 0.80$]. There was a significant main effect of age, where young adults showed better memory performance compared to older adults [$F(1,44) = 15.34$, $p < .001$, $\eta_p^2 = 0.26$]. We also found a significant interaction between face similarity and age group [$F(2,88) = 11.15$, $p < .001$], where the largest age differences were evident on easier memory measures (e.g., target recognition) compared to the most difficult memory measures (e.g., same person changed appearance lure discrimination) [post-hoc Scheffé: $F(1,44) = 18.50$, $p < .001$, $\eta_p^2 = 0.30$].

We also examined the raw false alarm data to determine whether age-related effects in d' were due to lower target recognition rates or increased false alarms in older compared to young adults. We conducted a mixed repeated-measures ANOVA across face similarity (new person, similar person, same person changed appearance) as the within-subject factor and age group (young, old) as the between-subjects factor for false alarms. We found a significant effect of face similarity [$F(2,88) = 113.03$, $p < .001$, $\eta_p^2 = 0.72$; Fig. 4B], where the greatest proportion of false alarms occurred for high similarity lure faces (same person, changed appearance), followed by low similarity lure faces (similar person), and the lowest proportion of false alarms occurred for new faces, as expected [$F(1,44) = 196.68$, $p < .001$, $\eta_p^2 = 0.82$]. There was a
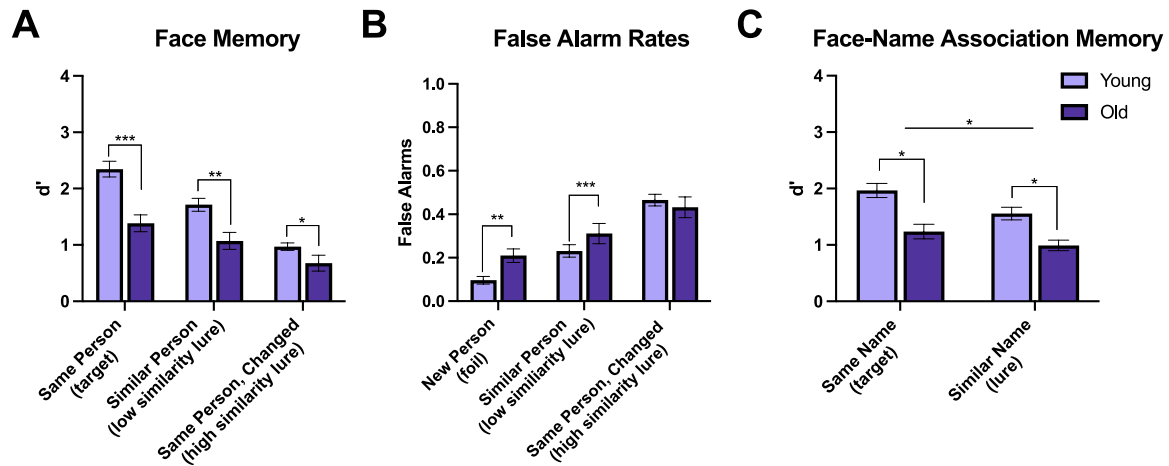
Fig. 4. Face-name association mnemonic discrimination performance comparing young and older adults. A) Face memory (d') for same person faces (targets), similar person lure faces (low similarity, lure d'), and same person lure faces (high similarity, lure d') in young and older adults, B) False alarm rates for new person faces (foils), similar person faces, and same person faces but with a changed appearance in young and older adults, C) Face-name association memory measured via target recognition and lure discrimination in young and older adults. Error bars represent SEM. Asterisks highlight a subset of significant findings. See text for full set of significant results. Single versus double/triple asterisks indicate the presence of an interaction.

significant interaction between face similarity and age group [$F(2,88) = 113.03$, $p < .001$, $\eta_p^2 = 0.72$], where older adults showed greater false alarms as interference in faces decreased [$F(1,44) = 11.95$, $p = .001$, $\eta_p^2 = 0.21$]. There was no overall main effect of age group [$F(1,44) = 1.67$, $p = .20$, $\eta_p^2 = 0.04$]. Raw target recognition scores (not corrected for response bias) showed significant differences across age groups [$t(44) = -3.38$, $p = .002$, $d = 1$; Table 4], where young adults showed better target recognition compared to older adults. Thus, both lower target recognition rates and increased false alarm rates were evident in older

relative to young adults.

