Assessing the long-term face memory of highly superior and typical-ability short-term face
recognisers

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Keywords

Face recognition, long-term memory, super-recognition, line-up, identification

Abstract

Outstanding long-term unfamiliar face recognition ability is the hallmark of the exceptionally skilled ‘super-recognisers’. Indeed, international police super-recogniser units rely on members identifying unfamiliar suspects from CCTV after substantial delays. Yet, virtually all research has employed brief retention intervals to evaluate super-recognisers’ capabilities. To address this gap in the literature, in Experiment 1, participants ($n = 597$), including 84 super-recognisers, viewed 10 60s target-actor videos and identified targets from 10 target-present line-ups after random delays of 1, 7, 14, 28, or 56 days. In Experiment 2, participants ($n = 1421$), including 206 super-recognisers, viewed 20 30s target-actor videos and identified targets from 10 target-present and 10 target-absent line-ups after delays of virtually none, 1, 7, and 28 days. Correct target-present identifications, and with smaller effect sizes, correct target-absent line-up rejections were predicted by short-term face memory and matching test scores, and decision confidence. Delay also predicted correct target-present identifications but not correct rejections. With higher confidence, most super-recognisers (82.5%) individually exceeded overall control mean hit rate accuracy. However, only a minority of comparisons were significant (28.5%). The important applied implication was the demonstration that not all super-recognisers can sustain their skills over longer retention intervals. Therefore, recruitment to super-recogniser research groups, or roles in policing or security require longer-term face memory tests. Important theoretically was the finding that super-recogniser’s estimated forgetting curve was shallower than that of controls, implying that their enhanced mnemonic system for faces allows representations in memory to be more reliably sustained for far longer.

Introduction

The face recognition ability spectrum in the population ranges from *developmental prosopagnosics* (DPs) who struggle to recognise even familiar faces (e.g., Behrmann, Avidan, Marotta, & Kimchi, 2005; Bobak, Parris, Gregory, Bennetts, & Bate, 2017; for a review see Susilo & Duchaine, 2013), to the so called *super-recognisers* (SRs) with exceptional unfamiliar face memory (e.g., Russell, Duchaine, & Nakayama, 2009; for a review see Noyes, Philips, & O'Toole, 2017). Ability is inherited (e.g. Shakeshaft & Plomin, 2015; Wilmer et al., 2010), impacted by exposure (e.g., cross-age effect: Wiese, Komes, & Schweinberger, 2013; cross-ethnicity effect, Meissner & Brigham, 2001), and bears only weak relationships with other cognitive skills, and the recognition of non-face objects (e.g., Bobak, Bennetts, Parris, Jansari, & Bate, 2016; McCaffery, Robertson, Young, Burton, 2018; Royer et al., 2018; Verhallen, Bosten, Goodbourn, Lawrance-Owen, Bargary, & Mollon, 2017; Wilmer et al., 2010).

Recent studies have evaluated SR's superiority at short-term unfamiliar face memory (e.g. Bate et al., 2018; Russell et al., 2009), simultaneous unfamiliar face matching (e.g., Bobak, Hancock, & Bate, 2016), and long-term *familiar* face recognition (e.g., Davis, Lander, Evans & Jansari, 2016; Russell et al., 2009). However, SRs often self-report exceptional long-term *unfamiliar* face memory (e.g. Russell et al., 2009), and yet only one study has investigated this (Davis & Tamoytè, 2017). The authors found that SRs were more accurate and confident than controls over retention intervals of about 10 days. However, only one target-actor was employed as a stimulus, limiting generalisability. Recruiting one of the largest SR samples to date, the current research aimed to address this gap in the literature.

This research has important theoretical and applied implications. Until relatively recently, face recognition research evaluating different ability groups tended to examine

controls scoring in the typical-ability range and/or prosopagnosics. Following the first empirical evaluation of SRs (Russell et al., 2009), and the understanding that the face recognition ability spectrum has a much wider range than previously realised, some reappraisal of theories may be necessary (i.e. those in relation to face expertise; Burton & Young, 2018). Empirically evaluating the capabilities of those at the top end of the spectrum across different retention intervals should enhance knowledge of human face memory capacity.

Practically, some police forces deploy SRs to roles utilising their superior skills. For instance, London's Metropolitan Police Service (MPS) created a full-time SR Unit (more recently labelled 'image recognisers') with staff daily reviewing CCTV images of unidentified suspects (Davis et al., 2016; Davis, Treml, Forrest, & Jansari, 2018; Robertson, Noyes, Dowsett, Jenkins, & Burton, 2016). Suspects are sometimes spontaneously later recognised in person in large crowds (i.e. the case of Ilhan Karatepe; O'Keefe, 2016, 22 August), or more commonly, when true identity was still unknown, in footage of subsequent crimes (i.e. the case of Austin Caballero; Robertson, 2016, April 2). In these cases, the SR officer could access the previous footage, or facial stills extracted from the footage stored on a database in order to simultaneously match images of the people depicted. SR police working in these teams therefore needed exceptional long-term unfamiliar face recognition ability and simultaneous face matching ability. In this manner, a team of seven police SRs made about 1,071 suspect identifications in 30 months (Davis et al., 2018). Although no data is available as to typical retention intervals between initial viewing and subsequent identification, the average delay between a crime occurring and images being available on the MPS database was about 40 days (M. Neville - former MPS Detective Chief Inspector, private communication, 2019, 6 August).

As face identification ability is not amenable to training (e.g., Towler et al., 2019), or improved from experience in a job role requiring such skills (i.e. passport officers, White, Kemp, Jenkins, Matheson, & Burton, 2014), understanding SRs' aptitudes on empirical tasks replicating real-world deployment may assist in suitable recruitment test development (e.g. Ramon, Bobak, & White, 2019).

Following precedent (e.g., Bobak, Bennetts et al, 2016; Bobak, Hancock et al., 2016; Russell et al., 2009), SR group inclusion criteria here were scores 2 standard deviations (SD) above the estimated population mean (i.e. top $\approx 2\%$) based on a representative sample (Bobak, Pampoulov, & Bate, 2016) on the short-term *Cambridge Face Memory Test: Extended* (CFMT+) (Russell et al., 2009). Ability was verified using a second short-term face memory test.

Long-term face memory

Research with participants scoring in the typical range has examined face recognition accuracy using retention intervals of four weeks or more (e.g., Courtois & Mueller, 1981; Sauer, Brewer, Zweck, & Weber, 2010; Shepherd & Ellis, 1973; Shepherd, Ellis, & Davies, 1982; Yarmey, 1979; for a review see Deffenbacher, Bornstein, McGorty, & Penrod, 2008). None evaluated individual differences in face recognition ability. The forgetting curve for the human face embraces a form determined by Ebbinghaus (1913) for other stimuli. Although factors such as facial distinctiveness (Wickham, Morris, & Fritz, 2000), initial memory strength (Deffenbacher et al., 2008), and repeated exposure (e.g. Deffenbacher, Bornstein, & Penrod, 2006) have an impact, most forgetting occurs in the first 24 hours, and gradually increases over longer periods (Deffenbacher et al., 2008).

If SRs' abilities are driven by enhanced face *encoding*, then their forgetting curve might be predicted to match the shape of typical-ability controls. However, if superiority is driven by enhanced long-term memory, then a shallower forgetting curve than controls might be expected. This was examined in the current research by varying retention intervals between learning and test.

Relationship between accuracy and confidence

Long-term face memory test decision confidence data were also collected. In an applied context, high confidence in a potential suspect identification, would likely drive decisions as to whether evidence should be followed up. It is important therefore to measure whether the calibration between confidence and accuracy is influenced by face recognition ability and delay. Most research finds moderate positive correlations between accuracy and confidence, although the relationship is normally stronger in choosers who select a face from a line-up, in comparison to those who make no selection (for a meta-analysis see Sporer, Penrod, Read, & Cutler, 1995). According to Weber and Brewer's (2004, 2006) *Information Asymmetry Hypothesis*, decisions to select a face and confidence in that selection will be based on the degree of match between the selected face and the target face representation in memory. As such, face representations will decay from delay reducing accuracy and confidence. However, a decision to reject a line-up as not containing the target draws on a qualitatively different experience, as no one matches that representation. As there is also no one-to-one comparison on which to reliably anchor confidence, this means the relationship between an accurate correct rejection and confidence should be weaker regardless of delay.

Superior face recognition ability is associated with higher confidence in accurate identifications, and lower confidence in misidentifications (Grabman, Dobolyi, Berelovich, &

Dodson, 2019; see also Davis, Treml, Forrest, & Jansari, 2018). These effects can be explained by Deffenbacher's (1980) *Optimality Model* which suggests that confidence reliability is based on the strength of a facial representation in memory. As poorer face memory is likely linked to weaker face representations, confidence reliability is also weaker. This suggests that there should be a stronger relationship between identification accuracy and confidence in a correct target identification by SRs than by controls.

SRs are also more accurate than controls at correctly rejecting previously unseen faces (e.g., Bate et al., 2019; Davis et al. 2016). This implies that SRs may be able to better determine when stored face representations do not match with viewed faces. Although the accuracy-confidence relationship is normally weak in non-choosers, this raises the intriguing possibility that there might also be a stronger relationship between correct rejection accuracy and confidence in SRs than in controls. On the other hand, if SRs cannot better employ stored representations to anchor correct rejection confidence, the relationship between accuracy and confidence in target-absent trials should be similar in SRs and controls.

The current research

The primary aim of the two experiments described here was to examine the relationship between unfamiliar short-term face memory, simultaneous face matching, and long-term face memory and confidence in SRs and participants with typical-range ability. Most long-term face memory research uses one target and one line-up to assess eyewitness performances. As SR unit police can encounter large numbers of unknown suspects, often displayed on moving images, participants were exposed to a series of action-varying videos of target-actors. Long-term face memory was assessed using six-persons line-ups of the type used in eyewitness identification procedures. In Experiment 1, all 10 line-ups were target-

present, and planned delays varied from one day to 56 days. Experiment 2 employed 10 target-present and 10 target-absent line-ups to better discriminate between high and low performers. Retention intervals varied from virtually no delay to 28 days.

As possession of superior long-term face memory and simultaneous face matching ability may be important in applied policing contexts, to measure the latter, participants completed the *Glasgow Face Matching Test* (GFMT) (Burton, White, & McNeill, 2010), a perceptual task with virtually no memory demands. The test's inclusion also allowed replication of previous research finding that although many SRs are outstanding at both face memory and matching tasks, some SRs display poor simultaneous face matching skills (e.g. Bobak, Bennetts et al., 2016; Bobak, Dowsett et al., 2016; Bobak, Hancock et al., 2016; Davis et al., 2016). These dissociations have generated suggestions that different types of SR might exist, although poor performances on any test may be due to a lack of engagement or other factors not related to face recognition ability.

