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Original Article

Out of Sight but Not Out of Mind: Memory Scanning is Attuned to Threatening Faces

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Abstract: Working memory (WM) theoretically affords the ability to privilege social threats and opportunities over other more mundane information, but few experiments have sought support for this contention. Using a functional logic, we predicted that threatening faces are likely to elicit encoding benefits in WM. Critically, however, threat depends on both the capacities and inclinations of the potential aggressor and the possible responses available to the perceiver. Two experiments demonstrate that participants more efficiently scan memory for angry facial expressions, but only when the faces also bear other cues that are heuristically associated with threat: masculinity in Study 1 and outgroup status in Study 2. Moreover, male participants showed robust speed and accuracy benefits, whereas female participants showed somewhat weaker effects, and only when threat was clearly expressed. Overall results indicate that working memory for faces depends on the accessibility of self-protective goals and on the functional relevance of other social attributes of the face.

Keywords: working memory, anger, male warrior hypothesis

Introduction

Think of the last time you witnessed an angry encounter between two people. Chances are your attention was pulled from other activities and you thought about the outburst for some time afterwards, perhaps even ruminating on the face of the aggressor in anticipation of subsequent encounters. William James (1890) proposed that this is what primary memory—or its modern variant, working memory (WM)—is for: It thrusts to center stage the key threats and opportunities of social life. Unfortunately, this functional thinking has not remained at the forefront of modern conceptions of WM, which tend to see it as a domain-general resource working equally well regardless of its contents.

We believe that WM does have specialized functionality; it prioritizes information relevant to goals fundamental to successful survival and reproduction (e.g., self-protection, disease-avoidance, mate acquisition, etc.). From this perspective, while many of the faces that we encounter in day-to-day life readily slip from our mind, clear threats (and possibly opportunities) should elicit encoding efficiencies in WM to facilitate adaptive responses should they suddenly reappear.

There is good precedent for the functionalist claim that basic motivational/emotional systems penetrate and modulate cognitive processes (see Kenrick, Neuberg, Griskevicius, Becker, and Schaller, 2009). Functional biases have been demonstrated for attention (e.g., Anderson et al., 2010; Maner, Gailliot, Rouby, and Miller, 2007), spatial memory (Becker, Kenrick, Guerin, and Maner, 2005), information pick-up (Becker et al., 2010), and categorization (Miller, Maner, and Becker, 2010). Surprisingly, however, little research has investigated how the availability of recently encountered faces in WM storage might reflect such functional considerations.

Indeed, although there are many purported demonstrations that angry faces elicit preferential attention, they tend to focus on attention to stimuli that are present (e.g., Fox, Russo, and Dutton, 2001) rather than looking at how attention efficiently encodes and holds onto the image of an angry face once it is out of sight. For example, there are well-known studies that purport to show that angry faces exert preattentional effects, automatically drawing our eyes to their location (e.g., Öhman, Lundqvist, and Esteves, 2001). We—and others—have recently argued against this claim: Well-designed studies suggest that the angry face actually eludes efficient detection, at least relative to happy targets (Becker, Anderson, Mortensen, Neufeld, and Neel, 2011; Becker et al., 2012; Horstmann, 2007, 2009). Nevertheless, despite doubts about the existence of preattentional benefits for angry faces, once attention has found a face and recognizes anger, we expect very efficient processing. We predict that this heightened vigilance will continue *even if* the angry face suddenly disappears. In other words, anger will be prioritized in short-term/working memory storage.

A functional approach to social cognition also entails that we cannot ignore the context and the perceiver's expectations about a face, because all angry faces are not equally threatening. Indeed, there are biological regularities that have been consistently encountered in our ancestral past, and such regularities have very likely become key inputs to any threat-avoidance calculus. Consider that men are more likely to be perpetrators of physical violence than women (Daly and Wilson, 1988). If threat avoidance mechanisms in the brain have come to account for this, angry *men*, rather than women, should be the ones that generate the strongest representations in WM storage.