Next, we conducted a mixed repeated-measures ANOVA to examine the effect of name similarity (same name, similar name) as the within-subject factor and age group (young, old) as the between-subjects factor on face-name association memory (Test 2). There was a significant main effect of name similarity, where participants showed better target recognition (same name) compared to lure discrimination (similar name) of face-name pairs [$F(1,44) = 32.34$, $p < .001$, $\eta_p^2 = 0.42$; Fig. 4C]. There was a significant main effect of age group, where young adults
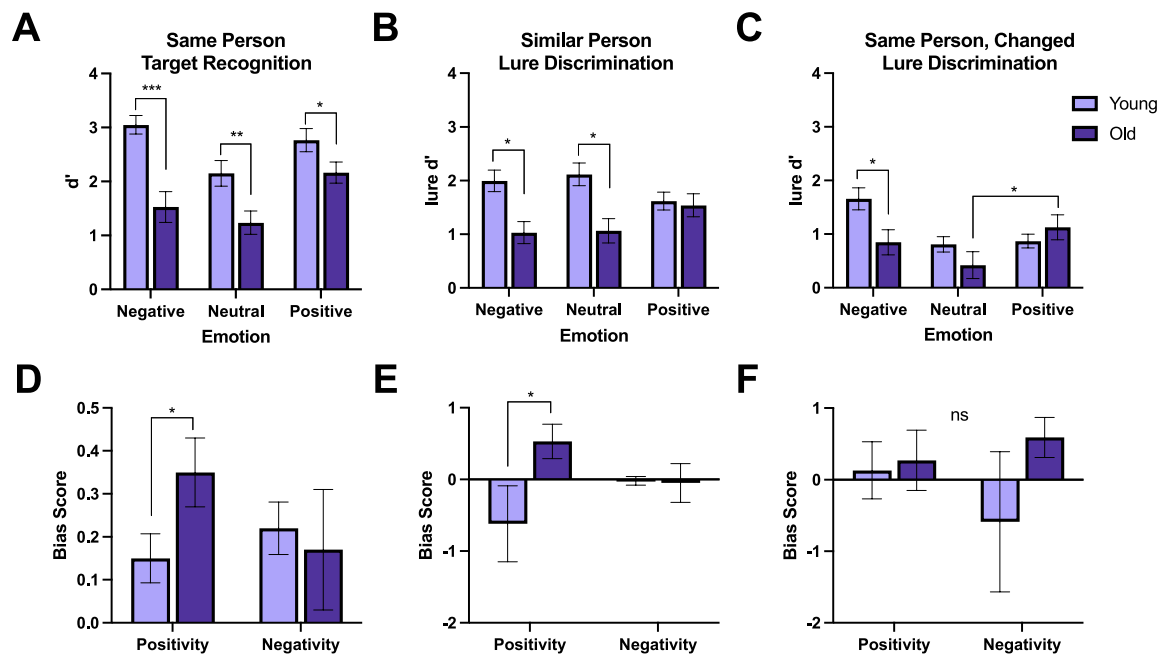

Fig. 5. The impact of emotional expressions on memory. A) Target face recognition across negative, neutral, and positive stimuli in young and older adults, B) Similar person lure discrimination across negative, neutral, and positive stimuli in young and older adults, C) Same person, changed appearance lure discrimination across negative, neutral, and positive stimuli in young and older adults, D) Positivity and negativity bias scores for target recognition, E) Positivity and negativity bias scores for similar person lure discrimination, F) Positivity and negativity bias scores for same person, changed appearance lure discrimination. Error bars represent SEM. Asterisks highlight a subset of significant findings. See text for full set of significant results. Single versus double/triple asterisks indicate the presence of an interaction and ns indicates non-significant effects.

recalled face-name pairs better than older adults [$F(1,44) = 17.20$, $p < .001$, $\eta_p^2 = 0.28$], but no significant interaction between memory type and age group ($p = .16$).

