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Chapter 12

VARYING BACKGROUND COLOURS REVEALS THAT ENHANCED SHORT-TERM MEMORY FOR ANGRY FACES IS A VALENCE AND NOT AN AROUSAL EFFECT

Sandra J. E. Langeslag[1*], Margaret C. Jackson[2], Jan W. van Strien[1] and David E. J. Linden[2]

[1]Erasmus Affective Neuroscience Lab, Institute of Psychology, Erasmus University Rotterdam, The Netherlands
[2]Wolfson Centre for Clinical and Cognitive Neurosciences, School of Psychology, Bangor University, UK

ABSTRACT

There is debate on whether the effect of stimulus emotionality on memory is a valence or an arousal effect. In a previous study, short-term memory (STM) was enhanced for angry compared to happy and neutral faces, and music-induced contextual arousal did not modulate this effect. The absence of such a contextual arousal effect could, however, have been due to the cross-modal nature of the study, as the contextual arousal was induced auditorily while the to-be-remembered stimuli were presented visually. In this study, we investigated the influence of visually-induced contextual arousal on the same STM task to determine whether the angry face benefit in STM is a valence or an arousal effect. Contextual arousal was successfully manipulated by presenting the background colours red, pink, and light pink. STM discrimination was enhanced for angry faces, and was not modulated by contextual arousal. High contextual arousal elicited by the red or pink backgrounds was accompanied by a more liberal response bias, regardless of facial expression. Because of this dissociation and because the effects of facial expression and background colour did not interact, it is concluded that the angry face benefit in STM is a valence and not an arousal effect. It is suggested

[*] Corresponding author S. Langeslag is now at: Erasmus MC – Sophia Children's Hospital, Department of Child & Adolescent Psychiatry, P.O. Box 2060, NL-3000 CB Rotterdam, The Netherlands, E-mail address: s.langeslag@erasmusmc.nl, Tel: +31 (0)10 703 7071, Fax: +31 (0)10 703 2111

that these stimulus valence and contextual arousal effects have different underlying mechanisms.

Keywords: Short-term memory; Working memory; Emotion; Faces; Facial expressions; Colours; Valence; Arousal.

INTRODUCTION

Emotions can be classified along the two independent dimensions of valence and arousal. The valence of an emotion describes whether the emotion is unpleasant or pleasant, whereas arousal reflects the intensity of an emotion (Bradley & Lang, 1994). Emotional pictures, words, and faces are typically better remembered than equivalent neutral stimuli in long-term memory (Kensinger, 2004). In the last couple of years, also the effect of stimulus emotionality on short-term memory (STM) has become a topic of research (e.g. Perlstein, Elbert, & Stenger, 2002).

There is some debate on whether the effect of stimulus emotionality on memory is a valence or an arousal effect. Because emotional information (whether negative or positive) is typically more arousing than neutral information, the often observed memory benefit for emotional compared to neutral information suggests that the emotion enhancement effect is an arousal effect. It has, however, been observed that also low-arousing negative and positive stimuli are remembered better than equally low-arousing neutral information (Kensinger & Corkin, 2003; Ochsner, 2000), in which case the emotion enhancement effect appears to be a valence effect. Moreover, an emotion enhancement effect sometimes also occurred for negative but not for positive over neutral stimuli, even when the negative and positive stimuli were matched in arousal (e.g. Ochsner, 2000), again implying a valence effect, albeit of negative valence only. It has therefore been suggested that both valence and arousal of emotional stimuli are capable of influencing memory for those stimuli (see Kensinger, 2004, for a review).

