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OBSERVATION

Face Recognition Ability Matures Late: Evidence From Individual Differences in Young Adults

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Does face recognition ability mature early in childhood (early maturation hypothesis) or does it continue to develop well into adulthood (late maturation hypothesis)? This fundamental issue in face recognition is typically addressed by comparing child and adult participants. However, the interpretation of such studies is complicated by children's inferior test-taking abilities and general cognitive functions. Here we examined the developmental trajectory of face recognition ability in an individual differences study of 18–33 year-olds ($n = 2{,}032$), an age interval in which participants are competent test takers with comparable general cognitive functions. We found a positive association between age and face recognition, controlling for nonface visual recognition, verbal memory, sex, and own-race bias. Our study supports the late maturation hypothesis in face recognition, and illustrates how individual differences investigations of young adults can address theoretical issues concerning the development of perceptual and cognitive abilities.

Keywords: face recognition, cognitive development, visual development, late maturation, individual differences

One of the most impressive feats of the human visual system is the ability to recognize a face by distinguishing it from thousands of other faces in memory. How does this remarkable skill develop? According to the late maturation hypothesis, face recognition ability does not reach adult level until adolescence or even later (Carey & Diamond, 1977; Mondloch, Le Grand, & Maurer, 2002). This hypothesis is consistent with findings of greater improvement on face recognition than nonface recognition tests across childhood (e.g., Carey & Diamond, 1977; Mondloch et al., 2002) and with recent neuroimaging reports of protracted development of face-selective regions relative to other category-selective regions (e.g., Golarai et al., 2007; Peelen, Glaser, Vuilleumier, & Eliez, 2009). In contrast, the early maturation hypothesis posits that face recognition ability matures early in childhood (Carey, 1981; Crookes & McKone, 2009). This hypothesis points out that adult-size face hallmarks (e.g., holistic processing, face-space coding) have been observed in children as young as 5 years old (e.g., Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007; Pellicano & Rhodes, 2003) and that studies that have found otherwise suffer from restriction-of-range limitations (Crookes & McKone, 2009; McKone, Crookes, Jeffery, & Dilks, 2012). Consequently, the hypothesis attributes improvement seen on face recognition tests throughout childhood and adolescence to the advancement of general cognitive functions rather than the development of face recognition itself.

These developmental hypotheses are typically evaluated by comparing child and adult participants in laboratory tests. Although these studies have made significant contributions to our understanding of development, their findings are challenging to interpret because children are inferior to adults in their test-taking skills and general cognitive functions. Indeed, it has been argued that laboratory tests dramatically underestimate children's face recognition ability: According to formal face recognition measures, typical 9- to 12-year-olds have scores indicative of prosopagnosia although they do not have significant deficits recognizing faces in the real world (McKone et al., 2012). Moreover, even when task difficulty for children and adults is equated, test-taking skills and general cognitive functions may still contribute differently across age groups.

Here we took a novel approach to sidestep these issues by evaluating the early- and late maturation hypotheses in young adult participants aged 18–33 years. This age range was chosen for several reasons. First, 18–33 year-olds are reasonably comparable in their test-taking skills. Second, general cognitive

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functions are thought to be relatively stable across this interval (Flavell, Miller, & Miller, 2001). Finally, face recognition performance was recently reported to peak at around age 33 (Germine, Duchaine, & Nakayama, 2011). Although consistent with the late maturation view, the Germine, Duchaine, and Nakayama (2011) study has two limitations. First, McKone, Crookes, Jeffery, and Dilks (2012) pointed out that the study might have been confounded by an own-race bias (i.e., better recognition for own- than other-race faces, Malpass & Kravitz, 1969): Germine et al. (2011) used Caucasian faces in their face recognition tests and their older adult groups had a higher proportion of Caucasian participants than their younger adult groups. Second, Germine et al. (2011) did not perform a regression analysis looking at the relationship between age and face recognition while holding other abilities (e.g., nonface visual recognition, verbal memory) constant. Given that face and nonface visual recognition are correlated (Dennett, McKone, Edwards, & Susilo, 2012; Wilmer et al., 2010), the observed age effects could have been accounted by these other abilities.

