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Angry faces are more resistant to forgetting than are happy faces: Directed forgetting effects on the identity of emotional faces

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Angry faces are more resistant to forgetting than are happy faces: directed forgetting effects on the identity of emotional faces

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ABSTRACT
Using the item-method directed forgetting paradigm (i.e. intentionally forgetting specified information), we examined directed forgetting of facial identity as a function of facial expression and the sex of the expresser and perceiver. Participants were presented with happy and angry male and female faces cued for either forgetting or remembering, and were then asked to recognise previously studied faces from among a series of neutral faces. For each recognised test face, participants also recalled the face's previously displayed emotional expression. We found that angry faces were more resistant to forgetting than were happy faces. Furthermore, angry expressions on male faces and happy expressions on female faces were recognised and recalled better than vice versa. Signal detection analyses revealed that male faces gave rise to a greater sensitivity than female faces did, and male participants, but not female participants, showed greater sensitivity to male faces than to female faces. Several theoretical implications are discussed.

KEYWORDS
Directed forgetting; facial expression; memory of faces; sex differences; facial recognition

Humans can intentionally forget information they consider irrelevant, unimportant, or unwanted. However, forgetting emotionally arousing information is more difficult than is forgetting emotionally neutral information because emotional material is more vivid and enduring (Cahill & McGaugh, 1995), suggesting that emotional material is prioritised in memory processing (for a review, see Hamann, 2001). Much of the current knowledge on intentional forgetting, including how it is affected by emotional valence, stems from the use of the directed forgetting paradigm. In the item-method directed forgetting paradigm, participants are presented with a series of items cued for either remembering or forgetting during the study phase. They are then asked to remember all of the items presented. Using this method, previous studies have reported forgetting costs which refer to the impaired memory for items cued to forget (hereafter, "to-be-forgotten" items) relative to those cued to remember ("to-be-remembered items"; for a review, see MacLeod, 1998). Interestingly, people are more resistant to forgetting negatively arousing emotional stimuli (words and pictures) than either neutral or positively arousing emotional stimuli (for a review, see Otani et al., 2012). These findings prompt an intriguing question: would emotional faces, which entail complex and unique neural and cognitive processing (for a review, see Rossion, Gauthier, et al., 2000), influence intentional forgetting? To date, however, few researchers have studied this subject.

Emotional faces differ from emotional words or pictures because of their affective characteristics (i.e. valence) – which are marked by specific facial features – and their communicative and adaptive values (e.g. angry faces signify potential threat). These unique qualities might influence attentional processing and remembering. However, it remains unclear how the emotional valence of faces (happy vs. angry) affect memory. Empirical findings on remembering emotional faces have reported somewhat mixed findings. Some studies support a "happy face advantage" – namely, people better remember happy faces than angry ones, likely because happy faces facilitate holistic processing via a broadened scope of attention (D'Argembeau & Van der Linden, 2007; D'Argembeau, Van der Linden, Comblain, & Etienne, 2003). In this regard, past research also suggests that visually salient facial features – especially smiling mouth – facilitate the detection of happy faces via initial attentional orienting (Calvo & Nummenmaa, 2008) and feature-based processing (e.g. Gosselin & Schyns, 2002 ; Schyns, Bonnar & Gosselin, 2002), all of which might contribute to the encoding aspects of happy faces.

In contrast, there is considerable evidence to suggest that angry faces are prioritised in selective attention. For instance, Fox et al. (2000) demonstrated that (a) schematic angry faces tend to hold visual attention and (b) angry faces are detected more readily and efficiently in the display of distracting (neutral or happy) faces than are happy faces. In the same vein, Cooper and Langton (2006) demonstrated that there is an attentional bias towards the locations of angry faces when individuals are presented with pairs of angry and neutral faces. Given that angry faces receive such attentional priority, it is likely that they would receive priority in memory processing. Indeed, some have posited an "angry face advantage" because angry expressions, compared to happy ones, (a) entail feature-based local processing via a narrow attentional focus (D'Argembeau & Van der Linden, 2007), (b) readily capture attention through both bottom-up (but see Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Frischen, Eastwood, & Smilek, 2008) and top-down processing (Huang, Chang, & Chen, 2011), and (c) facilitate encoding and maintenance of facial identity in visual working memory (Jackson, Linden, & Raymond, 2014).

With regard to the forgetting of emotional faces in the directed forgetting paradigm, Quinlan and Taylor (2014) demonstrated that despite emotional (i.e. angry) faces' potential benefits for remembering, they are still subject to forgetting, and the magnitude of the directed forgetting did not vary with the emotional expression. However, this study did not answer whether the facial identities of emotional faces can be forgotten because their participants were tasked with recognising the same emotional faces that had been presented during the study phase. Given how little is known about the process of forgetting the facial identities of emotional faces, more research on this topic would be necessary. Particularly, to clearly determine the effect of directed forgetting on the facial identities of emotional faces, it would be critical to test participants' memories of the facial identities of emotionally neutral faces as well. Moreover, since memory comprises both remembering and forgetting, it would be important to examine the influence of emotional faces on both processes simultaneously; this would illuminate how emotional faces influence memory decay and other critical aspects of memory processing, including encoding (i.e. the strength of a memory representation), maintenance, and retrieval (Basden, Basden, & Gargano, 1993).