In a couple of previous studies, STM has been found to be superior for angry compared to happy and neutral faces (Jackson, Wolf, Johnston, Raymond, & Linden, 2008; Jackson, Wu, Linden, & Raymond, 2009). In order to examine whether the effect of facial expression on STM was a valence or an arousal effect, the emotionality of the context was varied by playing calming or arousing background music, which did not modulate the memory benefit for angry faces (Jackson et al., 2009). The absence of such a contextual arousal effect could, however, have been due to the cross-modal nature of the study, as the contextual arousal was induced auditorily while the to-be-remembered stimuli were presented visually. Additionally, in the Jackson et al. (2009) study the general effect of playing background music was not directly investigated as there was no within-subject control condition without background music. Erk, Kleczar and Walter (2007) have shown the importance of including a no context condition as a control condition. In a STM test for letters they presented a neutral picture, an emotional picture or no picture during the retention interval. STM performance was equivalent in the emotional and no pictures conditions, and was inferior to those conditions in the neutral pictures condition. The presence of a neutral context may have decreased performance by increasing cognitive load or by distracting attention, for example. As the presence of emotional context did not impair performance compared to the no context condition, the emotionality of context appeared to counteract the impairing effect of the presence of context per se, for example by increasing general arousal levels.

The goal of the current study was to examine the effect of contextual arousal on STM for emotional faces in a way that takes into account the above-mentioned issues. First, we wanted to elicit the contextual arousal in the same modality as the emotionality of the faces, i.e. in the visual modality. Interestingly, background colours have been found to influence emotional processing, as questionnaires regarding murder or rape scenarios that were printed on pink paper elicited less angry reactions than did questionnaires printed on blue or white paper (Weller & Livingston, 1988). Variations in colour have further been associated with differences in (electro)physiological responses such as blood pressure, heart rate and brain waves (Cajochen, 2007; Yoto, Katsuura, Iwanaga, & Shimomura, 2007), suggesting that colour may influence arousal levels. Indeed, it has been shown that colour brightness is negatively related to arousal ratings, and that colour saturation is positively related to arousal ratings (Valdez & Mehrabian, 1994), and we therefore decided to use background colours to manipulate contextual arousal. The colours that we used were, in order of increasing brightness, decreasing saturation, and thus decreasing arousal: red, pink and light pink. Each of these background colours was presented throughout one entire block of the STM memory task. Because we wanted the background colours to confiscate processing resources as little as possible, the colours did not have a task attached. Second, we included a within-subjects control condition in which no other background colour was presented than the white background that was used in previous studies (Jackson et al., 2008; Jackson et al., 2009; Langeslag, Morgan, Jackson, Linden, & Van Strien, 2009).

Further, besides a measure of discrimination we also obtained a measure of response bias. The above mentioned findings concern the ability to distinguish faces that were or were not previously encountered, which is called discrimination. But to fully consider recognition memory, a measure of response bias needs to be considered as well (Snodgrass & Corwin, 1988). The response bias reflects the tendency to classify a certain stimulus as previously encountered, irrespective of its actual old or new status. Generally, people adopt a more liberal response bias for emotional than neutral stimuli (Ochsner, 2000; Windmann & Kutas, 2001), yielding higher hit and false alarm rates for emotional than neutral stimuli. This more liberal response bias for emotional stimuli would ensure that information that is relevant for survival and/or reproduction is not forgotten or missed (Windmann & Kutas, 2001).

We expected to replicate the increased STM performance for angry faces (Jackson et al., 2008; Jackson et al., 2009). Assuming that the background colours would not use processing resources needed for the STM task, we also expected that contextual arousal would not decrease performance. Crucially, any interaction between the effects of facial expression and contextual arousal would imply that the angry face benefit on STM has to do with arousal. The absence of such interaction, in contrast, would imply that the angry face benefit on STM is a valence effect.

METHOD

Participants

Twenty-four students (3 men, mean age 19.3 years, range 18-24) of the University of Wales Bangor, School of Psychology with normal (colour) vision volunteered to participate in return for course credit. The study was approved by the School's ethics committee in Bangor and all participants provided written informed consent before participation.