Our empirical strategy in this study was to investigate the relationship between age and face recognition ability while controlling for potential contributions from nonface visual recognition, verbal memory, sex, and own-race bias. Face recognition is modestly correlated with nonface visual recognition (Dennett et al., 2011; Wilmer et al., 2010) and weakly correlated with verbal memory (Wilmer et al., 2010). We included sex because some reports have found a female advantage in face recognition (McKelvie, Standing, Jean, & Law, 1993, but see Bowles et al., 2009). We addressed own-race bias by explicitly recording participants' ethnicity and visual exposure to Caucasian faces. The absence of a specific relationship between age and face recognition ability would be consistent with the early maturation hypothesis, and a positive association between age and face recognition ability, controlling for other variables, would support the late maturation hypothesis.

Method

Tests

Our main test was the Cambridge Face Memory Test (CFMT, Duchaine & Nakayama, 2006), a validated measure of face recognition that requires learning and recognition of unfamiliar Caucasian faces in different views and lightings. Participants attempted to memorize six target faces, and on each trial, they chose which one of three faces was a target in 72 trials (Figure 1A). Two other tests were used to measure nonface recognition abilities: an abstract art memory test (AAMT, Wilmer et al., 2010) and a verbal paired-associates memory test (VPMT, Woolley, Gerbasi, Chabris, Kosslyn, & Hackman, 2008). In the AAMT, participants studied 50 target abstract paintings and then selected which of three paintings was a target in 50 trials (Figure 1B). AAMT was chosen because abstract art is a nonface category that is similar to faces in terms of difficulty of verbalization and lack of obvious, identifiable contents. In the VPMT participants had to memorize 25 target word pairs, and then chose which one of four words was paired with a given word in 25 trials (Figure 1C).

All tests are highly reliable (all Cronbach's alpha > 0.78, Wilmer et al., 2010), thus appropriate for individual differences analyses (Wilmer, 2008).

Data Collection

All data were collected online via TestMyBrain.org, a Web site where visitors take part in behavioral experiments in exchange for feedback about their performance. TestMyBrain.org attracts participants with a wide age range from many countries, most of whom arrive from search engines or social networking sites. Data from TestMyBrain.org are comparable with data collected in the laboratory (Germine et al., 2012).

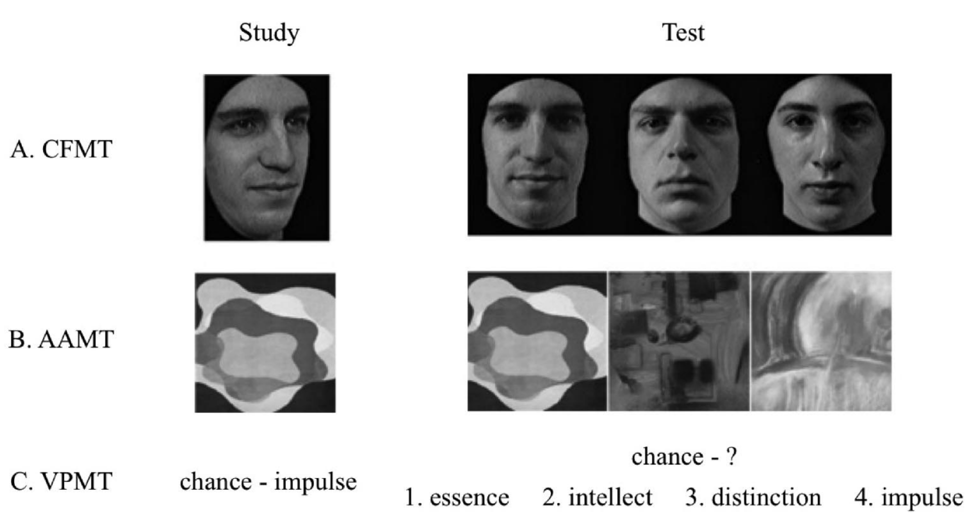

Figure 1. Example stimuli from (A) the Cambridge Face Memory Test (CFMT), (B) the Abstract Art Memory Test (AAMT), and (C) the Verbal Paired-associate Memory Test (VPMT). For the color version of the AAMT examples, please see Wilmer et al. (2010).