As with other online face recognition research that tends to attract far greater numbers of superior performers than in student-participant-dominated laboratory-typical (e.g., Belanova, Davis, & Thompson, 2018; Satchell, Davis, Julle-Danière, Tupper, & Marshman, 2019), a large proportion of participants in the current research achieved SR criteria. Many more scored slightly below our SR threshold, while only a few scored below the typical CFMT+ (Russell et al., 2009) control mean in research.

A three-component strategy was therefore employed to reduce the impact of this recruitment bias. First, with the inclusion of all participants, correlations examined relationships between all test outcomes, in order to evaluate predictors of long-term face test accuracy. Nevertheless, restricted range samples can reduce the strength of correlations (e.g. Goodwin & Leech, 2006). Therefore, for the second component, the performances of SRs and controls who scored in the typical-ability range on our short-term memory tests were

compared (i.e. by excluding participants scoring just below SR standard). Third, individual analyses compared performances of each SR against the mean of controls. This generated an estimate of the proportion of short-term memory test identified SRs who would also be considered SRs at simultaneous face matching and long-term face recognition.

Experiment 1

In Experiment 1, Participants completed the CFMT+ (Russell et al., 2009), the GFMT (Burton et al., 2010), and an ability-verifying *Short-Term Face Memory Test* (STFMT) prior to starting a 10-trial *Long-Term Face Memory Test* (LTFMT10) with delays of 1 to ≥ 56 days. In Phase 1 of the LTFMT10 (learning phase) they viewed ten 60s target videos. In Phase 2 (test phase) they identified targets from ten 6-person target-present *hybrid-video* line-ups. With these line-ups, each line-up member's video played sequentially, while still images of the others remained visible. The aim was to optimise identification likelihood, as simultaneously presented line-ups generate higher accuracy than sequential line-ups (e.g. Mickes, Flowe, & Wixted, 2012). Movement can also enhance unfamiliar face recognition (e.g. O'Toole, Roark, & Abdi, 2002), although this may be due to availability of additional cues in multiple video frames, rather than movement itself (although see Lander, Christie, & Bruce, 1999).

Before starting Experiment 1, participants provided self-assessments of their face recognition ability as an estimate of their domain-specific meta-memory, or knowledge as to their memory capabilities. Some memory research finds correlations between meta-memory and test performances (e.g. Kliegel & Jager, 2006). However, many self-professed SRs overestimate their ability (e.g. Bate et al., 2018), and responses on this type of scale are often not predictive of face recognition scores (e.g. Bobak, Mileva, & Hancock, 2019), or eyewitness

accuracy in non-SRs (e.g. Perfect, 2004). This suggests that the relationship between self-assessments and LTFMT10 accuracy in Experiment 1 might be low. However, meta-memory might be expected to have a stronger influence on identification decision confidence, and therefore the use of this one-item scale allowed isolation of the effects of ability self-beliefs, on LTFMT decision confidence and accuracy in Experiment 1.

Previous research has found positive relationships between simultaneous face matching and short-term memory (e.g. McCaffery et al., 2018), and between short-term and long-term face memory (e.g., Bindemann, Brown, Koyas, & Russ, 2012; Davis & Tamoytè, 2017), with longer delays resulting in lower accuracy and decision-confidence (e.g. Deffenbacher et al., 2008). Similar effects were predicted here.

Method

Design

In Experiment 1, participants first completed a single-item scale measuring face recognition ability self-beliefs, the CFMT+ (Russell et al., 2009), the GFMT (Burton et al., 2010), and the ability-verifying STFMT, before viewing ten 60s target-actor videos in Phase 1 of the LTFMT10. After random delays of 1, 7, 14, 28, or 56 days, they received invites to Phase 2 of the LTFMT10 during which they viewed ten 6-person target-present hybrid-video line-ups. The dependent variables were correct line-up identification rates (hits), incorrect foil identification rates (foil IDs), and incorrect rejections of the line-ups (misses), as well as decision-confidence (0%: guessing to 100%: absolutely certain). A correlational design examined the relationships between performances on each test, as well the variance associated with pre-tested ability, confidence, meta-memory, and delay on LTMT10 hit rates.

With a sub-set of participants, a 2 (*group*: SR, typical-ability control) x 5 (*actual delay interval*: 1-6, 7-13, 14-27, 28-55, 56+ days) between-subjects design evaluated outcome differences, while individual analyses (Crawford, Garthwaite, & Porter, 2010) compared performances of each SR against the control mean.

Materials

Cambridge Face Memory Test: Extended (CFMT+: Russell et al., 2009): This test is an updated 102-trial version of the standard 72-trial CFMT (Duchaine & Nakayama, 2006). Participants' short-term learning and recognition of six white-Caucasian male hairstyle-cropped target faces is tested in an increasingly difficult three-alternative forced-choice paradigm across four blocks. Bobak, Pampoulov et al.'s (2016) participants may be the most representative UK sample to take this test ($n = 254$, $M = 70.72$, $SD = 12.32$). Consistent with the expected recruitment bias, with strong effect sizes, a one-sample t-test revealed that participants in the current research significantly outperformed this standard ($M = 86.62$, $SD = 9.52$), $t(596) = 40.87$, $p < .001$, *Cohen's d* = 1.45.

Glasgow Face Matching Test (short version) (GFMT) (Burton et al., 2010): This 40-trial test contains simultaneously presented pairs of white-Caucasian male and female facial images. Twenty trials are matched. For these, a correct response is 'same' (recorded as a 'hit'); 20 are mismatched and require a "different" response ('CR'). Hits ($M = 0.93$, $SD = .08$), and CRs ($M = 0.93$, $SD = 0.08$), were transformed into signal detection theory (SDT) measures of sensitivity [$d' = z(\text{False Alarms} = 1 - \text{CRs}) - z(\text{Hits})$] ($M = 3.12$, $SD = 0.66$), and response bias ($C: \text{Criterion} = -0.5[z(\text{Hits}) + z(\text{False Alarms})]$) ($M = < 0.01$, $SD = 0.27$) (Green & Swets, 1966; Macmillan & Creelman, 2004). Current participants ($M = 37.3$ (93.3%), $SD =$

2.5), significantly outperformed Burton et al.'s norms ($M = 32.5$ (81.3%), $SD = 9.7$), $t(596) = 47.83$, $p < .001$, *Cohen's d* = 1.48.

Short-Term Face Memory Test (STFMT): This bespoke test's learning phase sequentially displayed 30 frontal-view colour photos of young adult white-Caucasian males wearing identical shirts for 10s (kindly provided by Meissner, Brigham, & Butz, 2005). In the immediate test phase, 60 males in varied clothing were sequentially displayed. Hairstyle was visible in both phases. With no time limits, participants judged whether faces were 'old' (hits: 30 faces) or 'new' (CRs: 30 faces). Data were collected of hits ($M = 0.77$, $SD = 0.13$), CRs ($M = 0.82$, $SD = 0.11$), d' ($M = 1.84$, $SD = 0.66$), and C ($M = 0.10$, $SD = 0.34$).

Long-Term Face Memory Test (10-trial: LTFMT10): To familiarise participants to requirements, this test commenced with a practice trial. Participants were shown an example cartoon character Phase 1-type video and immediately afterwards a cartoon Phase 2-type target-present line-up. The ten Phase 1 videos were then sequentially displayed for 60s each. The videos depicted white-Caucasian target males ($n = 5$) and females ($n = 5$) in good lighting. Clothing and actions differed to assist discrimination. For instance, some actors walked towards the camera, others sat or stood behind a table or desk. One played golf. Each video clip displayed some close-up facial views. The videos were time-limited and unless problems were reported (see below), they could not be replayed.

For Phase 2, actors wore different clothing, and PROMAT™ video line-ups (Promat Envision International, Nelson, Lancashire, UK) were created at a London police station by an experienced Metropolitan Police Service officer. A 15-sec head-and-shoulders video was filmed of each actor, and the officer selected eight foils of the same age, ethnicity, and 'position in life' from a database of over 23,000 videos (see Davis, Maigut, Jolliffe, Gibson,

& Solomon, 2015, for a video depicting the PROMAT system). Normally, PROMAT line-ups contain nine members, each displayed sequentially for 15s. However, pilot testing ($n = 40$) revealed close-to-floor performances after 7-day delays. Therefore, the three foils most often selected were excluded from each line-up, being probably the hardest to distinguish from targets. Furthermore, as simultaneously presented line-ups may generate higher accuracy (e.g. Mickes et al., 2012), a 3 x 2 *hybrid-video* design was created. With these, from top left, to bottom right, each line-up member's video played sequentially (12s each), while a still frontal image of the other members remained visible in an array. The sequence repeated until a response was made. Note: To reduce time demands, 1.5s was cut from the start and end of all PROMAT videos while all line-up members were facing the front.

The final line-ups were sequentially displayed in the same order as first phase videos (i.e. Actor A's Phase 1 video and Phase 2 line-up was displayed first). Target-actor and foil positions within line-ups were randomised and counterbalanced. Participants were correctly informed that "the target-actor is definitely present in each line-up". Participants identified targets by selecting a line-up number (1-6), or they rejected the line-up ('none of the above'). Regardless of response, they provided a confidence rating (0%: guessing to 100%: absolutely certain). Correct line-up identification rates (hits), incorrect foil identification rates (foil IDs), incorrect line-up rejections (misses), and mean decision confidence ratings were calculated.

Regardless of delay, mean hit rates to each actor on the LTFMT10 ranged from 68% to 26% (chance levels = 16.7%).

Participants

Participants contributed after reading media articles about super-recognition linked to an online anonymised 5-min fun, *Could you be a Super-Recogniser Test*¹. On completion, they were invited to participate in the current research and warned they would need to provide e-mail addresses removing anonymity. None were compensated for their time, and all duplicate entries, and participants who had taken any of the tests previously in our research were excluded. In total, 1570 viewed LTFMT10 Phase 1. Only 597 (38.0%) completed Phase 2. All were included in correlational analyses (male = 241, female = 356; aged 16-74 years, $M = 35.3$, $SD = 11.6$; White-Caucasian = 505 (64.3%), second largest group (black = 10)).

Inclusion criteria for SR and typical-ability control groups were based on CFMT+ scores and the ability-verifying STFMT. SR threshold was a CFMT+ score (95+ out of 102) in the top 2% (i.e. 2 SD above the mean) of Bobak, Pampoulov et al.'s (2016) sample.

To reduce the recruitment bias to attract high scorers, typical-ability controls scored within 1 SD of that mean (58-83 out of 102).

