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Preference for Happy Faces in Emotion-based Attentional Priority in Visual Short Term Memory

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Abstract

Prior literature provides contradictory claims regarding differences in preferential processing among different emotional stimuli. While some studies have indicated that happy faces are processed more effectively than others, Simione et al. (2014) demonstrated that threat superiority emerges when processing resources are constrained in the visual short term memory. Given the contrasting claims about angry vs. happy faces, we did a modified replication of the same study using real instead of schematic faces. We hypothesized that performance would be better with happy faces. We conducted two experiments by manipulating display times in experiment 1 and set sizes in experiment 2. We found a general emotional superiority effect and a "happiness superiority" effect in both experiments, which contrasts with Simione et al. (2014)'s results. These findings suggest that happy faces receive attentional priority for storage in VSTM, highlighting the need to incorporate saliency-based processing differences in theories of consolidation and processing in visual short-term memory.

Keywords: Visual Short Term Memory; Processing competition; Emotional superiority; Happiness superiority effect

Introduction

The human perceptual system is known to filter salient information from a complex, ever-evolving environment (Neisser, 1978) and one such information is considered to be the emotional state of another individual. Previous literature shows that a cue from the environment that is considered to be affectively salient is thought to be processed preferentially by the perceptual system (called the emotion-superiority effect) (Alpers & Pauli, 2006), and this has been indicated by decreased reaction times and improved accuracy of responses to such stimuli across many paradigms and tasks (Maratos, Mogg, & Bradley, 2008; Milders, Sahraie, Logan, & Donnellon, 2006; Anderson, 2005).

Emotional stimuli are processed more quickly and efficiently than neutral stimuli (Lang & Bradley, 2010), and for example, individuals suffering with anxiety have difficulty disengaging their attention from threatening stimuli (Mogg, Bradley, Miles, & Dixon, 2004). Studies have also shown that emotional stimuli capture an observer's attention even when the observer is not actively paying attention to the stimulus (Öhman & Mineka, 2001).

With reference to specific differences in processing due to emotional content, studies using the attentional blink paradigm have shown that happy expression show lesser attentional blink at short SOAs compared to sad faces (Srivastava & Srinivasan, 2010). Happy faces are recognized better when attention is distributed (Srinivasan & Gupta, 2010). Emotional expression is also shown to affect information processing through memory - identification of sad faces, but not happy faces, is seen to be affected by perceptual load (Gupta & Srinivasan, 2015). These results indicate that happy faces are more vividly processed through both attentional and memory mechanisms (D. V. Becker & Srinivasan, 2014) and do indeed have a privileged position compared to other emotional faces - a phenomenon we call the "happiness superiority effect".

The advantage for happy faces have been supported by studies comparing the attentional processing of happy, angry, and surprise faces (Ray, Mishra, & Srinivasan, 2020), and identification of real faces showing happy, angry and sad emotions (D. V. Becker et al., 2012). Using an RSVP paradigm, Ray et al. (2020) showed a lower attentional blink effect for happy faces compared to angry and surprise faces across two experiments. D. V. Becker et al. (2012) showed that happiness is detected earlier than anger when non-expressive faces evolve into expressive ones - the effect staying constant even when low and high spatial information is removed. Even when expressive faces are presented very briefly, the happy face processing advantage in the form of identification accuracy starts showing as early as 27ms (D. V. Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007).

However, the happiness superiority effect has been questioned by Simione et al. (2014) study, which showed angry faces to be encoded or stored more efficiently in visual short-term memory (VSTM) than happy faces. In their study, the authors used a VSTM report paradigm where they presented schematic faces displaying the emotions happy, angry and neutral, to people under varying competitive processing demands (manipulating exposure time in experiment 1 and set size in experiment 2). The first experiment tested for an "emotional superiority effect" and the second experiment showed that within competing emotional displays, threat takes precedence even in higher processing conditions i.e., 150 ms with set sizes of 3 and 5, angry faces were identified better than happy faces - a 'threat superiority effect'. Thus, they argue that task demands prioritize threatening stimuli more than non-threatening ones in VSTM.