Data Screening

Participants were excluded if at least one of the following criteria applied: (a) they had taken the same test before; (b) they failed to indicate whether they were female or male; (c) their score was 0 (indicating technical problems or database errors); (d) they did not indicate normal or corrected-to-normal vision; or (e) they listed an age other than 18–33 years.

Participants

A total of 3,968 individuals were tested, 2,032 satisfied our inclusion criteria. Their mean age was 24.21 years (SD = 4.25) and 53.94% were female. We recorded participants' answers to three questions concerning their exposure to Caucasian faces: (a) ethnicity, (b) places they grew up, and (c) places they lived in the last five years. We gave a score of "1" if they had answered "European/White" for question 1 and predominantly Caucasian countries (United States, Canada, European countries, Australia, New Zealand) for Questions 2 and 3. Other answers were scored as "0." The scores were used to compute an "own-race bias (ORB) score" for each participant, which ranges from zero to three. For example, a participant whose ethnicity is Asian (0), grew up in Australia (1), and lived in the United States for the last 5 years (1) would receive an ORB score of 2.

Results

Performance was virtually free from floor and ceiling effects for the CFMT (0.98% of participants scored at chance or perfectly) and the AAMT (1.33%). Relatively more participants scored at chance on the VPMT (15.85%), but the correlations between VPMT and all other variables were nevertheless significant (see Table 1).

Descriptive statistics, zero-order correlations, and regression coefficients are shown in Table 1A. Because the zero-order correlation between age and CFMT was significant, we ran a multiple regression analysis with age, sex, AAMT, VPMT, and ORB as predictors of CFMT. The regression model was significant, $F(5, 2026) = 32.83$, $p < .001$. Age, AAMT, VPMT, and sex emerged as significant predictors of CFMT, but ORB did not. Crucially, this is not because our sample did not exhibit an own-race bias in face recognition: The zero-order correlation between ORB and CFMT was significant, and this relationship persists when controlling for sex and age (b = 0.71, SE = 0.25, t = 2.83, p = .005). Holding other predictors constant, a year increase in age is associated with 0.27% improvement in CFMT, for a total of 4.08% increase between 18 and 33 years. The finding shows that age made positive contributions to CFMT, controlling for nonface visual recognition, verbal memory, sex, and own-race bias.

To rule out own-race bias as a potential confound more decisively, we conducted an additional analysis which only included participants with an ORB index of three; these are participants of European/White ethnicity who grew up and spent the last 5 years in either the United States, Canada, European countries, Australia, or New Zealand. The conservative screening resulted in a sample of 1,055 participants (57.73% female), with a mean age of 24.2 years (SD = 4.34). Descriptive statistics, zero-order correlations, and regression coefficients are shown in Table 1B. We obtained a similar result with this conservative dataset: The zero-order correlation between age and CFMT was significant, and the regression model with age, sex, AAMT, and VPMT as predictors of CFMT was significant $F(4, 1050) = 20.71$, $p < .001$. All predictors except sex made independent contributions to CFMT. Taking into account other predictors, CFMT performance increased by 0.25% per year increase in age, which amounts to a total increase

Table 1
CFMT Performance in 18–33 Years Age Range

	Zero-order correlations						Regression coefficients				
	Age	Sex	AAMT	VPMT	ORB	CFMT	*b*	*SE*	β	*t*	Sig.
A. Full dataset (n = 2,032)											
Age		−0.037*	−0.006	−0.054**	−0.004	0.075***	0.272	0.07	0.083	3.873	0.000***
Sex			0.074***	0.058**	0.121***	0.073***	1.451	0.602	0.052	2.409	0.016*
AAMT				0.263***	0.135***	0.241***	0.220	0.023	0.211	9.438	0.000***
VPMT					0.060**	0.141***	0.055	0.014	0.085	3.826	0.000***
ORB						0.071***	0.353	0.245	0.031	1.439	0.150
M	24.21	0.54	63.92	48.04	1.98	75.35					
SD	4.25	0.50	13.32	21.40	1.23	13.90					