Stimuli

The stimuli for the STM task were 18 gray-scaled male faces (approximate visual angle of 2.9° vertically and 2.5° horizontally) from the Ekman and Friesen (1976) series: six individuals each displaying angry, happy and neutral facial expressions. The stimuli were presented within a white rectangle (approximate visual angle of 7.7° vertically and 6.9° horizontally) surrounded by a red, pink, light pink or white background, see Figure 1. The RGB values of these colours were: 255, 0, 0 (red), 255, 121, 121 (pink), 255, 207, 207 (light pink) and 255, 255, 255 (white). Note that because in the previous studies (Jackson et al., 2008; Jackson et al., 2009; Langeslag et al., 2009) the faces were always presented on a white background, the white background condition served as a control condition (see also Mehta & Zhu, 2009). Stimuli were displayed on a 15-inch Toshiba SA60-352 notebook (16-bit colour; resolution 1068 x 768 pixels), generated by E-Prime version 1.1.

Procedure

Participants were seated in front of a computer in a room without any windows. After completion of informed consent, the participants were introduced to the STM task. A background colour was present throughout the entire trial, which consisted of the following displays, see Figure 1. First, a fixation cross that grew and shrunk indicated that the trial was about to start. During the encoding phase an array of faces was presented for 2,000 ms. This encoding array consisted of either two different to-be-remembered faces and two different scrambled faces or of four different to-be-remembered faces, resulting in a STM load of two or four respectively. The faces were arranged in a two by two grid around a black fixation cross (0.5°) in the centre of the screen. A 1,000 ms retention display followed, consisting of a black fixation cross. During the retrieval phase a probe face appeared in the centre of the screen. The participants had to decide whether or not the probe face matched one of the faces in the preceding encoding array (50% match trials). Participants were instructed to respond to the probe faces by pressing the left ('match') or the right ('mismatch') mouse buttons with their right index and middle fingers respectively. The response terminated the retrieval phase and participants hit the spacebar to initiate the next trial. Participants were asked to maintain fixation at the fixation crosses at all times. After the practice trials, the lights were turned off and the participants completed the five blocks of the STM task, interleaved with breaks.