To ensure all SRs outperformed all controls, STFMT threshold was additionally the sensitivity mid-point between SR and control means ($d' = 1.815$). As such, SRs who had achieved CFMT+ criteria but scored below this threshold were excluded. Likewise, controls scoring above the threshold were excluded. In addition, controls scoring more than 1 SD below the control STFMT mean, suggesting 'worse than typical ability' or possibly a lack of engagement, were also excluded.

Final SR ($n = 84$, male = 33, female = 51; aged 19-64 years, $M = 33.5$, $SD = 9.7$, white = 69 (83.1%)) and control groups ($n = 103$, male = 55, female = 48; aged = 16-74 years, $M = 35.7$, $SD = 13.8$, white = 86 (83.5%)), were matched on age, gender (Male = 1 vs. female = 0), and ethnicity (White = 1 vs. other ethnicity = 0) ($p > .05$).

¹ www.superrecognisers.com

Despite inclusion criteria designed to reduce the recruitment bias, controls still significantly outperformed Bobak, Pampoulov et al.'s (2016) representative sample mean on the CFMT+, $t(102) = 7.50, p < .001$, Cohen's $d = 0.47$.

Table 1: Results of between-group t-tests comparing ability self-beliefs, CFMT+, STFMT, and GFMT outcomes in Experiment 1

	SRs		Controls					
	SR and control group inclusion criteria							
CFMT+	95-102		58-83					
STFMT d'	> 1.815		1.03-1.815					
n	84		103		df	t	d	p
	M	SD	M	SD				
Self-belief	3.99	0.94	3.76	0.82	184	1.73	0.26	.085
CFMT+	97.1	1.90	75.3	6.27	124.4	33.33	4.71	<.001
STFMT								
Hits	0.87	0.08	0.72	0.11	183.9	10.32	1.56	<.001
CRs	0.90	0.07	0.77	0.10	183.5	10.76	1.51	<.001
d'	2.60	0.53	1.38	0.25	112.3	19.30	2.94	<.001
C	0.07	0.31	0.09	0.34	185	-0.31	0.06	>.2
GFMT								
Hits	0.97	0.05	0.89	0.09	167.5	6.82	1.10	<.001
CRs	0.96	0.06	0.88	0.11	158.4	6.51	0.90	<.001
d'	3.48	0.49	2.64	0.68	182.7	9.91	1.42	<.001
C	-0.03	0.21	-0.03	0.34	174.7	0.06	<0.01	>.2

Table 1 displays SR and control group ability self-ratings and mean test performances on the CFMT+, STFMT and GFMT. Independent-measures t-tests demonstrated no significant self-belief or response bias (C) differences. However, with strong effect sizes, SRs outperformed controls on all accuracy measures.

Procedure

Participants were invited to contribute to research loaded on the Qualtrics platform ², and asked not to use tablets/mobiles to optimise image size. After providing informed consent, and face recognition ability self-assessments to assess meta-memory (1: 'far below

² www.qualtrics.com

average' to 5: 'far above average'), they completed the CFMT+, STFMT, and GFMT. They were then fully debriefed and provided with scores on the three tests.

All participants were then immediately invited to participate in the LTFMT10. After providing informed consent for a second time, they viewed the Phase 1 videos. After each, questions asked whether, participants had seen that actor before (none had) and whether the video had played properly. If participants clicked 'no', that video was repeated. There were 372 reported problems out of 15,700 plays (2.36%) ($n = 203$ participants). Repeated plays had no impact on whether participants completed Phase 2 or not; or on results reported below ($p > .2$).

On completion of Phase 1, participants were warned to watch out for their Phase 2 invite e-mail. As delay was random, no information was provided as to when it would be sent. In total, 1,570 participants completing LTFMT10 Phase 1 were e-mailed Phase 2 invites, with 597 finishing the LTFMT10 (38.0%). A point-biserial correlation examining the relationship between CFMT+ scores and finishing or not (1 = finisher, 0 = non-finisher) was positive and significant, $r(1570) = .16$, $p < .001$. More SRs (48.0%) completed Phase 2 than controls (28.7%), $\chi^2(1, 534) = 19.28$, $p < .001$, Cramer's $V = .190$.

Results

LTFMT10 delay (Median = 14 days, $M = 24.1$, $SD = 23.9$) varied from 1-182 days (see Figure 1); and was skewed (Shapiro-Wilk (597) = 0.83, $p < .001$), so that where suitable, non-parametric tests were employed. Mean delay did not differ between SRs and controls, $t(185) < 1$. Seven participants achieved LTFMT10 scores of 10 out of 10 ($n = 21$ scored 0) (Median = 4, $M = 4.08$, $SD = 0.24$).

Figure 1: LTFMT10 delay and hit rates for all participants in Experiment 1 ($n = 597$)

Correlational analyses: With the inclusion of all participants, Table 2 presents Spearman's correlation coefficients across all test outcomes. While scores on all four face processing tests were as expected significantly positively related, the correlations between the face matching (GFMT) and short-term memory tests (CFMT+, STFMT), were stronger than those between these tests and LTFMT10 hits. Self-belief significantly, but weakly correlated with the CFMT+, GFMT, and LTFMT10 confidence, but not LTFMT10 hits. Finally, as predicted, LTFMT10 hit rates were negatively associated with delay, and positively with confidence.

Table 2. Spearman's correlation coefficients between all measures in Experiment 1 ($n = 597$)^{A B}

	CFMT+	GFMT	STFMT	LTFMT10		
				Delay	Hit rates	Confidence
Self-belief ^C	0.15 *	0.18 *	0.10 *	0.03	0.04	0.15 *
CFMT+		0.42 *	0.37 *	0.02	0.23 *	0.04
GFMT d/			0.31 *	<0.01	0.20 *	0.06
STFMT d/				-0.04	0.23 *	0.09 *
LTFMT10 (delay)					-0.31 *	-0.15 *
LTFMT10 (hits)						0.30 *

^A Pearson correlations were also conducted. The only different outcomes were that LTFMT10 delay and confidence, $r(597) = -0.07$, $p = .069$, as well as STFMT and self-belief, $r(595) = 0.04$, $p > .2$ were no longer significantly correlated

^B All coefficients marked * were significant ($p < 0.05$), following the Benjamini and Hochberg (1995) procedure (false discovery rate = .25).

^C Self-belief data were missing for 2 participants

We next conducted a hierarchical regression analysis with LTFMT10 hit rates as the dependent variable, and the remaining Table 2 variables entered in steps (see Table 3 for individual predictors at each step of the model). The primary aim of this analysis was to

evaluate the predictive power of pre-tested ability and confidence on subsequent LTFMT10 identification performance regardless of delay. Therefore, the first step examined the combined variance associated with pre-tested ability as assessed by CFMT+, STFMT (d') and GFMT (d') scores. All tests contributed significantly to the LTFMT10 hit rates model, $F(3, 570) = 17.68, p < .001$, accounting for 8.5% of the variance.

Table 3. Hierarchical regression analyses predicting Experiment 1's LTFMT10 hit rates, $R^2 = .19$, $F(6, 567) = 22.63, p < .001$

		Unstandardized Coefficients		Standardized Coefficients			
Model		B	SEM	β	t	p	95% CI
1	(Constant)	-0.02	0.083		-0.20	>.2	-0.18 0.15
	CFMT+	0.00	0.001	0.111	2.34	.020	<0.01 0.01
	GFMT(d')	0.04	0.016	0.112	2.43	.016	0.01 0.07
	STFMT (d')	0.05	0.015	0.155	3.52	<.001	0.02 0.08
2	(Constant)	-0.10	0.084		-1.12	>.2	-0.26 0.07
	CFMT+	0.00	0.001	0.096	2.08	.038	<0.01 <0.01
	GFMT(d')	0.04	0.015	0.110	2.44	.015	0.01 0.07
	STFMT (d')	0.04	0.014	0.129	3.01	.003	0.02 0.07
	Self-belief	-0.01	0.010	-0.028	-0.70	>.2	-0.03 0.01
	Confidence	0.00	<0.001	0.253	6.41	<.001	<0.01 <0.01
3	(Constant)	-0.06	0.082		-0.74	>.2	-0.22 0.10
	CFMT+	0.00	0.001	0.103	2.29	.022	<0.01 <0.01
	GFMT(d')	0.04	0.015	0.117	2.66	.008	0.01 0.07
	STFMT (d')	0.04	0.014	0.123	2.96	.003	0.01 0.07
	Self-belief	0.00	0.010	-0.010	-0.26	>.2	-0.02 0.02
	Confidence	0.00	<0.001	0.219	5.63	<.001	<0.01 <0.01
	Delay	0.00	<0.001	-0.219	-5.71	<.001	<0.01 <0.01

Collinearity diagnostics revealed no issues (tolerance = 0.709–0.969; VIF = 1.032–1.411).

In the second step, we entered hits confidence and ability self-belief ratings to determine whether these variables contributed any additional variance in hit rates beyond that predicted by the pre-tested ability variables. These variables correlated in Table 1, suggesting that confidence in an identification is associated with domain-specific meta-memory. By entering both here, it was possible to isolate confidence in identifications, from the impact of

pre-existing beliefs. With a significant change in R^2 , $F(2, 568) = 20.58$, $p < .001$, the combined variables explained an additional 6.2% of variance, although only confidence significantly contributed to the model.

Finally, to establish whether retention intervals provided any additional predictive power after accounting for all other variables included in the model, delay was entered on the third step. This added a further 4.6% to the variance in LTFMT10 hits, and this change in R^2 was also significant, $F(1, 567) = 32.56$, $p < .001$.

The overall model accounted for 19.3% of the variance in LTFMT10 hits.

Figure 2: LTFMT10 (a) hits (b) foil IDs (c) misses, and (d) hits confidence in Experiment 1 as a function of group and delay (dark bars = SRs, grey bars = controls)(error bars = 1 SEM). Significant values indicate Tukey post-hoc test differences.

Between-groups analyses: Three 2 (group: SR, control) x 4 (delay condition; 1-6 days (actual mean delay: $M = 1.52$), 7-13 days ($M = 7.75$), 14-27 days ($M = 15.82$), 28-55 days (M

= 31.01), 56+ days ($M = 64.21$)) ANOVAs on hits, foil IDs and misses examined actual delay-interval (regardless of randomised invite group) and group influence on the LTFMT10. Outcomes are reported in Figure 2 along with the results of Tukey's post-hoc tests.

Significant group main effects were found on LTFMT10 hits, $F_{Hits}(1, 177) = 36.63, p < .001, \eta^2 = .171$, and foil IDs, $F_{Foil\ IDs}(1, 177) = 36.36, p < .001, \eta^2 = .170$; but not misses, $F_{Misses}(1, 177) < 1$. SRs made more hits and fewer foil IDs than controls.