	Zero-order correlations					Regression coefficients				
	Age	Sex	AAMT	VPMT	CFMT	*b*	*SE*	β	*t*	Sig.
B. ORB = 3 dataset (n = 1,055)										
Age		0.003	0.047	−0.007	0.086**	0.246	0.095	0.077	2.590	0.010*
Sex			0.009	0.030	0.046	1.130	0.834	0.040	1.355	0.176
AAMT				0.230***	0.229***	0.208	0.032	0.197	6.457	0.000***
VPMT					0.165***	0.077	0.020	0.119	3.888	0.000***
M	24.20	0.58	65.34	48.60	75.76					
SD	4.34	0.49	13.14	21.32	13.86					

Note. Means, standard deviations, zero-order correlations, and regression coefficients for relevant variables using (A) all participants, and (B) those with an ORB index of 3. AAMT, VPMT, and CFMT scores are in percentages. Asterisks denote significance levels.
* $p < .05$. ** $p < .01$. *** $p < .001$.

of 3.69% between 18 and 33 years. This result indicates a positive linear association between age and face recognition, controlling for nonface visual recognition, verbal memory, and sex.

It is possible, however, that CFMT performance improves linearly at the beginning of the age range (e.g., between 18 and 20 years) then plateaus afterward. To examine this possibility we performed two kinds of analysis. First, we added age squared as a predictor in our multiple regression analysis. If CFMT improves linearly only up to a certain age, age should be a positive predictor, and age squared should be a negative predictor. We ran a stepwise regression analysis of CFMT with age, age squared, sex, AAMT, VPMT, and ORB as predictors for the full dataset, and without ORB for the conservative dataset. Although age remained a positive predictor of CFMT, age squared was not significant in either the full ($t = -1.15$, $p = .25$) or the conservative ($t = -0.66$, $p = .51$) datasets, showing that the linear relationship between age and CFMT holds for the whole age range of 18–33 years. Indeed, such linear relationship is visible when we plotted raw and corrected CFMT at each age for the full and conservative datasets (see Figure 2).

Second, we reanalyzed our datasets excluding participants aged 18–19 years (see Table 2). Controlling for other variables, the correlation between age and CFMT in the 20–33 years age range was 0.043 for both the full and conservative datasets, and CFMT performance improves by 0.15% per year. This effect size effectively replicates the results of Germine et al. (2011), in which the same correlation (i.e., between age and CFMT in the 20–33 years age range) was 0.049. The associated *p* values were not significant, but this is due the relatively smaller sample size: The power of our study to detect a correlation of ~0.05 in the full dataset ($n = 1,736$) was 67%, and in the conservative dataset ($n = 885$) it was 44%.

Taken together, all these analyses provide support for the late maturation hypothesis in face recognition. Specifically, our results indicate that after controlling for nonface recognition ability, verbal memory, sex, and race of participants, age and CFMT correlated at ~0.08 in the 18–33 years age range, and at ~0.05 in the 20–33 years age range. Finally, it is worth noting that our data were collected via the Web so the visual stimuli varied across participants in terms of image resolution, lighting, size, and so forth. Because these variations are unlikely to vary with age, they might have added noise to the data. This consideration adds to the robustness of our findings.

Discussion

In this study we addressed whether face recognition ability matures early in childhood (early maturation hypothesis) or continues to develop well into adulthood (late maturation hypothesis). To answer this question we conducted an individual differences study of 18–33 year-olds, an age interval in which all participants are competent test takers with comparable general cognitive function. We found a small but significant positive association between age and face recognition, controlling for nonface visual recognition, verbal memory, sex, and own-race bias. Taking these factors into account, face recognition ability (as measured by the CFMT) increased by about 4% between ages 18 and 33. This finding supports the late maturation hypothesis and is consistent with a previous report of protracted development in face recognition (Germine et al., 2011).