Our research goals are threefold. First, we examined the effect of facial expressions on the forgetting of facial identity in the directed forgetting paradigm. According to this paradigm, effective forgetting involves successful inhibition of previously encoded materials upon receiving the "forget" cue and selective rehearsal of materials cued to "remember" (Basden et al., 1993). Thus, we hypothesised that if angry faces, compared to happy ones, stimulate visual attention (Feldmann-Wüstefeld, Schmidt-Daffy, & Schubö, 2011) and visual working memory (Jackson et al., 2014) – which would in turn strengthen memory representations via improved encoding and maintenance – then angry faces will be retained better despite the considerable effort to forget (i.e. will hinder intentional forgetting).

Second, we examined the critical moderating factors of the effect of emotional faces on forgetting. People's ability to forget emotional faces may be moderated by inherent factors such as the sex of the presented face (hereafter, "expresser"). This is supported by literature showing that recognition memory is better for emotionally negative male faces than for emotionally negative female faces, especially when the perceiver is in a good mood (Wang, 2013a). Moreover, it is possible that angry male and happy female faces can be recognised more readily than can happy male and angry female faces, respectively (for review, see Tay, 2015). From an evolutionary perspective, these findings suggest that individuals benefit more from attending to angry male and happy female faces than to happy male and angry female faces because attending to the identities of men who display angry facial expressions allows men to avoid unnecessary conflict or competition costs and women to avoid physical harm, given that men are often physically larger (Montagne, Kessels, Frigerio, de Haan, & Perrett, 2005). Angry women, however, do not pose as great a physical threat; hence, attending to women with angry facial expressions may not be considered as vital. Conversely, attending to women with happy facial expressions might be adaptive because it signals their agreeableness to befriend and provide care (Taylor et al., 2000). However, this would not be the case for men with happy facial expressions because men are less likely to offer childcare and social support. Taken together, the evolutionary perspective suggests that angry male and happy female faces are more difficult to forget because of an initial attentional bias towards such faces, which would strengthen encoding and subsequent memory processing. Hence, we hypothesise that the identities of angry male and happy female faces will be better retained in memory and more resistant to forgetting than will those of happy male and angry female faces.

Third, we aimed to clarify the effect of participants' (i.e. perceivers') sex on forgetting emotional faces. Particularly, women are more sensitive to facial expressions than are men (McClure, 2000), which is a discrepancy that appears to span from infancy to early adulthood. Women also engage in face scanning more often than do men, especially for new faces, making women more likely to exhibit better face memory (Heisz, Pottruff, & Shore, 2013). Sex differences in the neural activity of emotional face processing have also been noted, with women exhibiting greater activation in the left amygdala, a critical brain region for emotional processing (Cahill et al., 2001). This sexually dimorphic neural activity is associated with a greater tendency for women to elaborate on detailed facial information, which would ultimately enhance their memory for faces (Guillem & Mograss, 2005). Considering the evolutionary account and extant evidence of emotional face processing, we hypothesise that women will show less forgetting and better recognition memory for emotional faces than will men.

Method

Participants

One-hundred and fifty undergraduates (73 men) with a mean age of 22 years (*SD* = 1.64 years) participated in exchange for either course credit or monetary compensation ($5). We excluded data from four participants because they did not follow the instructions.[1]

Design

Type of Memory Cue (forget, remember), Expresser Sex (male face, female face), and Facial Expression (happy, angry) were manipulated within participants, while Perceiver Sex (male, female) was treated as a between-participants variable.

Materials

We obtained Asian facial stimuli from three different databases and conducted a norming study to choose highly controlled stimuli based on ratings for their intensity of emotionality, attractiveness, and distinctiveness of facial stimuli (see appendix for details). This was done because the extant evidence suggests that male and female faces are more amenable to displaying angry and happy facial expressions, respectively (Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007; Hess, Adams, Grammer, & Kleck, 2009). In other words, male faces are structurally suited to displaying angry faces, given their generally thicker eyebrows and squarer jaws, whereas the female faces are more suited to displaying happy faces (Brown & Perrett, 1993; Burton, Bruce, & Dench, 1993; Hess et al., 2009; Keating, Mazur, & Segall, 1981). Given this, it seems critical to control for the influence of such structural differences in happy and angry facial expressions between male and female faces. The norming study involved selecting sets of male and female faces to control for emotionality (happy, angry, neutral), the emotional intensity between the emotional and neutral versions of the faces, and the emotional expression of the expresser (see appendix).