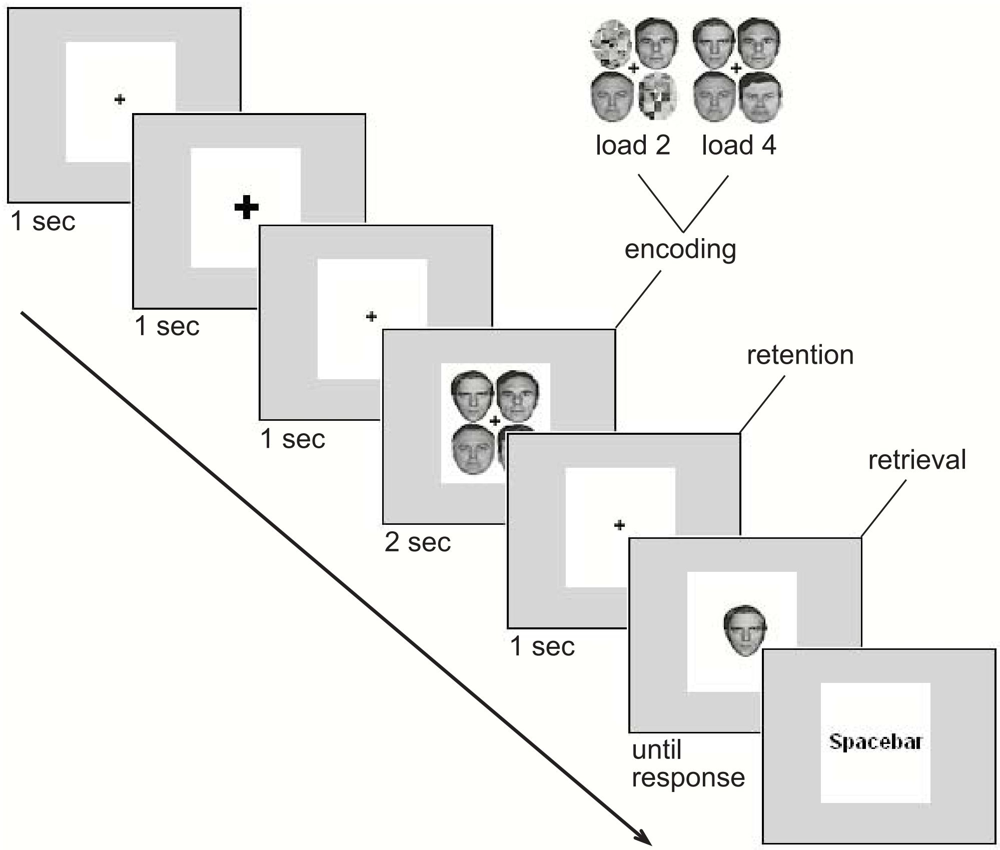

Figure 1 Trial overview. Note that the images here are not to scale and that the gray background was actually red, pink, light pink or white

Trials with different facial expressions and STM loads were presented pseudo randomly within blocks. The induction of contextual arousal (i.e. background colour), in contrast, was blocked to ensure a lasting arousal state (Shackman et al., 2006) and to avoid between-trial carry-over effects. The order of the blocks with red, pink and light pink backgrounds (60 trials each) was counterbalanced across participants. Two blocks with a white background (30 trials each, 60 trials in total) interspersed the blocks with red, pink and light pink backgrounds to minimize between-block carry-over effects. It is important to note that the STM task was an identity, and not an emotion, matching task. Moreover, all of the faces within one trial displayed the same facial expression, making facial expression uninformative for the task.

After the final block of the STM task, the participants rated the valence and arousal of the faces and the red, pink and light pink colours with a computerized version of the Self-Assessment Manikin (SAM) (Lang, 1980).

Analyses

Hit rates (*H*, i.e. proportion correct ‘match’ responses) and false alarms rates (*FA*, i.e. proportion incorrect ‘match’ responses) were computed using the correction recommended by

Snodgrass and Corwin (1988). These hits and false alarm rates were used to compute the discrimination index $Pr = H - FA$, where $Pr = 1$ reflects perfect performance and $Pr = 0$ reflects chance performance, and the response bias index $Br = FA / (1 - Pr)$. The response bias index describes the tendency of participants to respond 'match' irrespective of the true match or mismatch status of the probe stimulus, where $Br > 0.5$ indicates a liberal response bias and $Br < 0.5$ indicates a conservative response bias (Snodgrass & Corwin, 1988).

Valence and arousal ratings of the faces and colours were analyzed with planned comparisons between angry, happy and neutral faces and between the red, pink and light pink colours. The discrimination and response bias indices *Pr* and *Br*[1] were tested using repeated measures ANOVAs with the factors Colour (red, pink, light pink, white), Expression (angry, happy, neutral) and Load (2, 4). When applicable, degrees of freedom were corrected with the Greenhouse-Geisser correction. The *F* values, the uncorrected *df*s, the epsilon (ε) values and corrected probability levels are reported. A significance level of 5% (two-sided) was selected. Only effects involving the factors Colour and/or Expression are mentioned and significant effects were followed up by paired samples *t*-tests.

RESULTS

Valence and Arousal Ratings

See Table 1 for the valence and arousal ratings of the colours and faces.

Faces. Valence ratings were lowest for angry faces, intermediate for neutral faces and highest for happy faces, all ts(23) > |6.1|, all ps < .001. Arousal ratings were higher for angry and happy than for neutral faces, both ts(23) > |4.2|, both ps < .001, while arousal ratings for angry and happy faces did not differ, $t(23) = |0.3|$, $p = .75$.

Colours. Valence ratings were higher for pink than for red, $t(23) = |4.1|$, $p < .001$, with light pink non-significantly different in-between. Arousal ratings were highest for red, medium for pink and lowest for light pink, all ts(23) > |3.6|, all ps < .002. Thus, arousal was successfully manipulated using the colours red, pink, and light pink.