Significant delay effects were found on hits, $F_{Hits}(4, 177) = 4.34, p = .002, \eta^2 = .089$, and foil IDs, $F_{Foil\ IDs}(4, 177) = 3.38, p = .011, \eta^2 = .071$, but not misses, $F_{Misses}(4, 177) < 1$.

Longer delays were associated with reduced hits and increased foil IDs. However, only a few of the 10 paired comparisons examining the differences between all delay-intervals were significant (see Figure 2). There was no significant interaction ($p > .2$), suggesting that the recognition curves for SRs and controls were a similar shape.

LTFMT10 Confidence: Not all participants recorded all response types, and therefore, confidence in foil IDs and misses were combined into an 'incorrect' variable. A 2 (accuracy: correct (hits), incorrect (foil IDs, misses)) x 2 (group) x 5 (delay) mixed ANOVA revealed only a significant group effect, $F(1, 167) = 6.95, p = .009, \eta^2 = .040$. SRs ($n = 79$) reported higher confidence than controls ($n = 98$). However, participant numbers were low in some delay conditions, and this relationship was further examined in Experiment 2.

Individual level analyses: Modified t-tests for single cases (Crawford et al., 2010), individually compared the scores of each SR against the control mean on the CFMT+ (out of 102), the STFMT (d'), the GFMT (d'), and LTFMT10 (hits) within each delay interval (see supplementary Figure S1 depicting 95% CIs of the proportion of the general population each SR would be expected to exceed on each test).

Not surprisingly given inclusion criteria, all SRs ($n = 84$, 100%) scored significantly higher than the control mean on the CFMT+, $t(103) = 3.12-4.23$, $p < .05$, one-tailed, $z = 3.14$ (95% CI: 2.67-3.61) - 4.25 (95% CI: 3.64-4.87); and the STFMT (d'), $t(103) = 1.84-10.32$, $p < .05$, one-tailed, $z = 1.84$ (95% CI: 1.52-2.15)-10.37 (95% CI: 8.93-11.80).

Most SRs exceeded the control GFMT (d') mean ($n = 77$, 91.7%), 32 significantly (38.1%), $t(100) = 1.89$, $p < .05$, one-tailed, $z = 1.90$ (95% CI: 1.57-2.20) (i.e. with scores higher than 95% of the estimated population), although to achieve significance on GFMT, 100% accuracy was required. Noteworthy, seven SRs (8.3%) scored below the control GFMT mean.

For the LTFMT10, SRs were compared to controls from the matched delay-intervals described in Figure 2. The scores of 69 SRs (82.1%) exceeded the associated delay-interval control mean, although only 17 (20.2%) significantly outperformed controls, $t(84) = 1.90-4.03$, $p < .05$, one-tailed, $z = 1.94$ (95% CI: 1.29-2.58) -3.29 (95% CI: 2.60-5.70). A further 15 SRs scored below control means, none significantly. The worst SR performers on the LTFMT10 were not necessarily those who scored poorly on the GFMT.

Overall, however, 9 SRs only significantly outperformed controls on all four tests. However, if a more liberal criteria of achieving scores above approximately 90% of the population on each test is applied to account for ceiling effects, 18 SRs achieved threshold on all four tests.

Discussion

In Experiment 1, as expected, longer delays were associated with decreased LTFMT10 hits, and increased foil IDs. Nevertheless, effect sizes were small and only a few post-hoc comparisons were significant. With far stronger effect sizes, as a group, SRs were

significantly more accurate and confident in their decisions than controls across all delay conditions. Importantly, there was no interaction between group and delay. As such, the shape of SRs and controls' recognition curve appears roughly similar, and SRs' superiority over controls after 56 days is of approximately the same degree as after 1 day. SRs face memory advantage appears to be driven by superior encoding, as well as immediate, and longer-term retention.

Between-group outcomes were matched by the individual analyses. All SRs ($n = 84$, 100%) significantly exceeded the control group mean on the CFMT+ and the STFMT (d'). Most SRs also exceeded the GFMT (91.7%); and LTFMT (82.1%) control means. However, only a minority significantly outperformed the control group (GFMT: 38.1%; LTFMT: 20.2%). This may be due to low discriminatory power from relatively small trial numbers in these tests, as well as the bias to recruit better-than-typical face recognisers. Indeed, control group mean CFMT+ scores were significantly higher than in previous research (e.g. Bobak, Pampoulov et al., 2016). This will have reduced effect sizes. Nevertheless, a few SRs performed below the control mean on the GFMT (8.3%), supporting proposals for dissociated perceptual and memory-based processing components at the higher levels of ability (e.g. Bobak, Dowsett et al., 2016).

Some SRs also performed below the LTFMT10 control mean (17.8%). With 10 trials this test had even lower discriminatory power than the 40-trial GFMT, and regardless of delay, SR hit rates ($M = 0.52$) were only slightly higher than controls ($M = 0.33$). Again, this is likely due to the recruitment bias, particularly as a higher proportion of controls (71.3%) than SRs (52.0%) dropped out after completing Phase 1. It is possible many controls were aware that their scores would be poor and declined to continue. It is unclear whether the pattern of results would have differed if more had finished. On the other hand, the investment

in time of those who did finish was high, and it would be surprising for someone to take part but not try.

The hierarchical regression analyses provide further indication of how different factors drive LTFMT10 hit rates. Firstly, the combined face matching and short-term memory tests contributed 8.2% of the variance in hits, while mean confidence ratings in identifications explained an additional 7.9% of the variance. Pre-test self-rated ability in face recognition was also entered on this step, and although this measure correlated with LTFMT10 confidence, it was not a significant contributor to the regression model. These results are consistent with those from eyewitness (Perfect, 2004) and previous SR research (Bate et al., 2019) suggesting weak links between accuracy and domain-specific meta-memory or self-assessments of ability. However, participants only completed a single question in the current research, and more robust measures of meta-memory have recently been developed (e.g. Bobak et al., 2019; Saraiva, van Boeijen, Hope, Horselenberg, Sauerland, & van Coppen, 2019). Replication is recommended using these newer measures.

In the final step of the regression model, delay was also an important significant predictor even after all other variables had been accounted for, contributing a further 5.6% to the variance in LTFMT10 hits, so that in the full model the combined influence of the five predictor variables explained 22% of the variance in hit rates. However, a further 78% remains unexplained, and these effects were further investigated in Experiment 2.

In summary, Experiment 1 demonstrated that short-term face memory superiority predicts long-term recognition of faces. However, participants were correctly informed Phase 2 trials were all target-present, meaning participant deductions as to the most likely target in the line-up may have contributed to outcomes. Furthermore, most forgetting happens in the first 24 hours (Deffenbacher et al., 2008), and no performance baseline with virtually no

LTFMT delay was included in order to measure initial decline. Finally, a large number of participants failed to finish the LTFMT10 (62%). Experiment 2 addressed these factors.

Experiment 2

In Experiment 2, participants completed an extended 20-trial version of the LTFMT (LTFMT20). In Phase 1, they viewed twenty 30s target-actor videos. Although learning time for each video was reduced by half, this maintained Experiment 1's 10-min total phase time. After random delays (immediate, 1 day, 7 days, 28 days) they viewed ten target-present and ten target-absent 3 x 2 simultaneous photo line-ups. The use of photos instead of videos was expected to result in lower rates of accuracy than Experiment 1. However, it also reduced Phase 2 time demands, which may be one explanation for the large participant drop-out between Phase 1 and Phase 2 in Experiment 1. From an applied perspective, police are also more likely to first view suspects in CCTV stills, before deciding whether to access the original crime scene videos. As such, it is important to measure factors that might impact on performances in real world situations.

All participants had previously taken the GFMT (Burton et al., 2010) and the CFMT+ (Russell et al., 2009) in our team's unpublished research. Experiment 1's STFMT contained equal 'old' and 'new' Phase 2 trials, which might have encouraged guessing based on whether participants had responded to both response types roughly equally. To address this, a different ability-verifying *Face Array Memory Test* (FAMT) replaced the STFMT. Unlike Experiment 1, no face recognition ability self-assessments were collected, as all participants had previously contributed to our research and received performance feedback and would therefore have had a more objective insight into their ability.

In line with previous findings, a positive relationship was expected between short-term and long-term face recognition test performances and confidence. Delay was predicted to have a negative impact on LTFMT20 outcomes, with the largest effect sizes for delay expected for target-present than target-absent trials. Regardless of delay, SRs were predicted to generate more target-present hits and target-absent CRs than controls; and based on Deffenbacher's (1980) *Optimality Model*, SR's confidence in hits was also predicted to be higher than controls. However, as Weber and Brewer's (2004, 2006) *Information Asymmetry Hypothesis* predicts that no reliable one-to-one comparison on which to anchor confidence between a stored face representation and any line-up member can be made when correctly rejecting a line-up, no differences in CR confidence were expected between SRs and controls.

Method

Design

In the LTFMT20 Phase 1, participants viewed twenty 30s target-actor videos. In Phase 2 (immediately, 1 day, 1 week, or 28 days later), they attempted to identify the actors from 10 target-present and 10 target-absent counterbalanced six-person photo line-ups (target-presence order was random). After making an identification decision they provided confidence ratings in that decision (0%: guessing to 100%: absolutely certain). A correlational design examined relationships between scores on the CFMT+, the GFMT, and the FAMT, as well as LFMT20 delay, hits, CRs, and confidence in hits and CRs. Predictors of hits and CRs were also evaluated. A mixed 2 (*group*) x 5 (*delay*: < 1 day, 1-6 days, 7-13 days, 14-28 days, >28 days) x 2 (*target-presence*: target-present vs. target-absent) design,

with target-presence as the within-subjects factor, also evaluated each outcome. Individual analyses also compared test outcomes of each SR against the mean performances of controls.

Materials

Face Array Memory Test (FAMT): This bespoke test consists of a 12-trial learning phase and a 40-trial recognition phase. In the learning phase, with no time limits, participants sequentially memorise 12 White-Caucasian young adult male targets. In a 2 x 2 array, each target is presented in four colour photos taken under differing lighting conditions, and from different viewpoints to encourage more naturalistic learning (e.g. see Andrews, Jenkins, Cursiter, & Burton, 2015). In the recognition phase, participants were sequentially presented with 40 White-Caucasian young adult male colour photos, with clothing differing if a target had been depicted in Phase 1. Participants were not informed that not all Phase 1 targets were depicted in Phase 2. They were required to identify whether targets were ‘old’ ($n = 8$) or ‘new’ ($n = 32$). Phase 2 had no time limits. Data of hits, CRs, d' and C were collected.