Next, we examined the effect of emotional expression on face memory in aging, in which we varied emotional valence of the expression of the faces (Test 1). We conducted a mixed repeated-measures ANOVA across emotional expression (negative, neutral, positive) as the within-subject factor and age group (young, old) as the between-subjects factor for each memory measure. For target recognition, we found a main effect of emotional expression [$F(2,88) = 8.36$, $p < .001$, $\eta_p^2 = 0.16$; Fig. 5A], where memory for repeated emotional faces (both positive and negative) was enhanced compared to neutral faces [post-hoc Scheffé: $F(1,44) = 21.07$, $p < .001$, $\eta_p^2 = 0.32$]. We found a main effect of age group, where young adults performed better than older adults [$F(1,44) = 22.01$, $p < .001$, $\eta_p^2 = 0.33$]. No significant interactions were found between emotional expression and age group [$F(2,88) = 2.79$, $p = .07$, $\eta_p^2 = 0.06$]. Within the older adult group, older adults remembered more faces with positive relative to neutral expressions [$t(20) = 4.10$, $p < .001$, d = 0.89], but not negative relative to neutral expressions [$t(20) = 1.03$, $p = .313$, d = 0.23]. We calculated positivity and negativity bias scores for each participant and found a significant difference in positivity bias in young compared to older adults [$t(43) = 2.07$, $p = .045$, d = 0.62; Fig. 5D], in which older adults showed a greater positivity bias. There were no differences in negativity bias score ($p = .78$).

Next, we conducted a mixed repeated-measures ANOVA to examine the effect of emotional expression (negative, neutral, positive) as the within-subject factor and age group (young, old) as the between-subjects factor for lure discrimination of similar person faces (low similarity) (Fig. 5B). We found a significant main effect of age group, where young adults performed better than older adults [$F(1,44) = 11.47$, $p = .001$, $\eta_p^2 = 0.21$]. While there was no main effect of emotion ($p = .89$), there was a significant interaction between emotional expression and age group [$F(2,88) = 4.65$, $p = .01$, $\eta_p^2 = 0.10$], in which there were no age-related differences in memory for positive faces compared to neutral and negative faces which showed larger age-related differences [post-hoc Scheffé: $F(1,44) = 9.72$, $p = .003$, $\eta_p^2 = 0.18$]. We calculated positivity and negativity bias scores for each participant and found a significant difference in positivity bias in young compared to older adults [$t(43) = 2.69$, $p = .01$, d = 0.80; Fig. 5E]. There were no differences in negativity bias score ($p = .93$).

Finally, we conducted a mixed repeated-measures ANOVA to examine the effect of emotional expression (negative, neutral, positive) as the within-subject factor and age group (young, old) as the between-subjects factor for lure discrimination of same person faces but with a changed appearance (high similarity) (Fig. 5C). There was a significant main effect of emotional expression [$F(2,88) = 5.71$, $p = .01$, $\eta_p^2 = 0.12$], where participants showed better lure discrimination of emotional (positive or negative) faces compared to neutral faces [post-hoc Scheffé: $F(1,44) = 11.25$, $p = .002$, $\eta_p^2 = 0.20$]. There was no main effect of age group ($p = .08$). However, there was a significant interaction between emotional expression and age group [$F(1,88) = 4.01$, $p = .02$, $\eta_p^2 = 0.08$], where the smallest age-related differences were observed for positive faces followed by neutral and negative faces [post-hoc Scheffé: $F(1,44) = 6.92$, $p = .01$, $\eta_p^2 = 0.14$]. Older adults remembered significantly more positive relative to neutral faces [$t(20) = 2.19$, $p = .04$, d = 0.48], but not negative relative to neutral faces [$t(20) = 1.63$, $p = .12$, d = 0.36]. We calculated positivity and negativity bias scores for each participant and found no significant effects for lure discrimination of faces of the same person but with a changed appearance (all p's > 0.05; Fig. 5F).

3.4. Self-report face recognition ability

We also collected two measures of self-reported face recognition ability to determine if individual differences in people's perceived