One possible reason for the discrepancy could be the use of schematic faces in their study. The authors argued that the rationale for choosing schematic faces as stimuli was that it

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provides "an unambiguous representation of the key features of the emotion". However, schematic faces are oversimplified and overstyled abstract representations of human faces. Even though they permit a reasonable level of control over stimulus features, they are less ecologically valid, making it harder to generalise these results. Moreover, schematic faces frequently exhibit exaggerated emotional qualities and simplistic visual features, which may bias early visual processing. With visual search, the threatening face advantage found with early schematic face studies have been overturned by careful visual search studies done using real emotional faces (D. V. Becker, Anderson, Mortensen, Neufeld, & Neel, 2011)

To address the conflict between the threat superiority effect and the happy superiority effect in the context of VSTM processing, we investigated the emotional processing in visual short-term memory using real faces instead of schematic ones. Previous research has demonstrated differences between processing schematic and real emotional faces (Kendall, Raffaelli, Kingstone, & Todd, 2016). Our hypothesis was that happy faces would take precedence when competing emotional stimuli are presented together, even under maximum processing demands. In order to accomplish this, we replicated Simione et al. (2014)'s study with real faces without modifying the manipulated independent variables. In experiment 1, we presented people with real faces displaying happy, angry and neutral faces and manipulated the stimuli display time to replicate the emotional superiority effect. Under conditions of high (150 ms array exposure duration) and low (400 ms array exposure duration) perceptual processing competition, participants had to recall a probed stimulus from a set size of four real faces. In Experiment 2, we kept the display time constant (at 150 ms) and varied the set size (between three and five) to determine if the happy superiority effect, as opposed to the threat superiority effect, was elicited.

Experiment 1

In experiment 1, we wanted to replicate the "emotional superiority" effect with real faces rather than schematic faces. We expected a general emotion superiority effect with a higher response accuracy for both happy and angry faces compared to the neutral face. In addition, we test whether the happiness superiority effect holds with our stimuli in Simione et al. (2014)'s paradigm.

Method

Participants To detect a medium effect ($f = .25$) of the influence of emotional expressions on identification accuracy at an $\alpha = .05$ and power = .95, a sample size of 44 participants was required. We collected data from 45 participants. After removing one participant's data for not meeting the qualifying criterion (total accuracy greater than 33.33%), we analyzed data from 44 participants (19 females; Mean age [SD] = 21.34 [2.7] years). All participants had a normal or corrected-to-normal vision and gave explicit written consent before participating. The Institutional Ethics Review Committee approved the experiment.

Figure 1: A sample set of emotional expressions with the same facial identity.

Stimuli The stimuli were selected from the IIM - Indore Emotional Face Data Base for this study (Tewari, Mehta, & Srinivasan, 2023). All the images in the dataset have been rated by human participants. For each image, participants report the depicted facial expression (compiled as "accuracy"; correct response is the match between the emotion reported by the participant and the intended display of emotion on the face in the dataset), intensity, clarity, genuineness, and valence of the image and the average of each dimension was provided with the dataset. We first sorted the dataset to include only those stimuli that had at least 80% accuracy ratings. We then selected angry, happy, and neutral expressions for each face (referred to as Subject ID in Figure 1) to replicate the effect reported by Simione et al. (2014). After comparing the mean luminosity of each Subject ID and matching them on valence and arousal, eight distinct Subject IDs were picked for the main experiment. Each image was cropped at the edges keeping only the central portion i.e., the face, intact. Our final stimuli set contained eight distinct Subject IDs with three emotional expressions per ID (angry, happy, and neutral). We traced the outer edge of each Subject ID (neutral face) for the probe cues.

Each stimulus subtended $5° \times 6.5°$ visual degrees on the monitor screen and was presented at a distance of $10° \pm 0.5°$. This is different from the original dimensions of the schematic stimuli and was done so that participants can clearly see the identity and expressions of the real faces. All stimuli were presented on a black background with a fixation cross present throughout the experiment as seen in Figure 2.

Procedure The experiment was performed on a display monitor with a refresh rate of 100 Hz using the PsychoPy software (Peirce, Hirst, & MacAskill, 2022). We employed the same paradigm as Simione et al. (2014), which is an adaptation of the VSTM task proposed by Landman, Spekreijse, and Lamme (2003). A fixation cross was displayed at the centre of the screen to signal the start of a trial. After 1000 ms, an array of four stimuli was presented at any four of the eight possible locations around the fixation cross (see Figure-3). Facial Identity (subject IDs of all the faces) was kept constant for an image array presented during one trial. The display exposure time of this face array was either 150 ms (short display

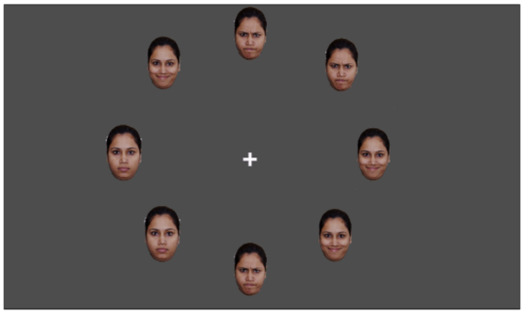

Figure 2: Stimuli were presented at a subset of eight possible locations around the fixation cross.