Long-Term Unfamiliar Face Memory Test 20 (LTFMT20): Phase 1 presented 20 30s videos of targets, ten of which were from Experiment 1’s LTFMT10 (“Actors A-H”), with clips cut at appropriate places to ensure action continuity. Ten new targets were additionally selected for Experiment 2 from an image database of about 500 students. Experiment 1’s LTFMT10 targets comprised the odd-numbered trials in the LTFMT20 (e.g. 1, 3, 5 etc.). The ten new Phase 1 videos and Phase 2 line-ups comprised the even-numbered trials. The new Phase 1 videos depicted targets moving their heads from side-to-side in a similar manner to the PROMAT line-ups described in Experiment 1. In Phase 2, participants were presented with 20 3 x 2 photo line-ups, consisting of two stills (frontal view, right profile). For the new

Phase 2 line-ups, the targets wore different clothing from Phase 1, but with the same blue background as foils. To ensure a balanced design with each target associated with a target-present and target-absent line-up, Phase 2 had two randomly allocated versions.

Mean hit rates on individual counterbalanced trials were not surprisingly significantly lower for nine out of the ten target-actors in Experiment 2 than Experiment 1 regardless of delay, $t(1303) = 3.68-9.31$, $p < .001$. This was possibly due to the greater trial numbers and use of video line-ups in Experiment 1, photo line-ups in Experiment 2. Overall Experiment 2 accuracy ranged from 82.0% to 13.0% for hits in target-present trials, and 51.0% to 27.0% for CRs in target-absent trials.

Participants

New volunteer participants who had completed the CFMT+ (Russell et al., 2009) and the GFMT (Burton et al., 2010) once only in previous unpublished research, completed the FAMT ($n = 1973$) and the LTFMT20 ($n = 1,421$; male = 445, female = 972, other = 3; white-Caucasian = 1236 (86.9%), aged 16-86 years, $M = 39.87$, $SD = 12.14$)³. A smaller proportion of participants failed to finish the LTFMT20 ($n = 551$, 27.9%) than in Experiment 1. Table 4 depicts the final group demographic information as well as mean CFMT+, GFMT and FAMT scores, with independent t-tests comparing groups.

Inclusion criteria for SRs and controls were based on Experiment 1's CFMT+ criteria, and, in place of the STFMT, a FAMT threshold of above or below the mid-point of SR and control means ($d' = 2.31$). Three SRs did not *significantly* score above the final control group FAMT mean ($p = .055$), and these participants were additionally excluded from the between-group analyses (Crawford et al., 2010). Controls scoring more than 1 SD below the control

³ Note: demographic information was missing for some participants (gender $n = 1$; age $n = 3$; ethnicity $n = 3$)

FAMT mean, suggesting ‘worse than typical ability’ or possibly a lack of engagement, were also excluded.

Final SR ($n = 206$; M age = 36.17, $SD = 9.29$; male = 54, female = 152; white = 179 (86.9%) and control groups ($n = 295$; M age = 41.36, $SD = 13.74$; male = 93, female = 204; white = 259 (87.8%)) did not differ in gender or ethnicity proportions. However, controls were significantly older than SRs, $t(498) = -4.71$, $p < .001$, Cohen’s $d = 0.44$.

As with Experiment 1, despite inclusion criteria to reduce the recruitment bias, controls still significantly outperformed Bobak, Pampoulov et al.’s (2016) sample mean on the CFMT+, $t(295) = 9.45$ $p < .001$, Cohen’s $d = .037$.

Table 4: Criteria for SR and control groups, and results for t-tests comparing their CFMT+, GFMT and FAMT outcomes in Experiment 2

	SRs (<i>n</i> = 206)		Controls (<i>n</i> = 295)		<i>df</i>	<i>t</i>	<i>Cohen's d</i>	<i>p</i>
	SR and control group inclusion criteria							
CFMT+	95-102		58–83					
FAMT <i>d'</i>	> 2.31		-0.57–2.31					
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>				
CFMT+	97.33	1.79	74.39	6.76	499	47.56	4.64	<.001
GFMT (40)	38.89	1.48	35.57	2.71	499	15.99	1.52	<.001
FAMT <i>d'</i>	3.39	0.71	1.43	0.56	499	34.60	3.07	<.001

Procedure

Invitees were e-mailed a Qualtrics (www.qualtrics.com) link and asked not to use tablets/mobiles to optimise image size. After providing informed consent, participants completed the FAMT, and viewed Experiment 1’s LTFMT cartoon practice trial, followed by the twenty target-actor videos (30s each) in Phase 1. As with Experiment 1, if participants reported problems with video play by clicking on an icon, they could view that video again at the end of the learning stage. There were 628 out of 28,460 video replays (2.21%), which had no effect on any reported results ($p > .2$). Participants automatically received Phase 2 URL link e-mails at random delay intervals (immediately, 1 day, 7 days, 28 days), although not all

took part immediately on receiving the e-mail. In Phase 2, they were asked to identify recognised actors by selecting a line-up number (1-6), or to reject the line-up ('none of the above'). They were not provided with any other instructions. Finally, they were debriefed, and provided with scores on all tests.

In total, 1691 participants completing LTFMT20 Phase 1 were e-mailed Phase 2 invites. Unlike Experiment 1, a point-biserial correlation examining the relationship between CFMT+ scores and finishing or not (1 = finisher, 0 = non-finisher) was not significant, $r(1689) = -.04, p = .142$. Yet more SRs (98.1%) completed Phase 2 than controls (83.8%), $\chi^2(1, 563) = 27.91, p < .001$, Cramer's $V = .223$.

Results

LTFMT20 delay (Median = 7.6, $M = 13.3$, $SD = 12.2$) varied from almost immediately to 50.5 days (see Figure 3); and was skewed (Shapiro-Wilk (1421) = 0.842, $p < .001$). However, mean delay did not differ between SRs and controls, $t(499) = 1.16, p = .247$, Cohen's $d = .11$. The highest total score by any participant ($n = 1$) was 19 out of 20 ($n = 3$ scored 0) (Median = 8.0, $M = 8.2$, $SD = 3.3$) (Figure 2).

Figure 3. Delay in days and total scores on the LTFMT20 in Experiment 2 ($n = 1,421$)

Table 5. Spearman's correlation coefficients across all measures in Experiment 2 ($n = 1421$)^{A B}

	GFMT	FAMT		LTFMT20 Accuracy		LTFMT20 Confidence	
		d'	Delay	TP Hits	TA CRs	TP Hits	TA CRs
CFMT+	0.47 *	0.40 *	0.04	0.25 *	0.13 *	0.10 *	<0.01
n^C	1422	1422	1422	1422	1422	1373	1269
GFMT		0.31 *	0.02	0.17 *	0.11 *	0.07 *	-0.03
n		1422	1422	1422	1422	1373	1269
FAMT d'			0.06 *	0.26 *	0.13 *	0.11 *	0.01
n			1422	1422	1422	1373	1269
Delay				-0.43 *	-0.04	-0.35 *	-0.16 *
n				1422	1422	1373	1269
LTFMT20 TP Hits					-0.06 *	0.38 *	0.06 *
n					1422	1373	1269
TA CRs						0.16 *	0.25 *
n						1373	1269
TP hits confidence							0.55 *
n							1223

^A All coefficients marked * were significant ($\alpha = 0.05$), following the Benjamini and Hochberg (1995) procedure (false discovery rate = .30).

^B Pearson correlation analyses generated similar results, except the probably spurious relationship between delay and FAMT (d') was no longer significant, $r(1421) = .05$, $p = .087$.

^C Participant numbers differ as not all participants provided a response on all outcome variables.

Correlational analyses: Table 5 presents correlation coefficients between test outcomes. Accuracy rates on all four face processing tests (CFMT+, GFMT, FAMT, and LTFMT20 hits, and CRs) were positively and significantly related; although the coefficients between the CFMT+, GFMT, and the FAMT, were stronger than those between these tests and the LTFMT20 outcomes. Delay negatively correlated with LTFMT20 hit rates, and hits and CR confidence, but not LTFMT20 CRs. The strongest correlations were between LTFMT20 hits and CRs confidence.

Table 6. Hierarchical regression analyses predicting Experiment 2's LTFMT20 hit rates, $R^2 = .32$, $F(5, 1367) = 128.27$, $p < .001$ ^A

Model	Unstandardized Coefficients		Standardized Coefficients		t	p	95% CI	
	B	SEM	β					
1 (Constant)	-0.05	0.081			-0.58	.563	-0.21	0.11
FAMT (d')	0.04	0.006	0.199		6.99	<.001	0.03	0.05
CFMT+	0.00	0.001	0.133		4.34	<.001	<0.01	<0.01
GFMT	0.00	0.002	0.057		1.92	.056	<0.01	0.01
2 (Constant)	-0.18	0.076			-2.41	.016	-0.33	-0.03
FAMT (d')	0.03	0.006	0.167		6.24	<.001	0.02	0.05
CFMT+	0.00	0.001	0.116		4.07	<.001	<0.01	<0.01
GFMT	0.00	0.002	0.049		1.77	.076	<0.01	0.01
Hits Confidence	0.00	<0.001	0.346		14.29	<.001	<0.01	<0.01
3 (Constant)	-0.09	0.071			-1.27	.205	-0.23	0.05
FAMT (d')	0.04	0.005	0.196		7.85	<.001	0.03	0.05
CFMT+	0.00	0.001	0.125		4.67	<.001	<0.01	<0.01
GFMT	0.01	0.002	0.058		2.25	.025	<0.01	0.01
Hits Confidence	<0.01	<0.001	0.226		9.43	<.001	<0.01	<0.01
Delay	-0.01	<0.001	-0.346		-14.55	<.001	-0.01	-0.01

^A As delay was skewed, data was transformed on all multiple regressions (i.e. square root). No outcomes differences were found, and the original untransformed results are reported. Collinearity diagnostics revealed no issues (tolerance = 0.699–0.982; VIF = 1.018–1.430).

Regression analyses: Part-replicating procedures in Experiment 1, the first hierarchical multiple regression was conducted on LTFMT20 hit rates, with CFMT+, GFMT, and FAMT scores entered in the first step, hits confidence in the second (no face recognition self-belief ratings were collected in Experiment 2), and delay in the third (Table 6).

At the first step, the three face processing tests (CFMT+, GFMT, FAMT) contributed significantly to the regression model, $F(3, 1369) = 48.81$, $p < .001$, accounting for 9.7% of the variance. On the second step, the change in R^2 was significant, $F(1, 1368) = 204.22$, $p < .001$, and confidence in hits explained an additional 11.7% of the variance. Finally, adding delay explained an additional 10.5% of the variance in LTFMT20 hits and this change in R^2 was also significant, $F(1, 1367) = 211.61$, $p < .001$.