ability to remember faces may be related to face-name memory performance. First, we examined the 20-item Prosopagnosia Index (PI20) (Shah et al., 2015), in which higher scores indicate poorer self-reported face memory ability. We found a significant negative relationship between perceived face recognition ability and memory performance in older adults, including target recognition of face-name pairs [Pearson's r = -0.46, $p = .04$], lure discrimination of face-name pairs [Pearson's r = -0.73, $p < .001$; Fig. 6A], and lure discrimination of similar person lure pairs (low similarity) [Pearson's r = -0.46, $p = .04$]. Thus, the poorer perceived face memory, the worse ability to remember and discriminate faces and face-name pairs. This effect was specific to older adults, as we did not find significant correlations with young adults' self-reported face memory ability and memory performance: target recognition of face-name pairs [Pearson's r = 0.37, $p = .08$], lure discrimination of face-name pairs [Pearson's r = 0.27, $p = .20$], and lure discrimination of similar person (low similarity) faces [Pearson's r = 0.05, $p = .82$]. When directly comparing the correlation coefficients across young and older adults using a Fisher's r to z transform, the relationship between self-reported face memory ability and memory performance was significant different across age groups: target recognition of face-name pairs [z = -3.75, $p < .001$], lure discrimination of face-name pairs [z = -2.76, $p = .003$], and lure discrimination of similar person lure faces (low similarity) [z = -2.42, $p = .01$]. We also found the same relationship between self-reported face recognition ability as measured by the Cambridge Face Memory Questionnaire (CFMQ) (Arizpe et al., 2019), where higher scores indicate greater perceived face memory, for lure discrimination of face-name pairs [Pearson's r = 0.55, $p = .01$; Fig. 6B]. Again, we only saw these relationships in our older adult group (young: Pearson's r = 0.02, $p = .91$), and there was a significant difference across young and older adults when comparing correlation coefficients across age groups [z = -1.86, $p = .03$], suggesting poorer self-reported face memory ability is associated with worsened recognition and discrimination of face-name pairs, as well as impaired lure discrimination of similar person lure faces (low similarity) in aging.

3.5. The other race effect

Next, we conducted exploratory analyses to investigate the impacts of race on face and face-name associative memory given prior work examining the ORE, which can be characterized as superior recognition for own-race faces relative to other-race faces (Hugenberg et al., 2010; Chang et al., 2015; Yaros et al., 2019). We did not recruit participants to explicitly test the impact of race on memory, thus, we performed *post-hoc* analyses on White participants, which made up a significant proportion of our sample.