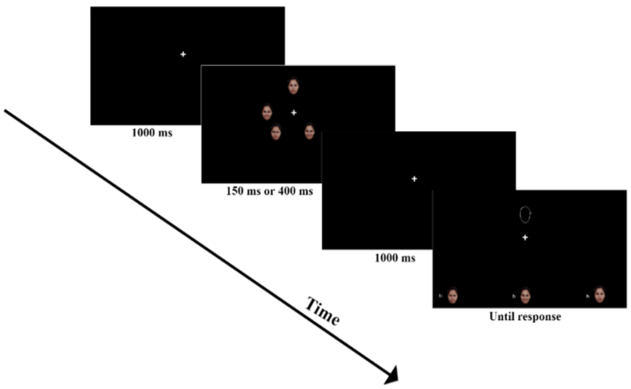

Figure 3: Trial structure of Experiment 1.

exposure time) or 400 ms (long display exposure time). This was followed by a 1000 ms inter-trial interval (ITI). Following it, a probe appeared at any one of the locations of the four presented faces. Participants then had to identify the emotional expression of the face that had appeared at the probed location from three options displayed at the bottom of the screen. The response choices were counterbalanced across participants. The trial ended after participant recorded their choice.

The experiment was conducted in a dark and noise-controlled room and lasted for approximately 40 minutes. Participants first completed 24 practice trials. After confirming that they had understood the instructions, the main experiment block commenced. The main block contained 192 trials. All faces (angry, happy, and neutral) were presented randomly and with equal probability (i.e., 8 and 64 trials on the practice block and main block for each face respectively).

Results

We report data from 44 participants whose mean accuracy was above the chance accuracy of 33.33% (one participant's data was removed). The mean percentage of correct report accuracy across all the conditions was 46.64%. Accuracy comparisons for the emotional expressions across the display exposure times are shown in Figure 4.

A 2 X 3 repeated measures ANOVA was conducted to examine the main effects of *Array Display Exposure time* (150 ms and 400ms) and *Emotional Expressions* (Neutral, Angry, and Happy faces) on the dependent variable *Response Accuracy* (in % correct). All post-hoc tests were Holm–Bonferroni corrected. The main effects of emotional expressions ($F(2,86) = 52.732, p < .001, \eta^2 = 0.281$) and array display exposure time ($F(1,43) = 44.743, p < .01, \eta^2 = 0.098$) on the response accuracy were significant. Additionally, the interaction between the two was also significant ($F(2,86) = 7.88, p < .001, \eta^2 = 0.046$).

We conducted post hoc tests to understand the effects of emotional expression. Overall response accuracy was significantly better in angry than neutral faces ($Mean_{diff} = 10.050, CI_{diff} = [6.36, 13.75], t = 6.776, p < 0.001, d = 1.014$), and also higher in happy than neutral faces ($M_{diff} = 14.808, CI_{diff} = [11.176, 18.440], t = 10.158, p < 0.001, d = 1.494$). More importantly, as hypothesized, the accuracy for angry was significantly less than that for happy faces ($M_{diff} = -4.759, CI_{diff} = [-8.435, -1.082], t = -3.224, p = 0.002, d = 0.480$). The presence of emotional content improved performance with a further advantage for the happy emotional expression as hypothesized.

We found a significant difference in response accuracy at 150 ms and 400ms for angry ($M_{diff} = -9.872, CI_{diff} = [-17.107, 2.637], t = -4.241, p < 0.001, d = 0.996$) and happy faces ($M_{diff} = -11.719, CI_{diff} = [-18.638, -4.799], t = -5.264, p < 0.001, d = 1.182$) but not for neutral faces. With 150 ms exposure time, we only found a significant difference between happy and neutral faces ($[M_{diff} = 9.091, CI_{diff} = [4.050, 14.132], t = 5.605, p < 0.001, d = 0.917$). When the exposure time was 400ms, there was a significant difference between angry and neutral ($[M_{diff} = 14.844, CI_{diff} = [8.302, 21.385], t = 7.053, p < 0.001, d = 1.497$), as well as happy and neutral ($M_{diff} = 20.526, CI_{diff} = [12.685, 28.366], t = 8.137, p < 0.001, d = 2.071$) but not between happy and angry faces.