Table 1. Mean valence and arousal ratings (standard deviation in brackets) of the colours and faces

	Colours			Faces		
	Red	Pink	Light pink	Angry	Happy	Neutral
Valence	5.6 (2.2)	7.5 (1.2)	6.6 (1.9)	3.1 (0.9)	7.6 (1.0)	4.3 (0.6)
Arousal	7.3 (1.4)	5.9 (2.1)	3.8 (1.9)	5.1 (1.5)	5.0 (1.8)	3.4 (1.0)

Note. Valence and arousal ratings ranged from 1 (extremely unpleasant or calming) to 9 (extremely pleasant or arousing) (Lang, 1980).

[1]When analyzing *d'* and *C*, as discrimination and bias indices respectively, the same pattern of results was obtained.

Recognition Performance

See Table 2 for the discrimination and response bias indices in all conditions.

Discrimination index. A main effect of Expression was found, $F(2,46) = 4.6$, $\varepsilon = .75$, $p = .026$. Overall, discrimination was significantly better for angry than for happy faces, $p < .001$, nearly significantly better for angry than for neutral faces, $p = .074$, and not significantly different between happy and neutral faces, $p = .55$. This main effect was modulated by a significant Expression by Load interaction, $F(2,46) = 5.7$, $\varepsilon = .77$, $p = .011$. In load 4, discrimination was significantly better for the angry vs. happy and neutral faces, both *p*s < .024, see Figure 2a.

All main and interaction effects involving Colour were non-significant, all *F*s < 1.3, all *p*s > .28. This absence of Colour effects shows that STM performance for emotional faces was not increased or decreased by the coloured backgrounds compared to the white background.

Response bias index. A significant main effect of Expression occurred, $F(2,46) = 7.8$, $\varepsilon = .96$, $p = .001$. Angry faces were associated with a more conservative bias than happy and neutral faces, both *p*s < .022. A significant Expression by Load interaction, $F(2,46) = 4.3$, $\varepsilon = .99$, $p = .019$, signified that only in load 4, the response bias was more conservative for the angry vs. happy and neutral faces, both *p*s = .001, see Figure 2b. This implies that under high memory load conditions, the participants were less inclined to respond 'match' to an angry probe face than to probe faces with happy or neutral expressions.

Table 2. Mean discrimination (*Pr*) and response bias (*Br*) indices in all conditions

		Pr		*Br*	
		Load 2	Load 4	Load 2	Load 4
Angry	Red	.69	.51	.47	.46
	Pink	.72	.44	.48	.47
	Light pink	.71	.41	.41	.40
	White	.69	.46	.39	.40
Happy	Red	.71	.42	.47	.55
	Pink	.67	.28	.48	.60
	Light pink	.68	.35	.47	.56
	White	.70	.33	.46	.50
Neutral	Red	.70	.35	.48	.56
	Pink	.69	.41	.39	.58
	Light pink	.69	.31	.40	.51
	White	.76	.32	.44	.51

Note. A greater discrimination index indicates better recognition accuracy. A response bias larger than 0.5 indicates a liberal response bias, whereas a response bias smaller than 0.5 indicates a conservative response bias (Snodgras & Corwin, 1988).