What about the gender of the perceiver? Men have historically been more likely to engage in intergroup conflict with other men, as well as intrasexual competition with one another for mates. The *male-warrior hypothesis* (Van Vugt, De Cremer, and Janssen, 2007) suggests that men evolved proclivities to form coalitions and battle with one another for mates and resources. Although the social implications of this hypothesis are typically discussed, it also stands to reason that this has led to a constellation of sex differences in threat cognition. Specifically, the male warrior hypothesis may entail that men will be more vigilant to anger in a strange male, maintaining such a face in WM so that they can rapidly respond if the individual is encountered again. Of course, women are also victims of male violence and sexual coercion, and in choosing mates, prefer kindness to meanness (Buss, 1989). These factors could sensitize their memory for strange male faces in a similar way, but we think the connection to an angry face is nevertheless more tenuous—other expressions often precede violence against a weaker opponent and/or sexual coercion. Consequently, in addition to hypothesizing that angry male faces elicit more activation in WM, we think it is reasonable to predict that male *participants* might show the effect more robustly, reflecting their biological preparedness for intergroup conflict with other males, and that this should particularly influence the speed with which they respond.

In the present experiments, we explore WM's attunement to threatening faces using Sternberg's (1969) memory scanning method, in which participants memorize a small set of items and are then presented with a series of "probes," each of which requires a rapid decision indicating whether it is a member of the memory set or not. It therefore yields measures of both the accuracy and the speed of retrieval. It is important to note that storage in WM is limited (e.g., Cowan, 2001); this bottleneck imposes constraints on threat attunement that are not present at other processing stages that do not have such constraints, like early perception or long-term memory.

We predicted a general attunement to anger but, following previous work (e.g., Miller et al., 2010; Becker, Mortensen, et al., 2011), also predicted that other cues to threat—particularly target sex—would moderate the effect. Moreover, given that WM is a limited capacity resource, anger vigilance may operate at the expense of performance with less threatening faces. We also thought it plausible that the profile of performance would differ for male and female perceivers, with men privileging rapid responses to threat.

Experiment 1

Materials and Methods

Thirty-two women and 32 men participated in exchange for course credit. Participants were greeted by an experimenter and directed to one of several computers, each separated by large dividers. Stimuli were presented to participants seated approximately 22 inches away from 17-inch color monitors, and E-Prime experiment display software was used to ensure precise recording of decision reaction time (registered with the computer keyboard).

Participants completed four blocks of 32 trials each. In each block, participants were instructed to view a set of four faces and hold these in memory. This memory set was presented for 10 seconds and consisted of two male and two female Caucasian faces, with one of each gender making a slightly angry facial expression. To control the degree of anger expressed across faces, we modified neutral faces in Photoshop, lowering the center of the brow and tightening the mouth. Pre-testing indicated that all of these faces were rated as "slightly angry" or "angry" in the context of other expressive faces culled from standard stimulus sets, and there were no sex differences in these ratings. Participants then viewed 32 memory probe trials, each consisting of an individual face and requiring a rapid decision concerning whether or not it was in the original memory set. Half of these faces were from the original memory set and half were from a set of four new faces selected to reflect the same factorial combination of gender and expression.

The order of the face types in the initial presentation of the memory set was fully counterbalanced across participants, as was whether the face appeared as a target or a foil for a given subject. In the memory test phase, each face was repeated four times, and the order of presentation was random.

Results

One female participant was eliminated from the analysis for having accuracy three standard deviations below the mean. Table 1 includes a variety of performance measures that collectively indicate the presence of response biases as well as sensitivity effects. Our analyses will focus on contrasts that address the specific hypotheses that motivated this research: 1) Do angry faces elicit more efficient processing? 2) Are angry *male* faces particularly memorable? This later hypothesis is best explored by a contrast of angry male faces with all others. Such contrasts are not necessarily (or even typically) the same as interaction tests of moderation; indeed, the power of such tests can differ considerably (Rosenthal, Rosnow, and Rubin, 2000). Since this contrast more directly addresses the special status of the most threatening face in a limited capacity storage resource like WM, it has the potential to better account for the variance in the results.