Discussion

We demonstrate that both emotion expressions and exposure times affect the detection accuracy. Both happy and angry faces were identified better than neutral faces, demonstrating that emotional faces are processed faster than non-emotional ones. This effect was evident for both display times (high and low processing demand conditions), thus bolstering the "emotional superiority" hypothesis. Overall, participants were more accurate when the probed face was happy than angry. This result suggests a 'happiness superiority' effect rather than a 'threat superiority effect' Simione et al. (2014), which we test further in our second experiment.

Experiment 2

Similar to the one conducted by (Simione et al., 2014), in Experiment 2, we introduced two array sizes of stimuli - 3 and 5, while keeping the exposure duration constrained at 150 ms

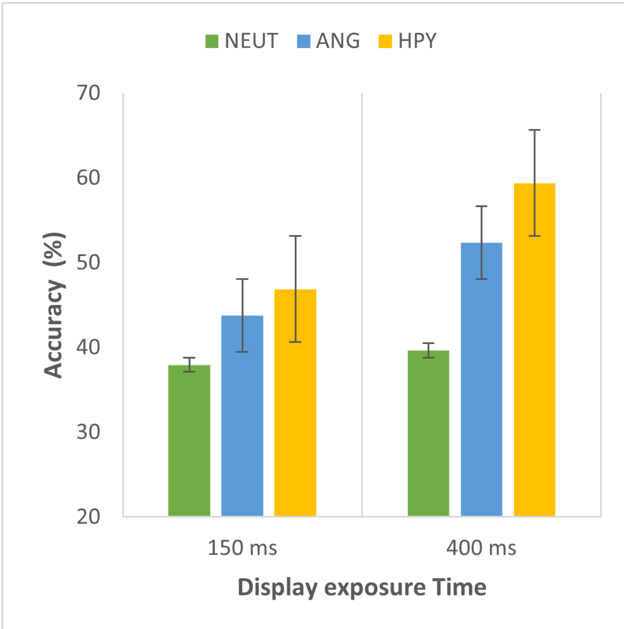

Figure 4: Mean accuracy for array display times (150 ms & 400 ms) grouped by the different emotional expressions as probed.

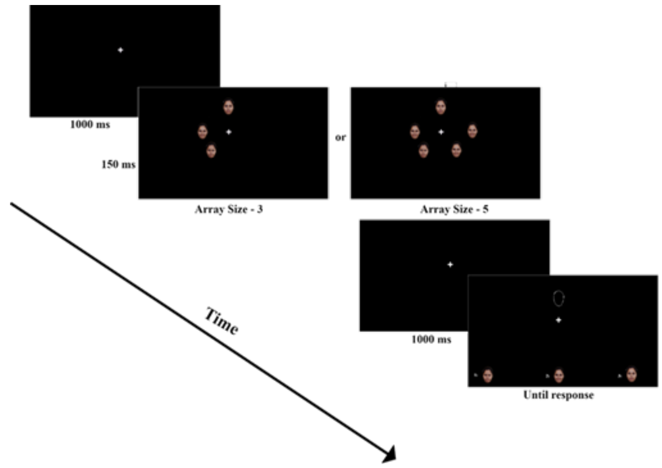

Figure 5: Example of sequence of events in every trial for Experiment 2.

to increase the processing competition. We expected better performance in terms of accuracy in trials with the smaller set size of 3 than 5. In terms of the effects of emotions, we again hypothesized a better performance with happy faces compared to angry faces.

Methods

Participants We collected data from 44 participants (22 females; Mean age [SD] = 22.25 [1.71] years), expecting to detect a medium effect size of $f = 0.25$, at $\alpha = .05$ and power = .95. Participants' vision was normal or corrected-to-normal. Ethical clearance and written consent were similarly obtained as in Experiment 1.

Stimuli Stimuli was the same as that used in Experiment 1.