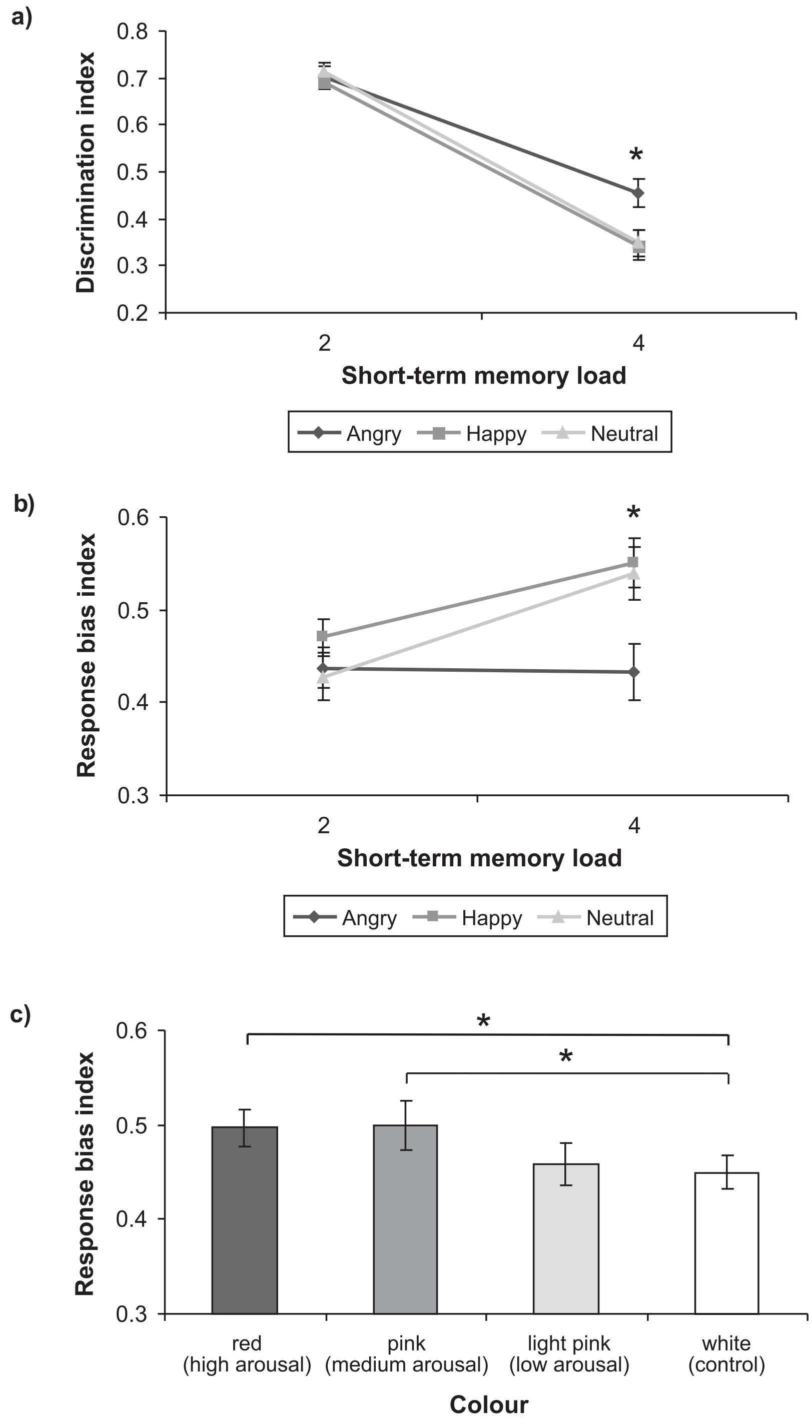

Figure 2. a) Discrimination index per facial expression and memory load. In load 4, discrimination was significantly better for angry faces, than for happy or neutral faces, * ps < .024 b) Response bias index per facial expression and memory load. In load 4, the response bias was more conservative for angry than for happy or neutral faces, * ps = .001 c) Response bias index per colour. Stimuli presented on a red (high arousal) or a pink (medium arousal) background were associated with more liberal response biases than stimuli presented on a white background (control), * ps < .044

There was a trend towards a significant main effect of Colour, $F(3,69) = 2.7$, $\varepsilon = .83$, $p = .065$. Stimuli presented on a red (high arousal) or a pink (medium arousal) background were associated with more liberal response biases than stimuli presented on a white background (control), both *p*s < .044, with light pink (low arousal) non-significantly different in-between, see Figure 2c. This means that the participants were more inclined to respond ‘match’ to a probe face presented under high contextual arousal compared to control conditions. All interaction effects involving Colour were non-significant, all *F*s < 1.0, *ns*.