The final model explained 31.9% of the variance in LTFMT20 hits.

Table 7. Hierarchical regression analyses predicting Experiment 2's LTFMT20 CR rates, $R^2 = .09$, $F(5, 1262) = 25.39$, $p < .001$ ^A

Model	Unstandardized Coefficients		Standardized Coefficients		t	p	95% CI	
	B	SEM	β					
1 (Constant)	0.09	0.101			0.90	.369	-0.11	0.29
FAMT (d')	0.02	0.007	0.097		3.15	.002	0.01	0.04
CFMT+	<0.01	0.001	0.064		1.92	.055	<0.01	<0.01
GFMT	<0.01	0.003	0.041		1.28	>.2	<0.01	0.01
2 (Constant)	-0.06	0.099			-0.59	.558	-0.25	0.14
FAMT (d')	0.02	0.007	0.093		3.12	.002	<0.01	<0.01
CFMT+	<0.01	0.001	0.064		1.99	.047	<0.01	0.01
GFMT	0.01	0.003	0.050		1.61	.108	<0.01	<0.01
CR Confidence	<0.01	<0.001	0.257		9.57	<.001	<0.01	<0.01
3 (Constant)	-0.06	0.099			-0.55	.580	-0.25	<0.14
FAMT (d')	0.02	0.007	0.093		3.14	.002	<0.01	0.04
CFMT+	<0.01	0.001	0.064		1.98	.048	<0.01	<0.01
GFMT	0.01	0.003	0.050		1.62	.105	<0.01	0.01
CR Confidence	<0.01	<0.001	0.254		9.34	<.001	<0.01	<0.01
Delay	<0.01	0.001	-0.015		-0.56	>.2	-0.01	<0.01

^A As delay was skewed, data was transformed on all multiple regressions (i.e. square root). No outcomes differences were found, and the original untransformed results are reported. Collinearity diagnostics revealed no issues (tolerance = 0.692–0.999; VIF = 1.001–1.445).

A similar analysis was conducted with LTFMT20 CR rates as the dependent variable, but with CRs confidence replacing hits confidence in the second step (Table 7). The pre-rested ability variables included in the first stage (CFMT+, GFMT, FAMT) again contributed significantly to the regression model, $F(3, 1264) = 10.93$, $p < .001$, although they accounted for far less of the variance (2.5%) in LTFMT20 CRs, than they had in hits. Introducing CR confidence explained an additional 6.6% of the variance in LTFMT20 CRs and this change in R^2 was significant, $F(1, 1263) = 91.57$, $p < .001$, albeit less than in the equivalent step in LTFMT20 hits. Delay did not significantly predict LTFMT20 CRs, $F(1, 1262) < 1$.

In total, the combined predictors explained 9.1% of the variance in LTFMT20 CRs.

LTFMT20 between-group accuracy and confidence: Two 2 (group: SRs, controls) x 5 (delay condition: < 1 day (actual mean delay: $M = 0.31$), 1-6 days ($M = 4.99$), 7-13 days ($M = 8.64$), 14-27 days ($M = 24.82$), 28+ days ($M = 30.72$)) ANOVAs were conducted on LTFMT20 hits and CRs, and another two 2 (group) x 5 (delay) x 2 (accuracy: correct, incorrect) mixed ANOVAs evaluated mean confidence in target-present hits and incorrect responses (foil IDs, misses), and target-absent CRs and false alarms (see Figure 4).⁴

Unlike Experiment 1, no 14-day Phase 2 e-mail invites were sent. However, many participants completed Phase 1 between 14-27 days, and for analyses, this delay-interval category was created to match with Experiment 1's results. All analyses were first conducted with the addition of the two Phase 2 counterbalanced conditions as a variable. Hit rates ($M = 0.51$, $SD = 0.22$ vs. $M = 0.39$, $SD = 0.21$) and decision confidence ($M = 75.53$, $SD = 21.48$ vs. $M = 61.09$, $SD = 24.21$) were significantly higher in one counterbalanced condition than the other ($p < .001$ for both outcomes). However, there were no effects or interactions involving other variables ($p > .2$), and these data were collapsed.

LTFMT20 hits: Significant main effects of group, $F(1, 491) = 123.53$, $p < .001$, $\eta^2 = .201$, and delay, $F(4, 491) = 32.42$, $p < .001$, $\eta^2 = .209$, showed that SRs ($M = 0.54$, $SD = 0.23$) outperformed controls ($M = 0.36$, $SD = 0.19$), and that hit rates were higher with shorter delays. Post hoc comparisons showed hits were successively reduced in each delay-interval, although not all paired comparisons were significant (see Figure 4). Consistent with Experiment 1, there was no significant interaction, $F(4, 491) < 1$.

⁴ Figure S2 in the supplementary data contains equivalent figures depicting sensitivity (d') and criterion (C).

LTFMT20 CRs: A main effect of group, $F(1, 491) = 32.42, p < .001, \eta^2 = .062$, showed that SRs ($M = 0.45, SD = 0.28$) outperformed controls ($M = 0.32, SD = 0.25$). No other effects or interactions were significant, $F(4, 491) < 1$.

LTFMT20 hits confidence: Significant main effects of group, $F(1, 463) = 15.97, p < .001, \eta^2 = .033$, and accuracy, $F(1, 463) = 313.48, p < .001, \eta^2 = .404$, showed that SRs ($M = 64.30, SD = 19.70$) were more confident than controls ($M = 56.84, SD = 22.07$), and confidence was higher for hits ($M = 68.61, SD = 23.85$) than for incorrect responses ($M = 51.30, SD = 23.24$).

A main effect of delay, $F(1, 463) = 7.55, p < .001, \eta^2 = .061$, and post hoc comparisons showed hits were successively reduced in each delay-interval, although not all paired comparisons were significant (see Figure 4).

There was a significant accuracy x group interaction, $F(1, 463) = 16.76, p < .001, \eta^2 = .035$. SR's hits confidence was higher than controls, $F(1, 463) = 30.71, p < .001, \eta^2 = .062$, but there were no incorrect response differences, $F(1, 463) = 2.67, p = .102, \eta^2 = .006$.

There was a significant accuracy x delay interaction, $F(4, 463) = 5.50, p < .001, \eta^2 = .045$. Delay generated a systematic reduction in hits confidence, similar to the main effect above, $F(4, 463) = 12.52, p < .001, \eta^2 = .098$ (see Figure 4). However, confidence did not significantly differ on incorrect trials, $F(4, 463) = 2.13, p = .076, \eta^2 = .018$. No other effects or interactions were significant ($p > .195$).

Figure 4. a. Hits b. CRs c. hits confidence d. CRs confidence, e. target-present incorrect response confidence (foil IDs, misses), and f. target-absent false alarm (FA) confidence by SRs and controls in each delay condition (< 1 day: SRs: $n = 34$, controls $n = 67$; 1-6 days: SR: $n = 39$, controls: $n = 66$; 7-13 days: SRs: $n = 54$, controls: $n = 53$; 14-27 days: SRs: $n = 22$, controls: $n = 41$; ≥ 28 days: SRs: $n = 60$, controls $n = 68$). (dark bars = SRs, grey bars = controls)(error bars = 1 SEM). Significant values indicate Tukey post-hoc test differences.

LTFMT20 CRs confidence: There was no main effect of group, $F(1, 423) < 1$, although there was a main effect of accuracy, $F(1, 423) = 28.46$, $p < .001$, $\eta^2 = .063$, confidence in CRs ($M = 52.41$, $SD = 26.43$) was higher than in false alarms ($M = 47.14$, $SD = 20.54$). A main effect of delay, $F(4, 423) = 2.58$, $p = .037$, $\eta^2 = .024$, showed that confidence was highest with shorter delays and was reduced in each delay-interval (see Figure 4), although only the difference between <1 day, and 14-27 and >28days were significant ($p < .050$). No other effects or interactions were significant ($p > .1$).

Individual analyses: As with Experiment 1, modified t-tests for single cases (Crawford et al., 2010), individually compared SR's scores against the control mean on the CFMT+, GFMT, FAMT (d'), as well as the LTFMT20 hits, CRs, sensitivity (d') and criterion (C) within each matched delay-interval (see supplementary Figure S3 depicting 95% CIs of the estimated proportion of the general population each SR would be expected to exceed on each measure). As there were significant accuracy differences between the two counterbalanced LTFMT20 conditions, SRs were compared against the controls in their condition only.

Not surprisingly given inclusion criteria, all SRs ($n = 206$, 100%) scored significantly higher than the control mean on the CFMT+, $t(206) = 3.04-4.08$ $p < .05$, one-tailed, $z = 3.05$ (95% CI: 2.78-3.32) – 4.08 (95% CI: 3.74-4.43), and the FAMT (d'), $t(206) = 1.73-5.74$ $p < .05$, one-tailed, $z = 1.73$ (95% CI: 1.55-1.91) – 5.75 (95% CI: 5.27-6.23).

Most SRs ($n = 199$, 96.60%) outperformed controls on the GFMT, though none significantly. Unlike Experiment 1, even maximum scores of 40 out of 40 were not significant.

For LTFMT20 hits, 171 SRs (83.01%) exceeded the associated delay-interval control mean, with 66 (31.88%) significantly outperforming controls, $t(206) = 1.71-4.65$, $p < .05$, one-tailed, $z = 1.72$ (95% CI: 1.34-2.10) – 4.69 (95% CI: 3.86-5.51). A further 34 SRs (16.50%) scored below the control mean, two significantly, $t(206) = -2.22 - -2.15$, $p < .05$, one-tailed, $z = -2.24$ (95% CI: -2.74 - -1.73) – -2.17 (95% CI: -2.60 - -1.72).

For the LTFMT20 CRs, 132 SRs (64.08%) exceeded the associated delay-interval control mean, although only 35 (16.91%) significantly outperformed controls, $t(206) = 1.72-3.02$, $p < .05$, one-tailed, $z = 1.74$ (95% CI: 1.31-2.16) – 3.04 (95% CI: 2.40-3.68). A further 74 SRs (35.92%) scored below control means, although no differences were significant (see Figure S3).

For LTFMT20 d' , 170 SRs (82.52%) exceeded the associated delay-interval control mean, with 54 (26.21%) significantly outperforming controls, $t(206) = 1.76\text{--}3.58$, $p < .05$, one-tailed, $z = 1.79$ (95% CI: 1.24–2.33) – 3.63 (95% CI: 2.73–4.52). A further 35 SRs (16.91%) scored below the control mean, one significantly, $t(206) = -3.81$, $p < .05$, one-tailed, $z = -2.46$ (95% CI: -3.11 – -1.79).