Procedure In Experiment 2, we fixed the array exposure time fixed at 150 ms. To increase stimulus competition, we introduced two array set sizes, i.e., the number of images that were displayed around the fixation cross in a trial. The array size was either three or five faces with each one randomly placed in any one of the eight possible locations (see Figure 2). Each emotional expression (angry, happy, and neutral) was presented randomly and with equal probability. The response choices were also counterbalanced across participants. Like in Experiment 1, participants underwent 24 practice trials before starting with the main block of 192 trials. The experiment was approximately 50 minutes long.

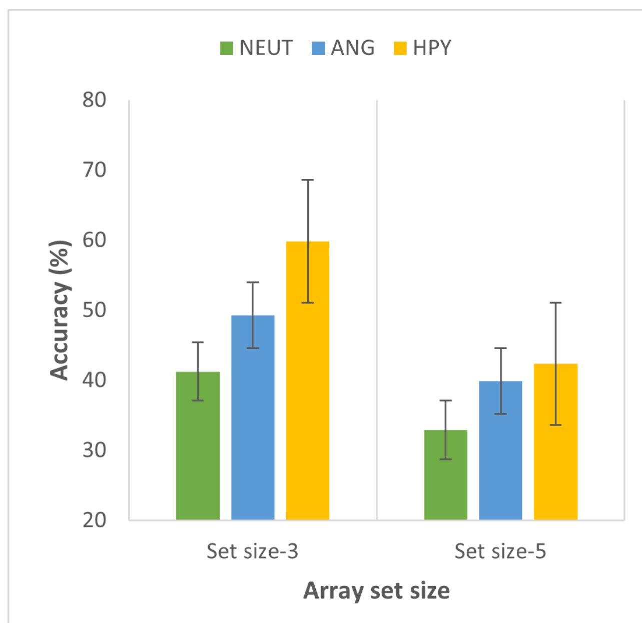

Figure 6: Mean accuracy for array set sizes (three & five) grouped by the different emotional expressions as probed.

Results

We report data from all 44 participants, who were above chance accuracy of 33.33%. The mean percentage of correct report accuracy across all the conditions was 44.23%. Accuracy comparisons for the emotional expressions across the display exposure times are shown in Figure 6.

A 2 X 3 repeated measures ANOVA, conducted to examine the main effects of *Array Set Size* (3 and 5) and *Emotional Expressions* (Neutral, Angry, and Happy faces) on the dependent variable *Response Accuracy* (in % correct), revealed significant main effects for emotional expression ($F(2,86) = 213.24, p < .001, \eta^2 = 0.369$) and array set size ($F(1,43) = 447.725, p < .001, \eta^2 = 0.391$). As expected, accuracy was better with set size 3 compared to set size 5. We conducted post-hoc tests to further examine the effects. Additionally, like in Experiment 1, the response accuracy changed as a function of probed emotional expression. Accuracy was significantly more when the probed face was angry than neutral ($M_{diff} = 7.493, CI_{diff} = [5.69, 9.29], t = 10.363, p < 0.001, d = 1.639$). There was also a significant difference in accuracy between happy and neutral faces ($M_{diff} = 13.991, CI_{diff} = [12.46, 15.53], t = 22.719, p < 0.001, d = 3.060$). Importantly, the accuracy for angry faces was less than happy faces ($M_{diff} = -6.499, CI_{diff} = [-8.220, -4.777], t = -9.406, d = 1.421, p < 0.001$).

The interaction between the two main effects was also significant ($F(2,86) = 24.449, p < .001, \eta^2 = 0.046$). For array set size of 3, we found significant difference between happy and neutral faces ($M_{diff} = 18.537, CI_{diff} = [15.61, 21.46], t = 18.871, p < 0.001, d = 4.055$), angry and neutral faces ($M_{diff} = 8.026, CI_{diff} = [5.10, 10.95], t = 8.170, p < 0.001, d = 1.755$), as well as angry and happy faces ($M_{diff} = -10.511, CI_{diff} = [-13.44, -7.59], t = 10.701, p < 0.001, d = 2.299$). For set size of five, we only found significant difference between angry and neutral faces ($M_{diff} = 6.960, CI_{diff} = [4.036, 9.884], t = 7.086, p < 0.001, d = 1.522$), and happy and neutral faces ($M_{diff} = 9.446, CI_{diff} = [6.52, 12.37], t = 9.616, p < 0.001, d = 2.066$).