CONCLUSION

The goal of the present study was to examine how STM for face identity of emotional faces would be influenced by visually-induced contextual arousal to clarify whether the effect of facial expression on STM is a valence or an arousal effect. Our manipulation of contextual arousal through colours was successful, given that the subjective ratings showed that red was associated with highest arousal, pink with medium, and light pink with lowest arousal.

As expected, we replicated previous findings of an increased discrimination index and thus enhanced STM for angry compared to happy and neutral faces (Jackson et al., 2008; Jackson et al., 2009), under high STM load (Langeslag et al., 2009). Moreover, participants were less inclined to incorrectly respond ‘match’ to angry compared to happy and neutral faces given that angry faces were associated a more conservative response bias when STM load was high. It is this conservative bias that appears to be the base of the angry face benefit in STM.

Contextual arousal did not affect discrimination between match and mismatch probe faces, which is in line with the study by Dougal (2003) as well as with the study using calming and arousing background music (Jackson et al., 2009). It does, however, stand in contrast to the results of the study by Erk et al. (2007), in which the context was formed by pictures that were presented during the retention interval. The context in that study appeared to be resource demanding, because performance was decreased when a neutral compared to no picture was presented. Our study suggests that background colours are not resource demanding, as they did not impair performance compared to the control condition with a white background. This makes manipulating background colours a promising approach for studying the effect of contextual arousal on cognitive processes.

As expected, the contextual arousal that the colours elicited influenced the response bias in the STM for faces. The response bias was more liberal in the high and medium arousal conditions compared to the control condition. This finding concurs with the finding of Dougal (2003) that neutral words studied in the presence of another emotional word (i.e. arousing context) were associated with a more liberal response bias at retrieval compared to neutral words studied in a the presence of another neutral word (i.e. non-arousing context). The arousing context in the current study may have increased the participant’s tendency to respond ‘match’, may have increased the perceptual fluency with which the faces were processed at retrieval and/or may have increased the familiarity of the faces.

Despite the fact that contextual arousal and stimulus emotionality were manipulated in the same modality, the effects of background colour and facial expression did not interact. Although the colour pink was rated as more pleasant than the colour red, the response bias reflected the pattern of colour arousal rather than valence, suggesting that the effect of context on response bias is an arousal effect (cf. Dougal, 2003). Because the angry and happy faces were matched with respect to arousal, the influence of facial expression on STM performance on the other hand appears to be a valence effect, which is in line with previous findings (Jackson et al., 2009; Kensinger, 2007). The non-interacting and distinct effects of contextual arousal and facial expression on STM suggest that these arousal and valence effects have different underlying mechanisms. It has been suggested that the amygdala increases memory for arousing stimuli, whereas the prefrontal cortex increases memory for non-arousing valenced stimuli (Kensinger, 2004; Van Strien, Langeslag, Strekalova, Gootjes, & Franken, 2009), and a similar distinction may exist for the effects of emotional stimuli and contexts on memory.

To conclude, we report here the first study of the influence of visually-induced contextual arousal on visual STM for emotional faces. Whereas high contextual arousal was associated with a more liberal response bias regardless of expression, negative valence of facial expression was associated with an increased discrimination and more conservative bias regardless of background colour. Thus, the present results suggest that the effects of colour-induced contextual arousal and facial expression on STM are different. Because colour-induced arousal did not interact with the effect of facial expression on STM, this latter effect appears to be a valence and not an arousal effect. More research is needed to determine what cognitive and neural mechanisms underlie the effects of contextual arousal and facial expression on STM. In the mean time, the use of background colours to induce and manipulate contextual arousal appears a promising method that could be used in future research studying the effects of emotional context on cognitive tasks requiring visual presentation of stimuli.

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