Our study also sheds some light onto the issue of sex differences in face recognition. Sex and CFMT was correlated in the full dataset ($r = 0.073$, $p < .001$), and the correlation remained when we controlled for ORB (b = 1.83, $SE = 0.62$, $t = 2.94$, $p = .003$). Specifically, females ($n = 1,096$; M = 76.28; $SD = 13.84$) did slightly but significantly better on the CFMT than males ($n = 936$; M = 74.24; $SD = 13.90$), $t(2030) = 3.30$, $p = .001$. The sex-CFMT correlation was almost significant in the conservative dataset ($r = 0.046$, $p = .07$), likely due to power issues: CFMT

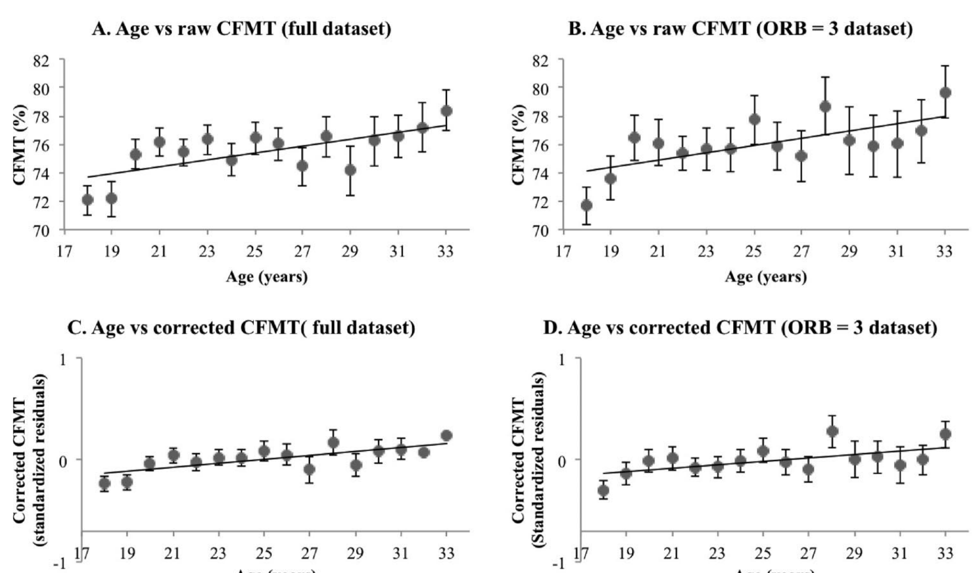

Figure 2. Mean CFMT scores in the 20–33 years age range. (A) Mean raw CFMT for the complete dataset. (B) Mean raw CFMT for the conservative dataset. (C) Mean corrected CFMT for the complete dataset. (D) Mean corrected CFMT for the conservative dataset. Error bars show ± 1 *SEM*.

Table 2
CFMT Performance in 20–33 Years Age Range

	Zero-order correlations						Regression coefficients				
	Age	Sex	AAMT	VPMT	ORB	CFMT	*b*	*SE*	β	*t*	Sig.
A. Full dataset (n = 1,736)											
Age		−0.038	−0.031	−0.080**	0.026	0.028	0.157	0.085	0.043	1.853	0.064
Sex			0.080***	0.056**	0.123***	0.072***	1.321	0.65	0.048	2.031	0.042*
AAMT				0.281***	0.148***	0.238***	0.211	0.025	0.203	8.32	0.000**
VPMT					0.075**	0.156***	0.063	0.016	0.098	4.026	0.000**
ORB						0.076***	0.36	0.264	0.032	1.36	0.174
M	25.19	0.54	64.10	48.16	1.96	75.92					
SD	3.81	0.50	13.29	21.55	1.24	13.85					

	Zero-order correlations					Regression coefficients				
	Age	Sex	AAMT	VPMT	CFMT	*b*	*SE*	β	*t*	Sig.
B. ORB = 3 dataset (n = 885)										
Age		0.007	0.016	−0.063*	0.039	0.154	0.117	0.043	1.320	0.187
Sex			0.023	0.024	0.036	0.807	0.915	0.029	0.882	0.378
AAMT				0.241***	0.224***	0.209	0.036	0.195	5.791	0.000**
VPMT					0.163***	0.076	0.022	0.118	3.501	0.000**
M	25.29	0.58	65.71	49.27	76.39					
SD	3.87	0.49	12.91	21.58	13.87					

Note. Means, standard deviations, zero-order correlations, and regression coefficients for relevant variables using (A) all participants, and (B) those with an ORB index of 3. AAMT, VPMT, and CFMT scores are in percentages. Asterisks denote significance levels.
* $p < .05$. ** $p < .01$. *** $p < .001$.

performance was still trending better for females (n = 609; M = 76.31; SD = 13.99) than for males (n = 446; M = 75.02; SD = 13.67). These results suggest that females are slightly better than males at recognizing unfamiliar (male) faces.