Table 1. Performance in experiment 1 as a function of participant sex and face type

	Hit Rates	False Alarms	Accuracy (*d'*)	Bias (*C*)	Median Correct RT Memory Set Hits	Median Correct RT Correct Rejections
Male Participants						
Angry Men	92.1 (7.7)	12.6 (12.3)	2.72 (0.7)	0.1 (0.32)	689 (96)	764 (116)
Angry Women	91 (8.4)	17 (13.9)	2.47 (0.74)	0.17 (0.31)	752 (144)	731 (141)
Neutral Men	88 (13)	13.9 (12.2)	2.5 (0.97)	0.05 (0.26)	731 (141)	802 (153)
Neutral Women	83.9 (11.7)	9.4 (11)	2.49 (0.85)	-0.16 (0.27)	762 (156)	781 (152)
Female Participants						
Angry Men	90.1 (9.4)	11.7 (10.9)	2.66 (0.7)	0.04 (0.32)	733 (125)	778 (146)
Angry Women	90.5 (9.2)	13.9 (13.9)	2.59 (0.84)	0.08 (0.31)	736 (139)	718 (136)
Neutral Men	87.3 (11.5)	8.6 (10.9)	2.69 (0.82)	-0.11 (0.3)	718 (136)	764 (132)
Neutral Women	86.9 (15.6)	9.2 (9.5)	2.67 (0.79)	-0.06 (0.38)	720 (116)	803 (175)

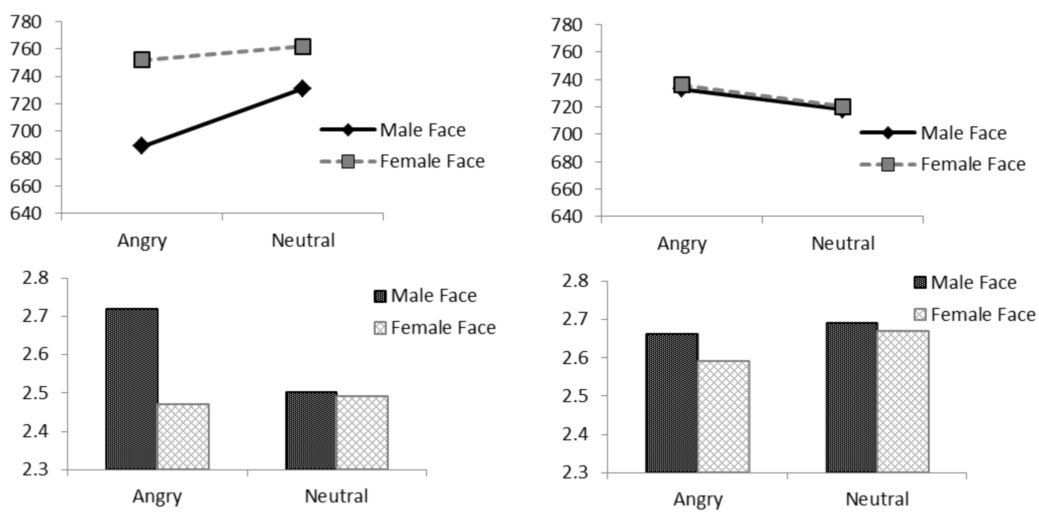
Note. Standard deviations in parentheses.

Do angry faces elicit more efficient processing? Hit rates were significantly higher for angry faces than neutral faces, $t(62) = 3.38$, $p = .001$, $d_{Cohen} = 0.43$, and there was no interaction with participant sex at this general level (see ahead). There was, however, also a difference (3.5%) in false alarms (i.e., incorrectly saying that a new angry face was part of the memory set), $t(62) = 2.99$, $p = .004$, $d_{Cohen} = 0.38$. As a result, there was no general accuracy advantage (d-prime) for angry faces, but there was a significant bias (c) to identify angry faces, regardless of their presence or absence in the memory set, $t(62) = 3.99$, $p < .001$, $d_{Cohen} = 0.50$. This bias marginally interacted with participant and target sex, $F(1,60) = 3.82$, $p = .055$, $\eta_p^2 = 0.59$, suggesting that the specific contrasts examining advantages for male faces presented in the next section may be more appropriate. Turning to median correct reaction times, we saw no general benefit for angry faces over neutral faces, although sex differences did emerge for both target-present trials, $t(62) = 2.12$, $p = .03$, and target-absent correct rejections, $t(62]) = 2.74$, $p < .008$. Overall, men performed marginally faster with angry faces compared to neutral faces, whereas women exhibited significantly slower reaction times to angry faces than neutral faces, $t(30) = 2.33$, $p = .027$. This is consistent with the idea that men need to be able to respond rapidly to a threat, whereas women process the same stimuli more slowly and maintain accuracy.