For LTFMT20 C, 126 SRs (61.17%) exceeded the associated delay-interval control mean, with six (1.93%) significant effects, $t(206) = 2.03\text{--}3.58$, $p < .05$, one-tailed, $z = 1.96$ (95% CI: 1.30–2.60) – 3.63 (95% CI: 2.68–4.57). A further 80 SRs (7.25%) scored below the control mean, 16 significantly, $t(206) = -2.00\text{--}-3.14$, $p < .05$, one-tailed, $z = -1.89$ (95% CI: -2.43 – -1.34) – -3.19 (95% CI: -4.02- -2.35).

Overall, however, only 9 SRs significantly outperformed controls on all four tests. However, if a more liberal criteria of achieving scores above approximately 90% of the population on each test is applied, 18 SRs achieved threshold on all four tests.

Discussion

The target-present results of Experiment 2 matched those of Experiment 1 and hypotheses. There were significant, positive, but moderate correlations between scores on the face matching (GFMT) and short-term face memory tests (CFMT+ and FAMT), and between those tests and LTFMT20 hits and hits confidence. Regardless of delay, and with significantly higher confidence ($M = 63.55$ vs. $M = 57.43$), on the LTFMT20, SRs made more hits (54%) than controls (36%). The individual analyses reveal that most SRs (82.6%) scored higher than their matched delay-interval control LTFMT20 hits mean, although only a minority of comparisons were significant (31.9%). Analyses using sensitivity (d') instead of

hits as the dependent variable also revealed that most SRs scored above the control mean (82.1%), with again far fewer comparisons being significant (26.6%).

Overall, confidence in hits was also significantly stronger than in incorrect decisions, while the latter did not differ between SRs and controls. Moderate negative relationships between delay and hit rates ($r = -.43$); as well as delay and LTFMT20 hits confidence ($r = -.35$), in all participants were supported by between-groups analyses demonstrating that regardless of group, successive delay-intervals reduced hit rates and confidence in hits, but not confidence in incorrect decisions. This might suggest SRs and control's facial representations in memory decay at approximately the same rate. However, alternative methods for estimating forgetting rates are evaluated in the General Discussion.

The results of the target-absent trials strongly contrast with target-present outcomes. When targets were not present in line-ups, the strongest effects were that for all delay conditions, SRs (45%) made significantly more CRs than controls (32%). There was virtually no correlation ($r = -.04$) between delay and CR rates, although a small negative relationship between delay and CR rate confidence was significant ($r = -.16$). CR confidence was significantly higher ($M = 52.43$) than incorrect (false alarm) confidence ($M = 47.16$), while non-significant between-group effects revealed that reductions in confidence from delay were independent of accuracy, and face recognition ability. Hierarchical regression analyses also demonstrated that the combined variables had far less predictive power in accurate target-absent than target-present decisions, as whereas they accounted for over 30% of the variance in LTFMT20 hits, they accounted for less than 10% of the variance in LTFMT20 CRs. Indeed, delay had no predictive power on the latter model.

These CR results suggest that in comparison to controls, SRs are better able to rule out that faces have not been seen before. However, consistent with Weber and Brewer's (2004) predictions, face recognition ability has no impact on CR confidence, as no one-to-one

comparison between a facial representation and any line-up face is provided on which to anchor assessments. Indeed, SR and control CR confidence was virtually equal regardless of delay.

General Discussion

The two experiments described here demonstrate that many SRs, classified as such due to achieving exceptionally high scores on two short-term face memory tests, possess better-than-typical long-term face memory as well. Retention intervals varied from virtually none in Experiment 2, to over 56 days in Experiment 1. With large effect sizes, SRs LTFMT hit rates and hits confidence were significantly higher than typical-ability controls. Combining results from both experiments, individual analyses show that most SR's hit rates (82.5%), exceeded the control mean in their associated delay-interval version of the LTFMT, although only just over one-quarter of comparisons were significant (28.5%). With smaller effect sizes, increasing retention intervals negatively impacted hit rates and confidence, with effects being roughly similar for SR and controls.

In Experiment 2's target-absent trials, SRs also made more CRs than controls, although while most SRs individually exceeded the control mean on the individual analyses (63.7%), only three comparisons were significant. There were however, no between-group differences in CR confidence, and although delay had virtually no influence on target-absent trial accuracy, longer delays were associated with slightly reduced CR confidence.

These effects are consistent with Weber and Brewer's (2004) *Information Asymmetry Hypothesis* and Deffenbacher's (1980) *Optimality Model* predictions. The target-present effects demonstrate that delay decreases the strength of facial representations in memory. This reduces accuracy (hits), and as confidence is based on the degree of match between that

facial representation and the actual face of the target, the reliability of confidence in correct identification decisions. There was no impact of delay or face recognition ability in confidence associated with target-present incorrect decisions. However, there was a systematic negative relationship between delay and confidence which affected both CRs and false alarms equally in target-absent decisions, suggestive of the influence of meta-memory and the understanding that longer delays impact memory reliability. These results also imply that facial representations are stronger in SRs than in controls. Indeed, SR group hit rates after 28 days in Experiment 2 (43%) were only slightly lower than control group hit rates in the immediate condition (49%), for which delays were less than one day.

Table 8: Mean hit rates (%) and estimated forgetting ratios (F) for SRs, controls, and all participants at each delay-interval in Experiment 1 and 2 assuming mean hit rates in the shortest delay intervals represent faces reliably committed to memory

		< 1 day	1-6 days		7-13 days		14-27 days		28-55 days		≥ 56 days	
	n	Hits	Hits	F	Hits	F	Hits	F	Hits	F	Hits	F
Experiment 1												
SRs	84		59.3		57.0	3.9	46.3	21.9	50.0	15.7	45.0	24.1
Controls	103		42.1		38.5	8.6	26.3	37.5	31.9	24.2	26.0	38.2
All	597		53.4		44.0	17.3	36.9	30.9	35.7	33.1	32.5	39.1
Experiment 2												
SRs	206	69.7	62.4	10.5	54.0	22.5	45.0	35.4	44.0	36.9		
Controls	295	49.4	41.4	16.2	37.6	23.9	24.4	50.6	25.0	49.0		
All	1421	59.4	48.5	18.4	44.0	25.9	33.7	43.3	33.9	43.0		

Importantly, in both experiments, there was no interaction between delay and group when evaluating hits. However, this does not necessarily imply that facial representations in controls and SRs decay at approximately the same rate, given that the immediate condition results in Experiment 2 also suggest that some Phase 1 faces were likely never committed to memory in the first place. As such, if hit rates in this condition are taken as being indicative of face representation establishment, then the ratio of hits in this condition to those in the longer delay conditions provide an estimate of within-group forgetting (F) rates over each increasing retention interval (see Table 8). These have been calculated for SRs, controls and all Experiment 1 (based on the 1-6 day shortest delay-interval condition) and Experiment 2 participants in Table 8.

Although values of F do not always systematically increase between each delay-interval in Table 8, in Experiment 1, the difference between SR's mean hit rates after 1-6 days compared to the 56-day condition (59.3% to 45.0%) represents a forgetting ratio (F) of about 24.1%, whereas controls display a higher forgetting ratio of about 38.2%. Similar calculations comparing Experiment 2's shortest and longest delays also reveal lower forgetting ratios in SRs ($F = 38.2\%$) than in controls ($F = 49.4\%$). The higher forgetting ratio values in Experiment 2 are also consistent with Ebbinghaus' (1913; see also Deffenbacher et al., 2008) proposals that most forgetting occurs in the first 24 hours. Indeed, examination of the complete participant sample for Experiment 2 suggests a gradual decline in forgetting rates over longer delays. Some caution is required. The results in Table 8 assess performances of groups of relatively small numbers of *different* participants at each delay-interval. Reliability would be increased by within-group testing of a larger set of participants over each retention interval.

These results also suggest that the driver of SRs' superiority is initial familiarisation, and the establishment of stronger face representations, which may involve larger face storage capacity (see Bobak, Dowsett et al., 2016; Jenkins, Dowsett, & Burton, 2018). These findings also suggest that SRs possess face-specific visual memory system mnemonic enhancements, allowing representations in memory to be more reliably sustained over longer retention intervals. Nevertheless, as with previous research (e.g. Bobak, Dowsett et al., 2016), there was substantial SR score variability, with some performing below control means on the LTFMT.

It is perhaps not surprising that only a few SRs *significantly* (28.5%) made more hits than controls on the LTFMT. With 10 target-present trials, the LTFMT in both experiments will have had low discriminatory power to distinguish between performers of different standards. Furthermore, both experiments suffered from a recruitment bias to attract

participants with superior face recognition abilities than would be expected from a more representative sample. This reduction of range will have likely reduced between-group effect sizes and correlations between variables. Steps were taken to reduce the impact of this bias by creating typical-range ability control groups based on scores within 1 SD of the mean on the CFMT+ (Russell et al., 2009) of a highly population-representative UK sample (Bobak, Pampoulov et al., 2016). Despite this, with medium effect sizes, both control groups still significantly exceeded Bobak et al.'s sample mean.

Defining super-recognition ability

Most previous research has primarily employed the CFMT+ to assign SRs to groups. Here, a substantial proportion of current participants (30.9%) who would have been included in a SR group based on Bobak, Pampoulov et al.'s (2016) rigorous conservative CFMT+ criteria alone (≥ 95 out of 102), were excluded following STFMT (Experiment 1) ($n = 36$; 30.0%) or FAMT verification (Experiment 2) ($n = 94$; 31.2%). Despite this, out of the 291 SRs who met Experiment's 1 and 2's combined test thresholds, the hit rates of 51 (17.5%) were below the equivalent delay-interval matched control mean. This suggests that a proportion of individuals who would have met SR criteria in most published research, cannot sustain these abilities over longer retention intervals.

Similar between-test inconsistencies have been demonstrated elsewhere. Some incontinency is to be expected, and may reflect varying levels of engagement, distractions, fatigue, or a range of factors unrelated to face recognition ability. In online studies such as the current research, control over conditions is far weaker than in a lab, and therefore a range of extraneous factors may have impacted results (i.e. internet connection breakdowns). On the other hand, recent research demonstrates that experimenter presence in a laboratory can

reduce visual memory retrieval performances, suggesting that sometimes, internet-based studies may better capture abilities (e.g. Souza, Rerko, & Oberauer, 2015).