Our main finding raises a natural question: Do nonface recognition abilities also mature late? Our data suggest they do not. The correlation between age and VPMT in our conservative dataset is virtually zero, which means there is no relationship between verbal memory and face recognition in the 18–33 years age range. (The age-VPMT correlation in the full dataset is significantly negative, but this value is hard to interpret because of the potential confound of English as a native language for participants with ORB scores of 0–2.) We also found no correlation between age and AAMT, suggesting no late improvement for nonface visual recognition. These results suggest that late maturation may be specific to face recognition. We note, however, that one limitation of our study is the lack of nonface recognition tests that are more similar in demands to the CFMT, namely tests that assess the ability to recognize exemplars from a nonface class across changes in view and shadow, such as the Cambridge Car Memory Test (CCMT, Dennett et al., 2011). Future studies should revisit this issue using the CCMT, the house and phone versions of the CFMT (Martinaud et al., 2012), the Vanderbilt Expertise Test (McGugin et al., 2012), and others.

At first glance, our finding may seem inconsistent with evidence showing adult-size face hallmarks (e.g., holistic processing, face-space coding) in very young children (Crookes & McKone, 2009; McKone et al., 2012). One explanation is that these face hallmarks are perceptual in nature, and that the late maturation we observed involves nonperceptual factors such as memory. However, our study does not speak to the perception-memory distinction because the CFMT measures not only face memory but also face perception and other aspects of face processing relevant to the test. This view is supported by the 0.61 correlation between the CFMT and the Cambridge Face Perception Test (CFPT, Duchaine, Yovel, & Nakayama, 2007), a well-validated test of face perception; this correlation is not far from the upper-bound correlation of 0.81 (Bowles et al., 2009). A proper investigation of face memory per se would require testing our participants with the CFPT, for instance, and examine whether the age-CFMT relationship holds controlling for CFPT.

What causes face recognition ability to mature late? One possibility is the quantity of faces one is exposed to in daily life. The early twenties to early thirties is a life stage when young adults typically leave home and start to build a career and social relationships, which would involve meeting and interacting with many new individuals. One way to test this idea is to examine whether face recognition ability is linked to size of social network, the latter of which has been reported to predict individual differences in amygdala volume (Bickart, Wright, Dautoff, Dickerson, & Barrett, 2011) and in gray matter density of regions implicated in social perception (Kanai, Bahrami, Roylance, & Rees, 2011). Alternatively, given evidence for a strong role of genes from twin studies (Wilmer et al., 2010) and familial prosopagnosia (Lee, Duchaine, Nakayama, & Wilson, 2010; Schmalzl, Palermo, & Coltheart, 2010), face recognition may mature late due to protracted expressions of genetic factors. Of course, these experience- and genetic-based accounts are not mutually exclusive.

To conclude, in this study we found a positive association between age and face recognition ability in 18–33 year-olds, controlling for nonface visual recognition, verbal memory, sex, and own-race bias. Our finding supports the late maturation hypothesis in face recognition, as measured by a test assessing both face perception and face memory abilities. Several points are worth noting. First, because our data were cross-sectional rather than longitudinal, as is the case for most developmental studies, we cannot rule out potential cohort effects (Schaie, 1965), and we had to assume that interindividual data can reveal developmental processes at the intraindividual level (Molenaar, Huizenga, & Nesselroade, 2003). Second, our study speaks only to the ability to recognize unfamiliar faces after a fairly short delay. Recognition of faces that are encountered multiple times, including those of friends, family, or famous individuals, may mature along a different developmental trajectory. Finally, our study illustrates how individual differences studies of young adults can address theoretical issues concerning the development of visual and cognitive abilities, and potentially of other faculties of the human mind.

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