For the study phase, we selected 48 faces with an equal number of male and female happy and angry faces matched for emotionality, attractiveness, and distinctiveness (see Table A1 in the appendix). These faces were further split into two sets (to-be-forgotten and to-be-remembered) and counterbalanced. Because we examined the recognition memory for faces' *identity*, the emotionally neutral versions of the above 48 faces were selected for the recognition test, together with 48 new neutral faces (i.e. foils) drawn from the same databases (see Figure 1).

Procedure

Participants were seated approximately 50 cm in front of a 15-inch computer screen. They first took part in a study phase, wherein a total of 48 faces were individually presented in random order for

[1]Two participants did not understand the instructions related to the memory cuing; one recorded details of the faces she saw during the study phase; and one identified all faces as "old" during the recognition test. The exclusion of these four participants did not alter the significance of our results.

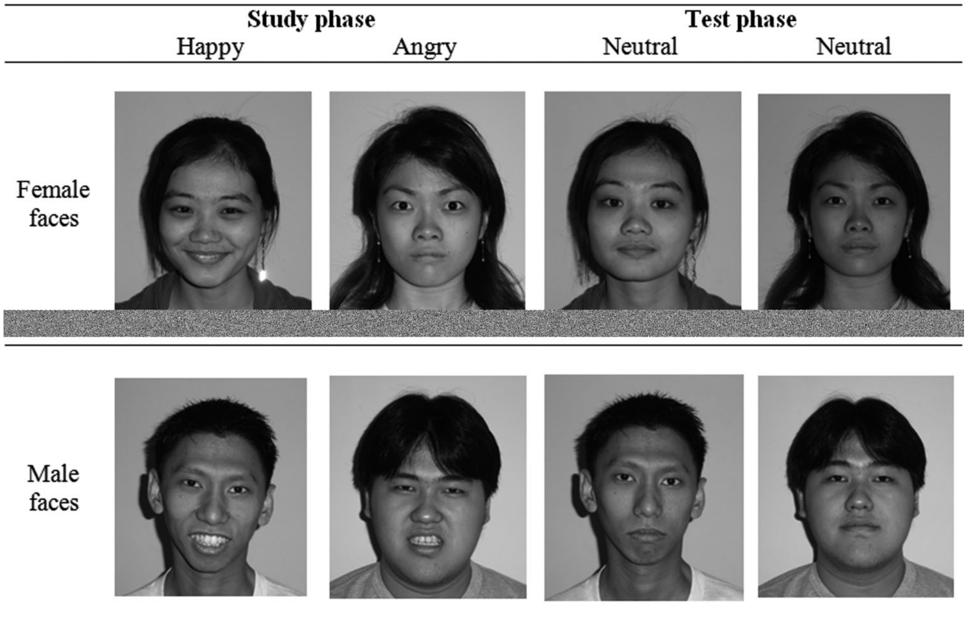

Figure 1. Facial stimuli used during the study and test phase of the main study.
Note: The faces were counterbalanced for memory cue (i.e. to-be-remembered, to-be-forgotten).

3 s each using the Direct RT software. Within each trial, a fixation cross (+) was presented on the screen for 1 s, followed by a face for 3 s. Then, a fixation cross (+) appeared again for 1 s before being replaced by a cue (remember or forget), which remained on the screen for 3 s. Half of the trials presented a remember cue and half a forget cue, and these trials were presented in random order. After the study phase, participants took part in a 1-min filler task, wherein they wrote down every third number in descending order from 157. This was done to reduce recency effects (Otani et al., 2012).

After the filler task, participants began the test phase. Ninety-six faces were presented, including neutral forms of the 48 faces from the study phase and 48 new neutral faces. Participants responded to each neutral face by pressing the "old" or "new" key, regardless of the memory cue (remember or forget) presented with the face during the study phase. To reduce participants' memory load, the response words, "old" and "new", remained on the screen, corresponding to the mouse click, for the whole phase. Although there was no time limit, participants were asked to respond as quickly and as accurately as possible. When the participants recognised the neutral face by pressing the "old" key, they were further asked to recall its previous facial expression (happy vs. angry). To minimise participants' memory load, response words – "happy" and "angry" – remained on the computer screen, corresponding to the mouse click location.