First, we assessed lure discrimination during Test 1 of same-race (White) and other-race faces (collapsed Black, Asian, and Multiracial into an Other race category) in White participants (N = 11 young, N = 20 old) by conducting a mixed repeated-measures ANOVA across face race (White, Other) as the within-subject factor and age group (young, old) as the between-subjects factor. For similar person lure discrimination (low similarity), we found a significant effect of face race [$F(1,28) = 5.67$, $p = .02$, $\eta_p^2 = 0.17$; Fig. 7A], where White participants discriminated White faces better than Other race faces. We found a significant effect of age group [$F(1,28) = 5.30$, $p = .03$, $\eta_p^2 = 0.16$], where older White participants showed worse memory for faces of a similar person (low similarity) compared to young White participants. There was no significant interaction between face race and age group [$F(1,28) = 1.18$, $p = .29$, $\eta_p^2 = 0.04$]. For lure discrimination of same person faces, but with a changed appearance (high similarity), we found a significant effect of face race [$F(1,28) = 6.63$, $p = .02$, $\eta_p^2 = 0.19$; Fig. 7B], where White participants discriminated highly similar White faces better than highly similar Other race faces. There was no significant interaction between face race and age group [$F(1,28) = 4.12$, $p = .05$, $\eta_p^2 = 0.13$] or main effect of age group [$F(1,28) = 0.93$, $p = .34$, $\eta_p^2 = 0.03$]. For target recognition, we did not find any significant impacts of
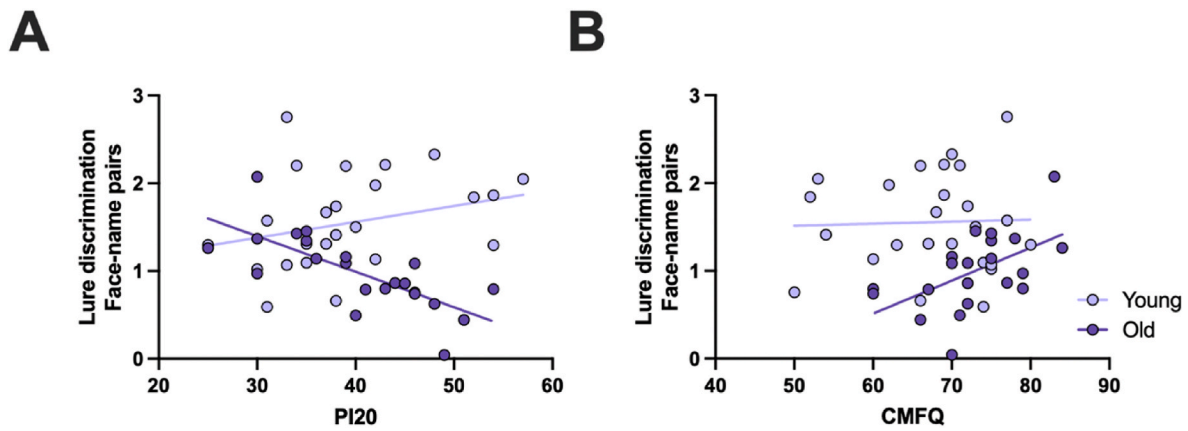
Fig. 6. Self-reported face recognition memory associations with face-name lure discrimination. A) Correlation between the 20-item Prosopagnosia Index (PI20) and face-name lure discrimination in young and older adults, B) Correlation between The Cambridge Face Memory Questionnaire (CFMQ) and face-name lure discrimination in young and older adults.
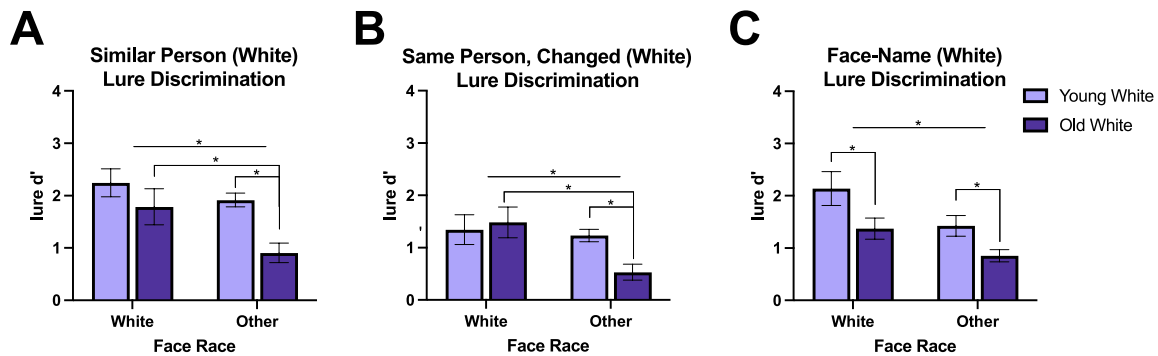

Fig. 7. Examining the impact of race on face-name mnemonic discrimination and the "other race effect". Young and old White participant performance in remembering White and Other race face stimuli across A) similar person lure discrimination, B) same person, changed appearance lure discrimination, and C) face-name lure discrimination. Asterisks highlight a subset of significant findings. See text for full set of significant results.

face race on memory (p's > 0.05).

Next, we examined face-name association memory of same-race (White) and other-race face-name pairs during Test 2 in White participants by conducting an ANOVA across face race (White, Other) as the within-subject factor and age group (young, old) as the between-subjects factor. For lure discrimination, we found a significant effect of face race [$F(1,28) = 15.06$, $p < .001$, $\eta_p^2 = 0.35$; Fig. 7C], where White participants showed enhanced face-name lure discrimination for White faces compared to Other race faces. We found a significant main effect of age group [$F(1,28) = 9.38$, $p = .01$, $\eta_p^2 = 0.25$], where older White participants showed worse face-name lure discrimination than younger White participants. There was no interaction between face race and age group [$F(1,28) = 0.39$, $p = .54$, $\eta_p^2 = 0.01$]. These effects were selective to face-name lure discrimination, as there were no significant impacts of face race on face-name target recognition (p's > 0.05).

4. Discussion

This study sought to develop a novel face-name mnemonic discrimination task that included more naturalistic face stimuli and conditions relative to existing face-name associative memory paradigms. To accomplish this, we developed a set of face stimuli of real people with naturalistic features (e.g., hair, glasses) and varied emotional expressions (negative, neutral, positive), similarity (same person with changed appearance, similar person), race (White, Black, Asian, Multiracial), and sex (male, female). We also generated lure names to mimic common

mistakes people make when trying to recall names by varying the beginning of the name (e.g., Jeffery and Jefferson), end of the name (e.g., Alissa and Melissa), or using similar sounding names (e.g., Simone and Sloane). The inclusion of lure stimuli has been shown to tax hippocampal pattern separation in a variety of mnemonic discrimination paradigms (Bakker et al., 2008; Yassa and Stark, 2011; Leal et al., 2014).