Are angry MALE faces particularly vivid in working memory? Across participant sex, hit rates were 3.0% higher for angry male faces than all other faces, $t(62) = 2.21$, $p = .030$, $d_{Cohen} = 0.28$, but there was no corresponding difference in false alarms. Although across participants there was a non-significant trend for greater accuracy (d-prime) identifying angry male faces relative to all others, $t(63) = 1.44$, $p = .073$, the effect was entirely driven by male participants, $t(31) = 1.84$, $p = .037$, $d_{Cohen} = 0.32$. This accuracy benefit for male participants occurred in the absence of any significant bias. Moreover, this sensitivity to angry male faces compared to all other faces was accompanied by a 59 ms decrease in median response time, $t(31) = -4.33$, $p < .001$, $d_{Cohen} = 0.77$. No equivalent effects were observed in female participants with the exception that their correct rejection times for angry male faces were slower than all other faces, $t(30) = 2.02$, $p = .026$, $d_{Cohen} = 0.36$.

As can be seen in Figure 1, Experiment 1 showed that male participants retrieved angry male faces from working memory more efficiently than neutral and/or female faces. This sex-specific vigilance is consistent with the male warrior hypothesis (Van Vugt et al., 2007), which should entail that men are more vigilant about signs of physical threat coming from other men. More generally, however, we see distinct profiles for the sexes: Men prioritize angry male faces at the expense of all others, whereas women show more equivalent performance for all faces. This may reflect the fact that women employ a more balanced set of strategies, and vigilance for affiliation opportunities may actually be more adaptive than a straightforward prioritization of interpersonal threat.

Figure 1. Male (left) and female (right) participant memory accuracy (d-prime) and retrieval speed (for memory set hits, in milliseconds) as a function of face gender and expression



Discussion

We expected and found more pronounced threat-vigilance in male participants. Although contrasts of anger vs. neutrality produced some significant anger benefits, analyses that contrasted angry faces vs. all others were far more informative. Here, male participants showed clear advantages in both speed and accuracy identifying angry male faces, which were likely to be the most threatening faces in the limited capacity storage of their WM.

Despite these positive results for male participants, it is curious that women showed equivalent processing of neutral faces, because they are also frequent victims of anger. One possibility is that the expressions in the stimuli—which were only slightly angry—may not have passed a threshold for threat-identification in our female participants. Furthermore, given that *outgroup* men are especially likely to be seen as posing a physical threat compared to ingroup men (e.g., Navarrete, McDonald, Molina, and Sidanius, 2010; Sidanius and Pratto, 1999), angry men of another race might be more likely to elicit advantages in WM. Finally, if men are chronically primed for intergroup conflict with other men, it may be that women need self-protective goals to be made more salient in order to bring them into alignment with male psychology.

To explore these possibilities, in Experiment 2 we used a different stimulus set in which anger was clearly expressed, and replaced all the female faces in the memory set with Black male faces, as a previous study using students from the same University found Black men were most stereotypically associated with the potential to do harm; Cottrell and Neuberg, 2005). In addition, half of our participants listened to a frightening story (used in Becker et al., 2010) to prime thoughts of interpersonal aggressive threat, in the hopes of enhancing the accessibility of self–protective goals. We predicted that this would further enhance the processing of threatening faces, and hoped that it would elicit a threat-vigilant profile in women that was similar to that seen in men in the control condition.

Experiment 2

Materials and Methods

Participants were 81 non-Black students from introductory psychology classes (42 male) in a design similar to that in Experiment 1, but with two important changes. First, each memory set consisted of two Black and two White male faces, with one of each race making a clearly angry facial expression (in order to have a sufficient numbers of faces, we used the expressive faces of Tottenham et al., 2009, whereas neutral faces were from Becker et al., 2010). Second, we primed self-protective concerns by exposing half the participants to a 3-minute audio recording asking them to visualize being alone in a house with an intruder, and compared this to a control condition in which the other participants visualized organizing their desks for a similar amount of time.

Results

Five participants were eliminated from the analysis for having mean accuracy more than three standard deviations below the grand mean. Means are included in Table 2.