Results

Facial identity recognition

Only correct responses were included in the analyses. Reaction times (RT) faster than 250 ms or slower than three SDs from the group mean were removed by following the typical RT trimming procedure. A total of 0.65% of trials were removed. The means and standard deviations of the correct recognition (hit) and false alarm rates as a function of memory cue, facial expression, expresser sex, and perceiver sex are presented in Table 1. Hit rate was submitted to a repeated-measures mixed-factor analysis of variance (ANOVA) with Memory Cue (forget, remember), Facial Expression (happy, angry), and Expresser Sex (male, female) as within-participant factors, and Perceiver Sex (male, female) as a between-participants factor. The only significant main effect was Expresser Sex, which indicates that male faces ($M = 0.49$, $SD = 0.02$) were more accurately recognised than were female faces ($M = 0.46$, $SD = 0.02$), $F(1, 144) = 4.10$, $p = .045$, $\eta_p^2 = .03$. Most critically, consistent with our hypothesis, we found a significant Memory Cue × Expression interaction, $F(1, 144) = 6, 195$, $p = .014$, $\eta_p^2 = .041$. Given that the effect of Memory Cue

Table 1. Mean hit and false alarm rates for male and female participants as a function of the sex of expresser, facial expression, and memory cue.

		(Hits)		Corrected recall[a]	
		Men	Women	Men	Women
Male faces					
Remember	Happy	0.48 (0.27)	0.46 (0.26)	.23 (.20)	.24 (.22)
	Angry	0.52 (0.27)	0.51 (0.23)	.29 (.22)	.27 (.24)
Forget	Happy	0.50 (0.28)	0.42 (0.26)	.21 (.21)	.26 (.23)
	Angry	0.51 (0.29)	0.54 (0.27)	.29 (.23)	.24 (.21)
False alarms		0.21 (0.19)	0.20 (0.15)		
Female faces					
Remember	Happy	0.47 (0.26)	0.55 (0.25)	.35 (.24)	.31 (.24)
	Angry	0.39 (0.22)	0.49 (0.21)	.23 (.20)	.20 (.18)
Forget	Happy	0.42 (0.26)	0.45 (0.26)	.29 (.21)	.28 (.23)
	Angry	0.43 (0.25)	0.47 (0.25)	.19 (.18)	.17 (.19)
False alarms		0.23 (0.18)	0.22 (0.13)		

Note: Standard deviations are shown in parentheses.
[a]Raw recall rates were adjusted to account for each individual's recognition rate by multiplying the individual's recognition and recall rates.

(remember, forget) is reflective of forgetting costs, our finding indicates that facial expression has a significant moderating effect on forgetting costs – that is, poorer memory for to-be-forgotten faces than for to-be-remembered faces. Follow-up analysis revealed that forgetting costs were evident for happy faces, $t(145) = 2.46$, $p = .02$, but not for angry ones, $t(145) = 0.89$, $p = .37$. Our results suggest that angry faces were more resistant to forgetting than were happy faces. Another marginally significant interaction was found between Memory Cue and Perceiver Sex, $F(1,\ 144) = 3.79$, $p = .056$, $\eta_p^2 = .03$, which indicates that forgetting costs were moderated by the perceiver's sex. Planned comparisons using *t*-tests showed that forgetting costs were evident only among female participants, $t(72) = 2.24$, $p = .03$, but not among male participants, $t(72) = -0.56$, $p = .58$. Further scrutiny, however, indicated that forgetting costs were attenuated in males because of their poorer recognition of to-be-remembered faces than of to-be-forgotten faces. No other interactions involving memory cue were significant.

We also found several interesting effects arising from expresser and perceiver sex differences in facial recognition. First, we found a significant interaction between Facial Expression and Expresser Sex, $F(1,\ 144) = 17.223$, $p < .001$, $\eta_p^2 = .11$. Consistent with our hypothesis, paired *t*-tests showed that angry male faces were recognised more frequently than were happy male faces, $t(145) = 4.09$, $p < .001$, while happy female faces were recognised more frequently than were angry female faces, $t(145) = 1.88$, $p = .06$. Additionally, angry male faces were recognised more frequently than were angry female faces, $t(145) = 4.30$, $p < .001$. Happy female faces, however, did not differ from happy male faces in terms of hit rates, $t(145) = -.81$, $p > .42$. These findings are, in part, in line with the evolutionary perspective of facial identity memory.

Another significant interaction was found between Expresser Sex and Perceiver Sex, $F(1, 144) = 7.724$, $p = .006$, $\eta_p^2 = .051$. Follow-up analysis revealed that male participants showed an own-sex bias (i.e. enhanced recognition for same-sex faces), $t(72) = 3.25$, $p = .0012$, whereas female participants showed no such bias, $t(72) = 0.56$, $p = .58$. Finally, we found a marginally significant interaction between Facial Expression and Perceiver Sex, $F(1,\ 144) = 3.63$, $p = .059$, $\eta_p^2 = .03$. Planned comparisons indicated that female participants recognised angry faces ($M = .47$) more frequently than they did happy faces ($M = .50$), $t(72) = 2.24$, $p = .03$; male participants showed no such difference ($M_{\text{happy}} = .47$, $M_{\text{angry}} = .46$), $t(72) = 0.38$, $p = .70$. Taken together, the results indicated that female participants had better recognition memory for angry faces than for happy faces (i.e. angry face advantage).