We found that across both young and older adults, our manipulation of lure similarity was successful such that memory performance showed a decreasing linear relationship with increasing interference across face and name features. These findings are in line with prior mnemonic discrimination tasks using face stimuli (Chang et al., 2015), but provides a more modern, naturalistic manipulation of facial features which will allow for greater generalization across individuals. This task has also been designed to include multiple levels of interference by manipulating face and name similarity, which offers a unique opportunity to test the individual's ability to resolve mnemonic interference (Leal and Yassa, 2018). The typically observed pattern of discrimination performance as a function of decreasing interference is largely linear. In conditions of altered memory such as aging, one might expect to see variations in this pattern, such that for certain interference conditions discrimination performance is lower or higher than that expected on the basis of young adult control performance. We indeed found age-related deviations from the linear relationship in young adults, where older adults performed worse than younger adults across our memory measures. Deviations from this linear pattern may be suggestive of impairments in hippocampal pattern separation, however, neurobiological data is required to

make such claims (Leal and Yassa, 2018).

We were surprised to find the largest difference across age groups for easier memory measures (e.g., target recognition) relative to more difficult memory measures (e.g., same person, changed appearance lure discrimination). Prior work has found a stronger relationship between age and lure discrimination relative to target recognition measures (Stark et al., 2013). Given our sample did not include a middle age group (35–60), we were unable to examine relationships between age and our memory measures continuously. Within the older adult group, we did not find significant relationships between age and any of our memory measures, likely due to the limited range of ages (ages 60–83) and small sample size (N = 21), but relationships were trending in the expected negative direction. Thus, future studies applying this task across the lifespan to examine how age interacts with target recognition and lure discrimination will be important to establish.

Our unique manipulation of similar person and same person lure faces allowed us to examine varying levels of similarity across faces that stem from different types of memory errors when remembering faces. For example, if you see someone you have met before, but they may be wearing glasses or have a different hairstyle, you would want to be able to recognize that it is the same person you saw before (same person, changed appearance lure manipulation). However, if you see someone who looks very similar to someone you met before, you might mistake them for someone you know even though they are a stranger (similar person lure discrimination). Participants performed most poorly on same person lure discrimination. While performance was quite low, it could be argued that poor memory in this case is a sign of adaptive cognition (e.g., recognizing someone even though their appearance changed). It is important to be able to create robust neural representations of people which can be retrieved given a partially overlapping or changed cue (e.g., a different hairstyle). However, the instructions given to participants while viewing the face stimuli was to indicate whether each face was *exactly the same* as before or if it was *new or different* in any way, so responding 'Same Exact Face' to a same person but changed appearance lure face would be characterized as an incorrect response. In sum, it is possible to interpret the low lure d' scores as an indication of impaired pattern separation, adaptive memory performance, or perhaps a misunderstanding of the instructions. Furthermore, the inclusion of highly interfering face and name stimuli in associative memory tasks may provide a more sensitive measure of face-name memory relative to traditional face-name memory tasks and may provide a potential mechanistic account underlying face-name associative memory. It will be important for future studies to examine what specific facial features people attend to most during successful lure discrimination, as studies suggest that people move their eyes to locations that maximize perceptual performance and tend to have optimal face recognition performance if looking just below the eyes (Peterson and Eckstein, 2012).

We also found that faces with emotional expressions tended to be better remembered than neutral faces across all memory measures. Interestingly, there was less memory impairment across same person and similar person lures for emotional information relative to neutral information, suggesting emotional facial expressions may protect memory from interference relative to neutral faces. However, these patterns of remembering emotional versus neutral faces differed across young and older adults, where older adults tended to best remember positive faces relative to negative or neutral faces. These findings are consistent with an age-related positivity effect (Mather and Carstensen, 2005). Previous studies have found that young adults better recall faces with emotional rather than neutral expressions. In contrast, faces with positive expressions are preferentially remembered in healthy older adults (Reed et al., 2014) and individuals with AD (Werheid et al., 2011; Maki et al., 2013). The socioemotional selectivity theory proposes that the awareness of having a limited remaining lifespan leads to older adults to prioritize positive experiences and well-being (Carstensen et al., 2003). We generally saw a positivity effect across all memory