Nevertheless, 15 SRs (5.2%) also achieved scores below the control mean on the GFMT, and these dissociations support proposals that separate perceptual and memory-based mechanisms may drive superior face processing skills (e.g. Bobak, Bennetts et al., 2016; Bobak, Dowsett et al., 2016; Bobak, Hancock et al., 2016; Davis et al., 2016). One factor that may explain dissociations is that accurate face matching mainly relies on a facial feature-by-feature comparison strategy (e.g. Megreya & Burton, 2006); whereas face memory draws more on holistic or whole face mechanisms (e.g. Tanaka & Farah, 1993). A proclivity to employ a holistic face processing style has been associated with superior face memory (e.g., DeGutis, Wilmer, Mercado, & Cohan, 2013; Wang, Li, Fang, Tian, & Liu, 2012; although see Konar, Bennett, & Sekuler, 2010). Therefore, dissociations may simply imply that some SRs use inefficient strategies when completing face matching tasks.

The failure of some SRs to achieve a score above the mean of controls on the LTFMT may also reflect a dissociation between short- and long-term elements of superior face memory. Indeed, some current SRs ($n \approx 5$) communicated with the researchers stating that although they found the short-term memory tests easy, they struggled with longer term face recognition. Further research is required to investigate this proposal. Nevertheless, the results of the current research suggest that recruitment criteria for superior face recognition critical roles in policing and security, should best be based on achieving test scores measuring a range of different skills, rather than high performances on a single short-term face memory test such as the CFMT+ (Russell et al., 2009).

Regardless of potential dissociations between different elements of superior face recognition ability, a few participants did achieve highly superior performances on all four tests. Nevertheless, despite SRs superiority over controls, even in Experiment 2's immediate

condition, SR's accuracy on the LTFMT20 was well below ceiling. Mean SR hit rates in this delay-interval were 70%, and their CR rates were 45%. This might imply poor SR reliability. However, task demands were very high, being the equivalent of 20 typical eyewitness identification experiments in one session. Additional factors may have impacted outcomes.

First, the LTFMT Phase 1 videos displayed actors from different viewpoints providing varying levels of full body, gait and facial movement information. The Phase 2 line-ups displayed head-and-shoulders information only. As no information was provided in advance as to Phase 2 task demands, it is possible that some participants concentrated on learning non-face features in Phase 1. Such a strategy would have reduced performances.

Second, in Experiment 2, all line-ups were photos, which will likely have increased task difficulty. Indeed, significant hit rate differences to nine out ten of the actors between Experiment 1 and 2, suggests that the hybrid-video line-ups in Experiment 1 may have aided accuracy.

Third, police worldwide usually warn eyewitnesses that "line-ups may or may not contain the target". No such warning was given in Experiment 2, although in Experiment 1 participants were correctly told all line-ups were target-present. This unbiased police warning reduces misidentifications of innocent suspects and foils (e.g. Clark, 2012). However, it often also induces a response bias to be cautious, reducing hit rates as well. It is possible that if such a warning had been provided to participants in Experiment 2, outcomes may have differed. Given the normal impact of the warning, CR rates would have been most likely increased, albeit at the possible cost of reduced hit rates.

Fourth, immediately prior to starting LTFMT20 Phase 1 in Experiment 2, participants had completed the FAMT, with its unequal numbers of Phase 1 trials ($n = 12$) and Phase 2 trials ($n = 40$), while not all Phase 1 images were depicted in Phase 2 ($n = 8$ out of 12 were shown). High scores on this test were primarily associated with correctly rejecting previously

unseen faces (32 out of 40 trials). As such, and particularly in the shortest delay conditions of the LTFMT20, carryover effects from this test may have also induced a conservative bias against making an identification on the LTFMT20. Such a cautious strategy would likely have reduced hit rates.

Standardised tests in this field tend to include equal numbers of matched and mismatched trials (e.g. GFMT, Burton et al., 2010), or trials in which a target is always present (e.g. CFMT+, Russell et al., 2009). In the policing or security identity verification workplace, such proportions are very unlikely. The limited published research in this area suggests that varying mismatched-matched ratios strongly influences identification task accuracy (Bindemann, Avetisyan, Blackwell, 2010), and the FAMT's structure may therefore be a more valid measure in this context.

Limitations

There are some limitations of this research that should be acknowledged. All tests employed white-Caucasian adults as stimuli. Future research could examine effects with actors of different ethnicities and ages, to measure the impact of the cross-age (e.g. Wiese et al. 2013) and cross-ethnicity effects (Meissner & Brigham, 2001). In addition, from a theoretical perspective, only long-term memory of the human face was tested here. Previous research (Bobak, Bennetts et al., 2016) demonstrates that superior face recognition ability is not always dissociated from object recognition ability, indicating possible domain-general mnemonic enhancements. Future research should therefore compare long-term memory for faces with tests assessing other classes of visual stimuli to better control for the confounding effects of generalized superior memory processes.

Body information may also enhance identification over faces displayed alone (e.g. Burton, Wilson, Cowan, & Bruce, 1999; Noyes, Hill, & O'Toole, 2017; Robbins & Coltheart, 2015), although body and face matching performances may not necessarily correlate (Noyes et al., 2017). For policing and security, it might be advantageous to deploy staff with exceptional face *and* body/gait recognition skills, particularly for roles reviewing CCTV footage, or surveillance and viewing suspects in real life. Recognition of persons of interest for instance in CCTV footage would not necessarily be limited to faces alone and as such, future research could investigate this with whole body line-ups perhaps in a hybrid-video style to capture idiosyncratic movements and gait.

The CFMT+ used here as the primary assessment of SR ability has been commonly employed in this type of research, although utility has been criticised (e.g., Bate et al., 2018; Esins, Schultz, Stemper, Kennerknecht, & Bulthoff, 2016). For instance, the CFMT+ employs only target-present trials, limiting the investigation of participants' face processing skills (i.e. it is not possible to generate data of correct rejections), while the highly controlled greyscale cropped images depicting no hairstyle do not reflect realistic daily face recognition scenarios (Bate et al., 2018). The current research demonstrates that CFMT+ scores do predict longer term face recognition performance, although alternative face memory test designs may be more suitable. Indeed, the Face Array Identification Test (FAMT) used in Experiment 2 possessed more predictive power for LTFMT20 hits and CRs than the CFMT+, despite its unbalanced old-new Phase 1 and Phase 2 design.

Finally, given the online design employed in this study, it is possible that some participants may have recorded Phase 1 videos to obtain optimal scores on the LTFMT. However, this does seem unlikely given the generally low CR rates.

Conclusions

The results from the two experiments reported here were the first to demonstrate that a majority of participants with outstanding short-term face memory ability, can sustain these skills over longer-term retention intervals. However, there were exceptions. This has important implications for policing, as some forces have created specialist SR units (e.g. Robertson et al., 2016), and if recruitment was based only on the short-term memory tests commonly used in research (e.g., Bate et al., 2018; Russell et al., 2009), the impact on crime detection might be lower than if such a unit contained individuals pre-tested over longer retention intervals. Regardless, tests can only provide a marker of ability. They will never guarantee actual workplace performance. In summary however, the results of the current research suggest that SR's superiority may be primarily based on enhanced early familiarisation to faces, with face memory decay being retarded in comparison to the pattern of most of the rest of the population.

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Supplementary materials

Figure S1a: CFMT+ (Controls ($n = 103$) $M = 75.33$, $SD = 6.27$) Figure S1b: STFMT (d') (Controls ($n = 103$) $M = 1.38$, $SD = 0.25$) Figure S1c: GFMT (d') (Controls ($n = 103$) $M = 2.64$, $SD = 0.68$) Figure S1d: LTFMT10 (Controls: 1-6 days ($n = 19$, $M = 0.42$, $SD = 0.17$); 7-13 days ($n = 27$, $M = 0.39$, $SD = 0.21$); 14-27 days ($n = 16$, $M = 0.26$, $SD = 0.15$); 28-55 days ($n = 16$, $M = 0.32$, $SD = 0.16$); 56+ days ($n = 25$, $M = 0.26$, $SD = 0.20$))

Figure S1: Upper and lower bound confidence intervals (95%) of the estimated proportion of the population expected to fall below each SR ($n = 84$) based on (3a) CFMT+ scores, (3b) STFMT d' , (3c) GFMT d' , and (3d) LTFMT10 hits. The 50% line on Figures 3c and 3d represents the control mean, so that 50% of the population would be expected to achieve above this level. Due to low SR variability on the CFMT+ and STFMT, the 95%-100% and 92%-100% ranges are depicted in Figures 3a and 3b. To enhance interpretability throughout, SRs are grouped based on delay condition (1-6, 7-13, 14-27, 28-55, 56+ days), and rank-ordered from left-to-right based on LTFMT10 hit rates.

Figure S2. a. Sensitivity b. Criterion C by SRs and controls in each delay condition (< 1 day: SRs: $n = 34$, controls $n = 67$; 1-6 days: SR: $n = 39$, controls: $n = 66$; 7-13 days: SRs: $n = 54$, controls: $n = 53$; 14-27 days: SRs: $n = 22$, controls: $n = 41$; ≥ 28 days: SRs: $n = 60$, controls $n = 68$). Error bars denote standard error of the mean.

LTFMT20 sensitivity (d') and criterion (C): Two 2 (group: SRs, controls) x 5 (delay condition: < 1 day, 1-6 days, 7-13 days, 14-27 days, 28+ days) ANOVAs were conducted on LTFMT20 sensitivity and criterion (See Figure S2).

With sensitivity, significant main effects of group, $F(1, 491) = 109.15, p < .001, \eta^2 = .182$, and delay, $F(4, 491) = 8.08, p < .001, \eta^2 = .062$, showed that SRs ($M = -0.07, SD = 1.19$) outperformed controls ($M = -1.06, SD = 1.06$), and that hit rates were higher with shorter delays. Post hoc comparisons showed hits were successively reduced in each delay-interval, although not all paired comparisons were significant. There was no significant interaction, $F(4, 491) < 1$.

With criterion, only the main effect of delay was significant, $F(4, 491) = 8.03, p < .001, \eta^2 = .061$. There was a trend for responses to become more conservative with longer delays in that participants were more likely to respond, 'not present'. However, not all effects were significant.

Figure S3: Upper and lower bound confidence intervals (95%) of the estimated proportion of the population expected to fall below each SR ($n = 206$) based on CFMT+, GFMT, FAMT d' scores, LTFMT20 hits (conditions A and B), and LTFMT20 CRs, LTFMT20 d' scores and LTFMT20 C. To enhance interpretability throughout, SRs are grouped based on delay condition (>1, 1-6, 7-13, 14-27, 28+ days), and rank-ordered from left-to-right based on LTFMT20 sensitivity (d') scores.