In summary, our first hypothesis was supported: angry faces were resistant to intentional forgetting but happy faces were not, suggesting that angry faces are better retained in memory despite participants' considerable effort to forget. Furthermore, our second hypothesis was partially supported, as we found greater recognition for angry male and happy female faces, regardless of memory cue (remember, forget). Our third hypothesis, however, was not supported: forgetting costs were evident only among female participants, suggesting that they are able to intentionally and efficiently forget emotional stimuli.

Signal detection theory

Using the signal detection theory procedure (MacMillan & Creelman, 1991, 2005), we computed and analysed sensitivity (d') measure, which can be interpreted as a perceiver's ability to discriminate studied faces from non-studied faces (i.e. foils). We adjusted the raw hits and false alarms to eliminate values of 0 or 1. Then, a z-transformation was performed to convert the hit and false alarm rates into z-scores. We calculated the sensitivity measure (d') using the formula, $d' = z(\text{Hits}) - z(\text{False alarms})$. Notably, since new faces in the test phase are all neutral in expression, false alarm rates can only vary according to expresser sex and perceiver sex, but not according to cue type (forget, remember) and facial expression (happy, angry). Therefore, variations in d' scores do not necessarily illuminate the impact of memory cue and facial expression. Hence, we submitted the participants' d' scores to a repeated-measures mixed-factor ANOVA with Expresser Sex (male, female) as a within-participant factor and Perceiver Sex (male, female) as a between-participants factor. We found a significant main effect of Expresser Sex, $F(1, 143) = 10.1$, $p = .002$, $\eta_p^2 = .066$. Planned comparisons showed that participants were more sensitive to male faces than they were to female faces ($M_{\text{male}} = .93$, $M_{\text{female}} = .75$), $t(144) = 3.134$, $p = .002$, suggesting that male faces may have a stronger representation in memory. However, the effect of Perceiver Sex was not significant, $p = .70$, indicating that male and female participants did not differ in terms of their recognition sensitivity ($M_{\text{Male}} = .85$, $M_{\text{Female}} = .82$), $t(143) = .38$, $p = .70$. We also found a marginally significant interaction between Expresser Sex and Perceiver Sex, $F(1, 143) = 3.59$, $p = .060$, $\eta_p^2 = .03$. Follow-up analysis revealed that only male participants, but not female participants, showed significantly greater recognition sensitivity to male than to female faces.

Facial emotion recall

For each face correctly recognised as "old", participants were further asked to report its facial expression (i.e. happy or angry) displayed during the study phase. We analysed only those faces with correctly recalled facial expressions. Recall rates were adjusted to account for participants' individual recognition rates by multiplying each individual's recognition and recall rates. These adjusted recall rates were then submitted to a repeated-measures mixed-factor ANOVA with Memory Cue (remember, forget), Facial Expression (happy, angry), and Expresser Sex (male face, female face) as within-participant factors, and Perceiver Sex (male, female) as a between-participants factor. We found a significant main effect of Facial Expression, which indicated that, once accurately recognised, participants recalled happy expressions ($M = 0.27$, $SD = 0.15$) more accurately than they did angry facial expressions ($M = 0.24$, $SD = 0.14$), $F(1, 133) = 5.01$, $p = .027$, $\eta_p^2 = .036$. We also found a significant main effect of Memory Cue, $F(1, 133) = 4.68$, $p = .032$, $\eta_p^2 = .034$, indicating that to-be-remembered faces ($M = 0.27$, $SD = 0.12$) were recalled better than were to-be-forgotten faces ($M = 0.24$, $SD = 0.13$). Moreover, consistent with the recognition results, we found a significant interaction between Expresser Sex and Facial Expression, $F(1, 133) = 36.91$, $p < .001$, $\eta_p^2 = .22$. Planned comparisons indicated that happy expressions on female faces were recalled more accurately ($M_{\text{happy}} = .31$) than angry expressions ($M_{\text{angry}} = .20$), $t(144) = -4.08$, $p < .001$, whereas angry expressions on male faces were recalled more accurately ($M_{\text{happy}} = .24$, $M_{\text{angry}} = .27$), $t(144) = 1.92$, $p < .057$. These findings further support the second hypothesis, which was based on the evolutionary perspective. Additionally, happy female faces were recalled more accurately than happy male faces were, $t(141) = -5.28$, $p < .001$, and angry male faces were recalled more accurately than angry female faces were, $t(140) = 2.29$, $p = .02$.