measures; however, it was most evident during similar person lure discrimination, suggesting this level of facial feature overlap may be most sensitive to the positivity effect. During same person, changed appearance lure discrimination, the influence of positive emotion on memory was weaker, suggesting emotion may not be able to compensate for age-related memory decline when interference is high. Taken together, our findings suggest that the inclusion of faces with varying emotional expressions may provide a more nuanced metric of age-related changes in memory relative to general memory measures alone. The inclusion of emotional expressions further contributes to the naturalistic features of this task, as our social interactions with people are often colored by emotional context which may impact face-name associative memory (Chen, 2014). Future studies utilizing face-name mnemonic discrimination tasks may be able to parse these effects more clearly and provide a potential neural mechanism for these shifts in emotional processing with age.

While this study was limited to behavioral data, our hypotheses are rooted in the neuroscientific principles underlying mnemonic discrimination paradigms. Several studies have parametrically varied same person similarity and found evidence of differential responses in MTL activation and/or behavioral responses (Bencze et al., 2021; Youm and Moscovitch, 2021). Cross-species studies have found evidence of an age-related shift away from hippocampal pattern separation and towards pattern completion, or generalization in the face of interference, where there is reduced input into the DG and hyperactivity in the CA3 subregion of the hippocampus (Wilson et al., 2006; Leal and Yassa, 2015). In our prior work, we have found that even in cognitively normal older adults, some show signals consistent with emotional pattern separation in the DG/CA3 while others with subclinical memory impairment show DG/CA3 hyperactivity during false recognition (Leal et al., 2016). However, this was not the case for positive stimuli, suggesting older adults may start to show dysfunction in memory and MTL activity for negative and neutral events before positive events. Interestingly, we have also found evidence of MTL hyperactivity during positive false recognition in older adults with depressive symptoms (Leal et al., 2017), suggesting the examination of positive relative to neutral and negative memory may be a critical component of age-related memory decline. However, most studies of memory in aging focus on more general memory measures, either devoid of emotional content or included but not examined. Capturing memory and MTL changes across a range of older adults (e.g., those with subclinical memory impairment) will be important for future studies to determine whether the positivity effect often seen in aging is compensatory or a sign of a dysfunctional memory system.

The role of the amygdala in modulating hippocampal function (McGaugh, 2004) is also important to consider. Previously, we found a selective deficit in connectivity between the basolateral amygdala (BLA), lateral entorhinal cortex (LEC), and DG/CA3 in older adults with subclinical memory impairment that was selective to negative lure discrimination. The BLA's impact on DG/CA3 function was dependent on subclinical memory impairment (Leal et al., 2016). It will be important to examine amygdala-hippocampal connectivity during the face-name mnemonic discrimination task to determine how this connectivity changes as a function of age and subclinical memory impairment. Other studies have examined cortical regions outside the MTL, such as the fusiform face area (FFA), that show signals consistent with pattern separation for faces specifically (Rotshtein et al., 2005). The FFA, occipital face area (OFA), and other regions involved in face processing (Sperling et al., 2001, 2003; Zhao et al., 2018) will be important to examine in addition to how their connectivity with the hippocampus may change as a function of memory and age.

As part of the current study, we also collected self-report measures of face recognition memory. Interestingly, we only found relationships between older adults' self-reported face recognition memory with lure discrimination performance, not young adults. This suggests that older adults may be aware of the deficits they have in remembering faces and

names (Matsuyoshi and Watanabe, 2021) and that lure discrimination measures may selectively tap into these self-reported perceptions of face-name memory.

Finally, we also performed exploratory analyses examining the impact of the race of the face stimuli on memory. While we did not power our study to examine these effects, we had a large enough sample of White participants in which we were able to perform post-hoc analyses examining how White participants remembered White and Other race faces. We found that across all lure discrimination measures, but not target recognition, White participants remembered White faces better than other race faces. Furthermore, we found that these effects were true for both young and older adults, however, older adults showed a larger ORE when faces were highly similar (same person, changed appearance lures). Prior work examining ORE in the context of hippocampal pattern separation suggested that expertise plays an important role in resolving mnemonic interference, which may offer a mechanistic account for the ORE (Chang et al., 2015). Follow up studies found that the ORE is not simply attributable to visual and/or attentional processes, but depends on mnemonic functions (Yaros et al., 2019). Thus, the ORE may emerge in part due to "tuned" memory mechanisms that may enhance own-race, at the expense of other-race, face detection. Future studies powered across the races and ethnicities of the faces included in the current study (White, Black, Asian, Multiracial), will be an important next step to determine if these effects hold true across other races/ethnicities as well, especially given increased risk of AD in Black and Latino populations (Alzheimer's Association, 2023).