Table 2. Performance measures in Experiment 2 as a function of participant sex, condition, and face type

		Hit Rates	False Alarms	Accuracy (*d'*)	Bias (*C*)	Median Correct RT Memory Set Hits	Median Correct RT Correct Rejections
Male Participants							
Angry Black	control	93.6 (9.1)	9.3 (14)	2.99 (0.85)	0.05 (0.28)	736 (132)	718 (85)
	self-protection	92.5 (9.7)	7.6 (9.4)	2.98 (0.66)	0.01 (0.29)	710 (95)	809 (269)
Neutral Black	control	84.5 (13.9)	20 (15.8)	2.12 (0.85)	0.08 (0.44)	752 (90)	806 (129)
	self-protection	84.5 (10)	17.4 (15.2)	2.16 (0.74)	0 (0.38)	801 (165)	819 (202)
Angry White	control	87.9 (12.4)	10.1 (8.6)	2.63 (0.75)	-0.03 (0.31)	733 (211)	751 (164)
	self-protection	93.4 (6.3)	7.7 (9.3)	3 (0.58)	0.01 (0.26)	720 (98)	773 (199)
Neutral White	control	84.5 (11.9)	15.1 (11.3)	2.23 (0.86)	-0.01 (0.25)	735 (139)	811 (120)
	self-protection	85.6 (9.5)	11.9 (11.5)	2.41 (0.84)	-0.07 (0.23)	733 (131)	829 (210)
Female Participants							
Angry Black	control	94.9 (8.2)	8.6 (9.4)	3.04 (0.67)	0.09 (0.28)	741 (143)	809 (172)
	self-protection	95.5 (7.4)	11.1 (14.4)	3 (0.74)	0.14 (0.34)	712 (102)	828 (134)
Neutral Black	control	85.9 (12.5)	13.8 (13.5)	2.41 (0.8)	-0.01 (0.38)	785 (128)	822 (155)
	self-protection	88.3 (9.1)	22.2 (16.2)	2.14 (0.81)	0.2 (0.33)	753 (139)	866 (159)
Angry White	control	91.6 (6.8)	9.9 (13)	2.8 (0.69)	0.01 (0.3)	728 (167)	813 (177)
	self-protection	89.3 (8.1)	8.1 (8.8)	2.75 (0.65)	-0.07 (0.27)	730 (110)	808 (131)
Neutral White	control	93.4 (9.2)	11 (13.2)	2.88 (0.74)	0.1 (0.34)	757 (155)	824 (142)
	self-protection	87.9 (16.2)	16.9 (13.7)	2.41 (0.1)	0.12 (0.29)	755 (112)	860 (114)

Do angry male faces elicit processing benefits? Across participant sex, hit rates were 5.8% higher for angry male faces than for neutral male faces, $t(74) = 6.19$, $p = .001$, $d_{Cohen} = 0.71$, and there was a lower rate (7.4%) of false alarms, $t(74) = 6.11$, $p = .001$, $d_{Cohen} = 0.70$. There was thus a large accuracy advantage with regard to angry male faces (d-prime), $t(74) = 8.12$, $p < .001$, $d_{Cohen} = 0.93$, and no evidence of any bias (c). Turning to reaction times, participants were faster to identify angry male faces, $t(74) = -3.15$, $p = .002$, $d_{Cohen} = -0.36$, and they were faster to correctly reject angry male faces not in the memory set, $t(74) = -4.25$, $p = .001$, $d_{Cohen} = -0.48$.