We also found a significant interaction between Memory Cue and Expresser Sex, $F(1, 133) = 4.155$, $p = .043$, $\eta_p^2 = .03$. Planned comparisons revealed that female faces showed significant directed forgetting costs in recall, ($M_{\text{female\_remember}} = .28$, $M_{\text{female\_forget}} = .23$), $t(144) = 2.84$, $p = .005$, whereas male faces were more resistant to forgetting ($M_{\text{male\_remember}} = .26$, $M_{\text{male\_forget}} = .25$), $t(144) = .52$, $p = .60$. The remaining effects were not significant.

False alarm recall of facial emotion

We analysed false alarm recall of facial emotion for foils which were not presented during the study phase but erroneously recognised as "old" at test; thereby, participants falsely recalled their facial expressions (happy or angry; see Table 2). We submitted false alarm recall data to a three-way repeated-measures mixed-factor ANOVA with Expresser sex (male, female) and Facial expression (happy, angry) as within-participant factors and Perceiver sex as a between-participants factor. Consistent with facial emotion recall results presented above, we found a significant main effect of Facial Expression,

Table 2. Mean false alarm recall of facial expression for male and female participants as a function of the sex of expresser and facial expression.

		False alarm recall of facial expression	
		Men	Women
Male faces			
	Happy	.13 (.09)	.14 (.09)
	Angry	.10 (.08)	.09 (.09)
Female faces			
	Happy	.13 (.09)	.16(.09)
	Angry	.09 (.07)	.08 (.08)

Note: Standard deviations are shown in parentheses.

$F(1, 95) = 45.9$, $p < .001$, $\eta_p^2 = .33$. Follow-up analysis of paired *t*-tests showed that happy expressions ($M = .14$) were more likely attributed to foils than angry expressions ($M = .09$), $t(96) = 6.86$, $p < .001$. We also found a marginally significant interaction between Expresser Sex and Facial Expression, $F(1, 95) = 3.72$, $p = .057$, $\eta_p^2 = .04$. Follow-up analysis showed that happy expressions were more likely attributed to female faces ($M = .13$) than to male faces ($M = .11$), $t(127) = -2.65$, $p = .009$, but angry expressions did not show any significant pattern $p > .05$. The rest of the effects did not reach significance. Our finding of greater false attributions of happy expression to the female foils indicates the presence of happy expression biases towards female faces than male faces; however, we did not observe angry expression bias towards male faces.

Discussion

Using the directed forgetting paradigm, we investigated how emotional faces influence individuals' remembering and forgetting of facial identity and emotional expression. We demonstrated the following: (a) angry faces were resistant to forgetting; (b) male faces were better recognised and recalled than were female faces; (c) male faces gave rise to a greater sensitivity; (d) male participants, but not female participants, were more sensitive to male faces than to female faces; (e) angry expressions on male faces and happy expressions on female faces were more accurately recalled; (f) forgetting costs were evident among female participants, but not among male participants; and (g) female participants recognised angry faces more accurately than they did happy faces.

The finding that angry faces are more resistant to forgetting than are happy faces does not entirely contradict the studies whose findings supported the "happy face advantage" in memory (D'Argembeau & Van der Linden, 2007; D'Argembeau et al., 2003). Despite happy faces being more amenable to forgetting in recognition memory than angry faces, we found some evidence that supports the happy face advantage. Specifically, we observed such an advantage when happy facial expressions were presented on female faces, suggesting that the happy face advantage is moderated by the expresser's sex. Moreover, happy expressions appeared to be recalled more accurately if their corresponding faces were correctly recognised during the test phase. At the same time, however, happy expressions were more inclined to be ascribed to female faces (foils) that were not presented during the study phase. Given that human memory is a dynamic process of remembering and forgetting (Bjork, 2011; Nørby, 2015; Schacter, 2002), our findings suggest that forgetting and remembering emotional faces might operate differently in some circumstances (Yang, Yang, & Park, 2013).

Angry faces' resistance to forgetting can be explainable by the following two major factors: (a) attention bias to angry faces and (b) cognitive resources devoted to encoding angry faces. From an evolutionary perspective, angry faces would signal threat or danger in certain contexts. As such, speedy and efficient detection of angry faces (Fox et al., 2000) and enhanced encoding and representation of such faces in memory would help individuals avoid potential danger or conflict in the future. In line with this notion, there is growing evidence suggesting that participants' attention bias to angry faces enables angry faces to be detected more readily than happy faces would be (Becker, Mortensen, Anderson, & Sasaki, 2014). Becker and colleagues have also demonstrated that angry faces with threatening cues such as masculinity (i.e. male angry face) elicit encoding benefits – via more efficient scanning – in working memory (Becker et al., 2014). The greater attention bias to angry faces might lead to better encoding of those faces in short-term (Jackson et al., 2014) and working memory (Becker et al., 2014), which entails a greater likelihood of their being transferred into long-term memory; this, in turn, hampers their forgetting. Additionally, not forgetting the identities of angry faces would confer a similar adaptive advantage, thus suggesting that a bias towards angry faces is plausible and would lead to distinctive encoding and rehearsal. Together with previous evidence on how forgetting arises from selective rehearsal (i.e. terminating rehearsal of to-be-forgotten items via inhibitory suppression), our findings suggest that attention bias might modulate the forgetting and remembering of emotional faces.