We also examined the impact of sex of the participants as a factor, but did not find any significant effects, likely due to small sample size that was biased towards females (68% female in the young sample and 81% female in the older adult sample). This impacted our ability to examine how sex of the participant may impact memory for faces of same and opposite sex. We hypothesized that participants would be better at discriminating faces within their own sex, and while we saw trends of this pattern in the female participants, the results were non-significant. This will be another important area for future studies to be powered to examine sex differences in face-name associative memory, especially given the increased risk of AD in women (Alzheimer's Association, 2023).

This study has some important limitations to note. First, given that we chose to include face images that were more naturalistic, this also limits our ability to control every aspect of image similarity since the images were not systematically varied. Future studies could characterize these components in more detail to capture which features of faces may be most helpful in remembering face/name information with varying levels of similarity (e.g., where are people's eyes focused). Second, while we developed a mnemonic discrimination task that includes lure stimuli thought to tax hippocampal pattern separation (Stark et al., 2013; Leal and Yassa, 2018), we did not include neurobiological data to provide support that the task measures this computation. This will be an important next step to determine the role of the MTL network and other relevant brain regions in performance on this task. Third, due to the COVID-19 pandemic, the study was conducted virtually through Zoom, which limits the control we have over technical difficulties, interruptions, and the space participants are in when participating in the study as well as who could participate in the study (e.g., those who lack access to a computer). We tried to control for these factors by asking participants to have a working camera, stable internet connectivity, and a quiet room throughout the duration of the study, but in general more variability may be introduced given this limitation. Fourth, while we categorized facial expressions into positive, negative, and neutral categories, there could be differential effects of emotional expression depending on the specific emotion within those valence categories (e.g., anger vs. sadness) (Liu et al., 2014). This will be another important direction for future studies to determine which emotional expressions may be most influential on our memories. Fifth, implicit categorizations observers make regarding the perceived sex, age, or race of faces may

also impact memory. While we aimed to include a diverse set of face stimuli and began to examine these effects in our exploratory analyses, we were not powered to assess all possible interactions due to the limits of our sample. The sample was weighted towards females versus males, and White versus other race subjects, which may impact the generalizability of our results. It will be essential for future studies to include a larger, more diverse sample to determine the effects of sex, age, and race on face-name associative memory. Finally, we examined cognitively normal older adults here; however, we do not have measures to indicate whether our older participants could have underlying AD pathology or subclinical memory deficits. Future studies should incorporate measures such as neuropsychological tests to ensure normal cognition as well as PET imaging techniques to measure amyloid and tau pathology that may be present in older adult brain decades before clinical symptom onset (Villemagne et al., 2013). This would then allow us to determine whether our age-related effects are indicative of cognitive decline due to normal or pathological aging.

5. Conclusion

This study sought to develop a novel face-name mnemonic discrimination task that included naturalistic face stimuli varied across similarity, emotional expressions, race, and sex. Results suggest the ability to discriminate lure faces and names from previously viewed faces and names decreases linearly as a function of similarity. Therefore, the inclusion of similar lure items, which are thought to tax hippocampal pattern separation, in a face-name associative memory task may provide a sensitive measure and mechanistic account of face-name memory impairment in aging. We also found that the inclusion of faces with emotional expressions may provide additional context about the nature of face-name associative memory. Future studies examining the neural mechanisms underlying these effects will be important.

Credit author statement

R.M. contributed to formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, and funding acquisition. A.H. contributed to project administration and writing – review and editing. F.M.C. contributed to formal analysis and writing – review and editing. S.L.L. contributed to conceptualization, Formal analysis, Writing – review & editing, Visualization, and supervision.

Declaration of competing interest

None.

Data availability

A link to the data included in the paper is included via GitHub..

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.neuropsychologia.2023.108678.

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