Discussion

In experiment 2, we find a main effect of array set size, with greater accuracy when the set size was three as compared to five, under already constrained array exposure time of 150 ms. As expected, performance is better when the processing load is lower. The main effect of emotional expressions was significant indicating that there was an overall difference in the response accuracy as a function of emotional expression. We found overall better accuracy for both emotional faces compared to neutral face and more importantly better accuracy for happy compared to angry faces. There was a significant interaction effect between exposure time and emotional expression. With a challenging stimulus presentation time and a higher load of set size of five, there was only an emotional superiority effect. The preference for happy over angry face is present when the set size is below the typical VSTM storage capacity of four.

General Discussion

The novel VSTM task used in the study by (Simione et al., 2014) was designed such that the demands of the task modulate the availability of processing resources; consequently, only preferential stimuli are expected to be given storage priority in VSTM under more demanding processing conditions. This paradigm therefore permits the testing of the perceptual processing difference between emotional and non-emotional stimuli and also allows us to test whether attentional priority is given to particular emotions when competition for processing resources increases as a result of task demands. Simione et al. (2014)'s study used schematic faces instead of real faces to check differences in priority in VSTM as a function of emotional content.

In experiment 1, we wanted to replicate the "emotional superiority" effect for storage of emotional stimuli in the visual short-term memory under constrained display exposure time, but using real faces instead of schematic faces. The shorter display time is considered the higher competition condition. Specifically, we predicted and obtained higher response accuracy for both happy and angry faces as compared to neutral faces in the VSTM report task consistent with Simione et al. (2014)'s results. We find a main effect of the array display time on the response accuracy, with higher accuracy at 400ms as compared to 150 ms. The emotional superiority effect indicates that under limited processing capacity (Bundesen, 1990; Lavie, Hirst, De Fockert, & Viding, 2004; Lavie, 2010) emotional stimuli do have a perceptual processing advantage. The emotional superiority effect seems to temporally precede the happiness superiority effect. Interestingly, as predicted, we find contrasting results, with happy faces having a greater processing advantage (as evidenced by the response accuracy) compared to angry faces, when real faces are used. This is consistent with (Srivastava & Srinivasan, 2010; D. V. Becker & Srinivasan, 2014)'s hypothesis that happy faces require lesser processing resources as compared to angry faces. Unlike Simione et al. (2014) who found their threat superiority effect in the more difficult 150 ms condition, we appear to have a larger happy superiority effect at 400ms indicating the happy superiority effect is present only when there is adequate display time for consolidation in VSTM.

Greater stimulus competition was introduced in Experiment 2 with the similar paradigm, keeping the array display time constant at the already constrained 150 ms, by manipulating the stimulus array set size (three or five). Response accuracy of the participants was greater when the task was easier (i.e., when the set size was three), which was expected. Once again there was a happy face advantage contrary to Simione et al. (2014)'s results. Once again, with higher task demand with set size 5, we could see only an emotional superiority effect. When the task demand was lower with set size

3, with adequate resources, there is a clear happy superiority effect.

The results from both experiments indicate attentional priority for happy faces but also indicate that this priority is present only when processing load is lower (display time 400ms or set size 3). When the processing demands become high (set size 5 or display time 150 ms or both), then happy superiority is not present but a general emotional advantage is still present. The results indicate two possible stages of selection with a more general emotion-based selection followed by a more emotion-specific selection. Theories of attention like Bundesen (1990)'s "Theory of Visual Attention" (Bundesen, 1990) or Visual selection and awareness (ViSA) (Simione et al., 2012) would need to incorporate these stages of selection to explain the emotion-based effects obtained in the study.

A weakness of Simione et al. (2014)'s study that they point out in their paper is the lack of control of the non-probed stimuli. In this study, we had better control over the non-probed images. S. I. Becker, Horstmann, and Remington (2011) found that perceptual asymmetries between early identification of angry faces compared to happy faces in many of the change detection paradigms could be a result of the feature level perceptual grouping instead of because of emotions or "threat superiority" effect. As we discussed in the introduction, schematic faces are abstract representations of human faces that have been simplified by either removing or exaggerating features. They allow for a high degree of control over the stimulus properties but results obtained using schematic faces are not generalizable to real faces therefore making them less ecologically valid. Schematic faces are also less variable and therefore biases because is contrary to how facial expressions occur and are identified in the real world.

In conclusion, we successfully show that there is an attentional bias for processing emotional faces (happy and angry faces) for storage in the VSTM compared to non-emotional (neutral faces). Further happy faces are more preferentially processed as compared to angry faces using the same VSTM report paradigm used by Simione et al. (2014).

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