Notably, women showed significant forgetting costs, but men did not. This finding might be because women are more likely to follow memory instructions, and thus are better able to forget faces that they are asked to forget. Alternatively, it may indicate that women are better at regulating memory processing; in other words, females are better able to forget information that is designated as irrelevant, so that they can better remember information perceived as relevant. This is, in part, consistent with the considerable evidence suggesting that women overall have better memories (McClure, 2000) and greater emotional regulation ability (Garnefski, Teerds, Kraaij, Legerstee, & van den Kommer, 2004). Women's greater capacity to regulate their emotions may be related to their greater levels of oxytocin, which has been shown to attenuate the effect of emotional responses in the amygdala when women view happy and angry faces (Domes et al., 2007). Applying this to our results, female participants might have been better able to detach themselves from the emotionality of the faces upon receiving the forget cue, and thus were better able to suppress any subsequent rehearsal of angry faces. Future studies might investigate whether women's forgetting costs can indeed be attributed to their better emotion regulation and ability to inhibit or suppress subsequent rehearsal when directed to forget emotional faces.

Women also showed greater recognition for angry facial expressions than for happy expressions. This finding is consistent with existing literature indicating that females, both children and adults, show increased physiological reactance to emotionally negative pictures, suggesting a greater bias towards such stimuli (Bradley, Codispoti, Sabatinelli, & Lang, 2001; McManis, Bradley, Berg, Cuthbert, & Lang, 2001). From an evolutionary perspective, it would be adaptive for women to have a good memory for angry faces because they could better avoid dangerous conflicts with others; this is especially necessary for them because they tend to have smaller statures and less physical strength than men do (Becker et al., 2007). Taken together, our findings suggest that women are better able to intentionally forget and remember emotional faces than are men, although they are particularly attuned to negative (i.e. angry) stimuli. Considering that memory for faces potentially involves both feature-based or holistic processing (Cabeza & Kato, 2000; Rossion, Dricot, et al., 2000), it would be interesting to further examine the cognitive processing women deploy specifically for angry faces.

Another important finding is that individuals' memory of emotional faces was moderated by expresser sex. Specifically, among all participants, there was a tendency towards greater recognition of (a) angry male faces compared to happy male faces, (b) happy female faces compared to angry female faces, and (c) angry male faces compared to angry female faces. Similar results were obtained for recall: participants recalled angry male and happy female faces more accurately than they did happy male and angry female faces, respectively. These findings support the notion that the adaptive value of face memory conferred by facial expressions is closely associated with expresser sex. Furthermore, our findings expand on prior findings regarding the links between males and angry facial expressions and between females and happy facial expressions in terms of the detection and presentation of facial expressions (Fischer, 1993; Tay, 2015) by suggesting that those links are similarly evident for facial recognition memory. Arguably, however, our findings can be attributed to the idea that male angry faces and female happy faces express greater emotional intensity than do male happy faces and female angry faces, respectively. This coincides with the phylogenetic model of facial emotions (Becker et al., 2007), which proposes that sexually dimorphic facial architecture (i.e. masculine male faces and feminine female faces) promotes the detection of angry and happy expressions on male and female faces, respectively. However, our norming study results (see appendix) indicated that this is unlikely because we carefully controlled for various aspects of emotionality among the faces (i.e. intensity of emotion, similarity between neutral and emotional faces, arousal, attractiveness, distinctiveness, and so on). As such, the memory effects for male angry and female happy faces are unlikely to have emerged from the sexually dimorphic architectural features of the faces and any qualitative differences in emotionality among the faces.