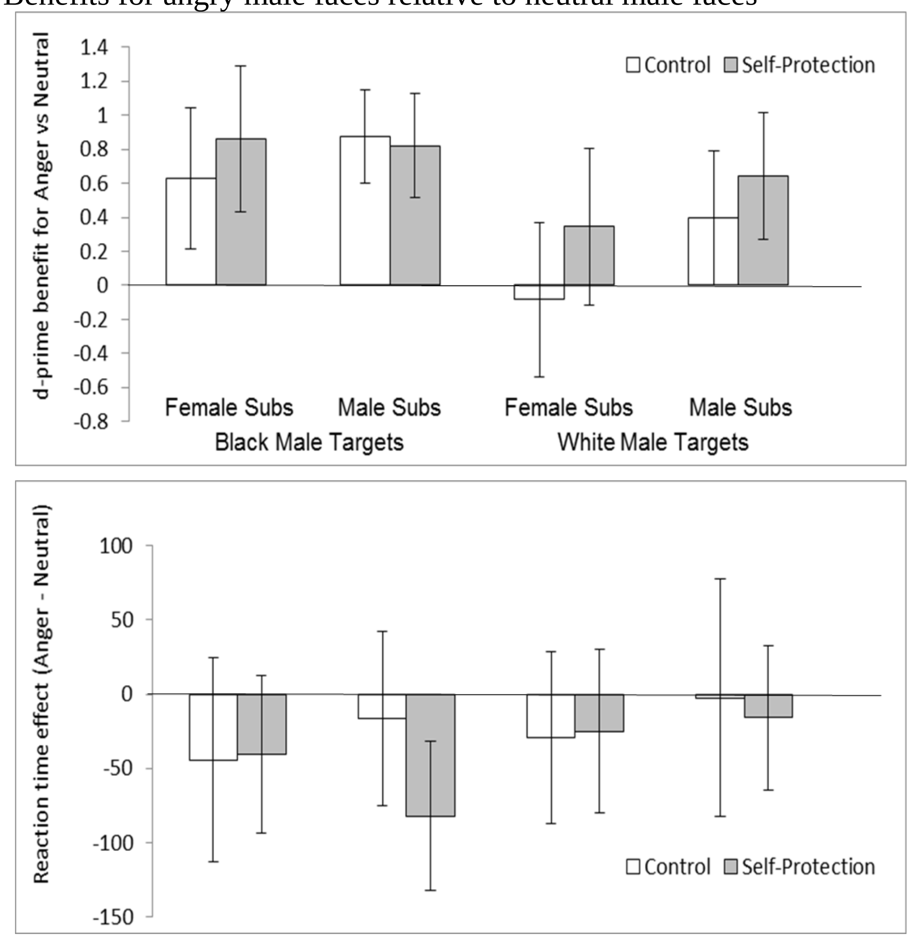
Are angry Black male faces even more efficiently processed? For hit rates, there was an interaction of race and expression, $F(1,72) = 7.61$, $p = .007$, $\eta_p^2 = .096$, with the highest accuracy for angry Black faces. The accuracy (d-prime) effect was even larger, $F(1,72) = 14.70$, $p < .001$, $\eta_p^2 = .17$, and no reaction time differences compromised this sensitivity benefit.

Are these effects moderated by participant sex? Men had higher hit rates for angry faces relative to women, $t(74) = 2.25$, $p = .027$, $d_{Cohen} = 0.43$, as well as greater accuracy (d-prime), $t(74) = 2.15$, $p = .033$, $d_{Cohen} = 0.42$. No response bias or latency effects compromised these effects.

Are these effects moderated by the self-protection manipulation? There were no overall benefits of the self-protection prime—i.e., it did not make working memory work more efficiently—but there were effects that arose as a function of face type and participant sex. There was a marginal accuracy (d-prime) benefit for angry faces under the self-protection manipulation, $t(74) = 1.73$, $p = .053$, $d_{Cohen} = 0.20$ compared to the control condition. Intriguingly, this effect seems largely driven by female participants—$t(35) = 1.93$, $p = .063$, $d_{Cohen} = 0.51$—because they had the lowest anger benefit in the control condition, consistent with our speculation that interpersonal aggression concerns are not as chronically active in women as men. The self-protection prime also marginally enhanced women's bias to say that they had seen Black men, regardless of whether they were present in the memory set, compared to the control condition, $t(35) = 1.84$, $p = .070$, $d_{Cohen} = 0.31$. In contrast, male participants, who were already at ceiling performance in their accuracy for angry Black male faces, showed marginally greater accuracy for ingroup angry faces in the self-protection condition, $t(36) = 1.88$, $p = .068$, $d_{Cohen} = 0.31$, suggesting that it is male anger to which men are attuned, rather than race.

Figure 2 illustrates these results. The upper panel shows that non-Black male participants under the self-protection manipulation showed the greatest accuracy benefits for remembering angry Black faces. The lower panel shows that they also showed the only significant reaction time improvement when self-protection had been primed. Interestingly, women also showed significant benefits for accuracy and trends toward faster responding under the self-protection manipulation.

Figure 2. Benefits for angry male faces relative to neutral male faces



Note. Error bars represent 95% confidence intervals

Discussion

The results of two experiments suggest that angry male faces are vividly represented in WM. The first experiment revealed that slightly angry male faces were more rapidly and accurately retrieved, but the effect was driven by male participants (see Figure 1). This finding supports a novel prediction derived from the male-warrior hypothesis (Van Vugt et al., 2007): Men's WM processes are attuned to evidence of anger in another *male* face.