Finally, we noted that some recognition rates hovered at around 50%, but we found it unlikely that participants' performance could have been at the chance level for a number of reasons. First, in a two-alternative forced choice task, participants' discrimination is accurate to the extent that the hit rate exceeds the false alarm rate (e.g. Verde, Macmillan, & Rotello, 2006). According to the Receiver Operating Characteristic (ROC) curve, which represents how the hit rate changes as a function of changes in the false alarm rate, a random change performance is evidenced when the hit rate equals the false alarm rate which is represented by the chance diagonal. However, if hit rates are significantly different from false alarm rates, this indicates that participants' recognition decisions are not made on chance. Hence, we have performed paired *t*-tests to compare hit rates with their corresponding false alarm rates. We found that false alarm rates were significantly lower than were overall hit rates for both male faces, $t(145) = 22.2$, $p < .001$, and female faces, $t(145) = 18.7$, $p < .001$. Moreover, the mean hit rate in each of 16 conditions was significantly greater than the mean false alarm rates, all *p*s < .001, indicating that participants were clearly able to distinguish faces they had seen in the study phase from those that they had not. Second, we tested participants' memory for faces that they had actually been instructed to forget, which is likely to be more challenging than typical recognition tests, wherein participants are proactively involved in encoding stimuli with a clear intent to remember. It is also noteworthy that the recognition rates we observed were not entirely different from those reported in previous studies examining memory for faces, including those using the directed forgetting paradigm and those using more challenging memory tests (e.g. Wang, 2013a, 2013b). Moreover, despite our task's more challenging nature (i.e. identifying the identity of faces), the hit and false alarm rates were similar to those reported by a previous study using the same directed forgetting procedure to investigate memory for emotional faces (Quinlan & Taylor, 2014, Table 1). Finally, we employed a well-controlled laboratory experiment with an adequate sample size; we carefully counterbalanced our facial stimuli for remember and forget cues to remove any statistical artefacts emerging from qualitative differences in the faces; and our results are based on confirmatory analyses rather than an exploratory analysis. Taken together, our findings cannot likely be attributed to systematic errors associated with methodological problems.

Our study provides preliminary evidence that angry facial expressions are more resistant to forgetting than are happy expressions, and that recognition and recall memory for emotional faces are moderated by the expresser's and perceiver's sex. Given that we focused on the impact of emotional faces on forgetting and remembering, our results expand on those of previous studies demonstrating the advantages of happy faces (e.g. D'Argembeau et al., 2003) and angry faces in the detection and memory of facial stimuli. Thus, future memory research might examine both processes – remembering and forgetting – to improve their understanding of the phenomena under study, as these processes might involve different underlying mechanisms (Yang et al., 2013). Additionally, future studies should consider how forgetting facial expressions manifests among clinical populations (e.g. patients with depression), and how individual differences in motivational (approach vs. avoidant) orientation moderate memory for emotional faces in the directed forgetting paradigm.

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Appendix

Norming study

The norming study was conducted to obtain ratings on the emotional intensity, attractiveness, and distinctiveness of the male and female faces that we selected. A total of 152 happy and angry East Asian faces were selected from the Asian Emotion Database (Wong & Cho, 2009, 2007), the Cohn-Kanade Action-Unit-Coded Facial Expression Database (Kanade, Cohn, & Tian, 2000), and Matsumoto and Ekman's Japanese faces (Matsumoto & Ekman, 1988). Fifty-two were male happy faces, 48 were male angry faces, 30 were female happy faces, and 22 were female angry faces (see Figure 1). All faces were cropped such that they showed only the faces without any extraneous information such as the background or details of the clothing. Each image was 340 × 300 pixels. Fifty-eight undergraduate students (30 men) with a mean age of 22 years ($SD = 2.88$) rated the faces in terms of the intensity of the happiness and anger as well as the level of attractiveness, distinctiveness, and arousal on a 5-point scale ranging from 1 (*not at all*) to 5 (*very much so*). We also examined how the emotional intensity of each face differed from that of the neutral version of the face by presenting participants with both versions and having them rate on a 9-point scale the degree to which the emotional intensity differed between the two versions.

Faces with outlier ratings for emotional intensity, attractiveness, distinctiveness, or arousal were excluded. Faces with extreme difference scores between emotional and neutral expressions were also excluded. We selected a total of 48 faces with an equal number of male and female happy and angry faces matched for the degree of happiness and anger, distinctiveness, and arousal (all ps = ns). Female faces, however, were rated more attractive than male faces for both happy and angry expressions, $ps < .05$. Overall, happy faces of both males and females were rated happier, less angry, and more attractive than their counterpart angry faces, all $ps < .05$. The mean (*SD*) scores for emotional intensity, attractiveness, arousal, and distinctiveness of the faces used in the main study are displayed in Table A1.

Table A1. Means ratings in the norming study for the intensity of happiness and anger, attractiveness, distinctiveness, and arousal for male and female happy and angry faces ($N = 58$).

	Male faces			Female faces		
	Happy	Angry	*t*	Happy	Angry	*t*
Degree of happiness	3.73 (0.48)	1.81 (0.46)	21.9*	3.82 (0.44)	1.83 (0.47)	22.1*
Degree of anger	1.45 (0.40)	3.42 (0.58)	21.9*	1.40 (0.34)	3.40 (0.62)	21.8*
Attractiveness	2.32 (0.72)	1.87 (0.57)	7.4*	2.63 (0.59)	2.05 (0.53)	10.0*
Distinctiveness	2.73 (0.67)	2.82 (0.63)	1.53	2.84 (0.60)	2.75 (0.68)	1.94
Arousal	2.51 (0.71)	2.63 (0.74)	1.73	2.57 (0.64)	2.68 (0.65)	1.68

Note: Standard deviations are shown in parentheses.*$p < .05$.