A second experiment verified this anger vigilance effect with faces that were more clearly angry, and found the effect for women as well as men. This second study also included faces of Black men—an outgroup that our non-Black participants presumably associate with physical threat (given the findings of Cottrell and Neuberg, 2005, using the same participant population). Although the overall accuracy and speed benefits were larger for Black angry male faces, these effects were not as robust as the general anger advantage collapsing across race.

Priming a sense of self-protection by having participants imagine the threat of interpersonal violence enhanced this general anger vigilance, but in different ways for male and female participants. Male participants showed more rapid identification of angry outgroup men once self-protection had been primed. But self-protection primes led to slower responses to the correct identification of black males with neutral facial expressions, and these targets also garnered the lowest accuracy. This suggests that the well-known capacity limitations of WM may be strategically reallocated when self-protective motivations are aroused—we do not have evidence that these manipulations increase the capacity or efficiency of WM. Female participants show different reallocations of efficiency when self-protection has been primed: more rapid identification of all black male faces, regardless of expression, accompanied by a marginal bias to say that black men were present in the memory set, regardless of whether they were. Taking these results together, our self-protection prime appears to enhance men's vigilance (both speed and accuracy) to angry (male) faces at the expense of neutral (especially Black) faces, while it biases women toward saying that outgroup men have been seen before. Navarrete and colleagues (2010) also observed effects specific to participant sex, with the implication that men were attuned to threats of interpersonal aggression, while women were more attuned to threats of sexual coercion from outgroup members.

In light of the finding that male participants show the most robust WM attunements to angry male faces, it is important to note that we know of no past memory studies that have shown such a sex difference. Men were the only participants to show any effects with the slightly angry faces in Experiment 1, and they showed larger effects than women in Experiment 2. Given that these sex differences have not been observed in past experiments that focus on retrieval from long term memory (e.g., Ackerman et al., 2006; Becker et al, 2010), it may suggest that WM is a better place to find functional sex differences. This stands to reason if it is truly limited in its capacity—reallocation of processing resources would be one adaptive solution to such a bottleneck. We nevertheless think it is premature to entirely dismiss the possibility that emotional/motivational manipulations can sensitize or amplify the capacity of WM.

Conclusion

Past research has suggested that angry faces are "special," in the sense that self-protective goals have sculpted perceptual and cognitive systems to be on the lookout for anger (Fox et al., 2001). Although a growing chorus of researchers have questioned the preattentional basis for anger advantages (e.g., Becker, Anderson, et al., 2011; Horstmann, 2009), we should not dismiss the claims that angry faces are privileged once we *have* attended to them. It seems clear that angry faces hold onto attention, resisting efforts to rapidly look away from them (Becker, Anderson, et al., 2011; Fox et al., 2001), and that they elicit better recognition (Ackerman et al., 2006). Our results provide direct evidence that WM is also attuned to anger, which suggests a link between visual attention and long-term benefits. Moreover, the functional relevance of the face appears to exert nuanced effects in WM storage, which suggests that this testing method could be used to establish a hierarchy of the functional priorities of the WM system.

Consistent with this, other cues to threat appear to potentiate the effect, because it is the angry *man* that is most privileged in WM processing. This vigilance to angry men suggests that self-protective goals are automatic and autonomous; it can be seen even in the control condition. Priming participants to think about self-protective goals enhances the degree to which angry male faces grip WM resources, and the present results suggest that it may recruit additional processing to bring other threat cues—like race—to the foreground.

Goals and needs have been known to modulate the initial stages of cognition since the early days of cognitive psychology, when Bruner ushered in the "New Look" in perception by showing that poor children perceive coins to be physically bigger than do more affluent children (Bruner, 1957; see Fessler and Holbrook, 2013 for a conceptual replication). We believe that all cognitive processes are on the threshold of receiving a similar "New Look" (Kenrick et al, 2009). Memory researchers, in particular, are beginning to investigate how survival and reproductive fitness concerns differentially engage memory systems (Nairne, Thompson, and Pandeirada, 2007). The present findings show a more domain-specific enhancement of the stimuli linked to particular survival concerns. Overall, the present results suggest that encoding efficiency can depend on perceivers' current social goals and the functional relevance of the social information being processed. The presence of such encoding priorities may reveal key insights into how WM deals with the important threats and opportunities of social life.

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