

Task demands moderate the effect of emotion on attentional capture

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The current experiment examined the effect of task demands on attention to emotional images. Eighty participants viewed pairs of images, with each pair consisting of an emotional (negative or positive) and a neutral image, or two neutral images. Participants' eye movements were recorded during picture viewing, and participants were either asked 1) which picture contains more colour? (colour task), 2) are the images equally pleasant? (pleasantness task), 3) which picture do you prefer? (preference task), or 4) were given no task instructions (control task). Although the results did not suggest that emotional images strongly captured attention, emotional images were looked at earlier than neutral images. Importantly, the pattern of results were dependent upon the task instructions; whilst the preference and colour task conditions showed early attentional biases to emotional images, only positive images were looked at earlier in the pleasantness task condition, and no early attentional biases were observed in the control task. Moreover, total fixation duration was increased for positive images in the preference task condition, but not in the other task conditions. It was concluded that attention to emotional stimuli can be modified by the demands of the task during viewing. However, further research should consider additional factors, such as the cognitive load of the viewing tasks, and the content of the images used.

Keywords: attention; emotion; task demands

Introduction

Research suggests that emotional information captures early attention, and evidence comes from a range of methodologies, including: dot-probe experiments (e.g. Armony & Dolan, 2002; Bradley et al., 1998; Mogg & Bradley, 1999; Mogg et al., 2000), visual search tasks (e.g. Öhman et al., 2001, Tipples et al., 2002), rapid serial visual presentation (RSVP) studies (e.g. Junghöfer et al., 2001; Schupp et al., 2003; Schupp et al., 2004; Wieser et al., 2006), and eye-tracking studies (e.g. Calvo & Lang, 2004; Calvo et al., 2007; Nummenmaa et al., 2006; 2009). This research indicates a pre-attentive processing bias to emotional information versus neutral information. This processing bias could be due to emotional stimuli being highly salient and dependent on specialised neural mechanisms (Compton, 2003; Vuilleumier, 2005). There is also evidence of a negativity bias whereby emotionally negative material captures attention over emotionally positive material (Fox et al., 2000; Van Dillen & Koole, 2009). This negativity bias could be due to survival instincts to identify potential threats (e.g. Bradley, 2009; Öhman, 2007). It has been argued that the capture of attention by emotional stimuli is automatic and not influenced by attentional resources (Morris et al., 1999; Vuilleumier et al., 2001). However, the automatic nature of attentional capture by emotional stimuli has been challenged (Acunzo & Henderson, 2011; Pessoa, 2005).

There is evidence to suggest that early attentional biases to emotional stimuli are dependent upon competing processing demands. Pessoa et al. (2002) demonstrated that emotional stimuli only capture attention if attentional resources are not engaged by other tasks. Research has also shown that attentional capture by emotional stimuli is less likely to occur when the task demands whilst viewing the stimuli are challenging (Schupp et al., 2007; Shafer et al., 2012). In addition, emotional stimuli are also less

likely to capture attention when viewed during high cognitive load (Sassi et al., 2014; Uher et al., 2014), and increasing cognitive load can specifically remove biases towards negative over positive stimuli (Van Dillen & Koole, 2009). Other research has highlighted the importance of task goals in moderating the effect of emotion on attention (e.g. Stein et al., 2009; Van Dillen et al., 2011; Vogt et al., 2013; Vromen et al., 2015). For example, using a spatial cueing task Vromen et al. found that the presence of a non-target spider interfered with target detection only when the target set contained a spider, but not when the spider was irrelevant to the task. This research supports the notion of attentional control settings, which are dependent upon task goals (Folk et al., 1992). Taken together, research suggests that emotional stimuli can be analysed pre-attentively, however there is also evidence to suggest that any automatic capture of attention may be being mediated by cognitively driven task demands.

The automaticity of attentional capture by emotional stimuli has also been challenged by Humphreys et al. (2010). Humphreys et al. presented participants with paired images taken from the International Affective Picture System (IAPS, Lang et al., 2005): emotional-neutral and neutral-neutral pairs. During picture viewing, participants were required to state which image out of each pair they preferred. The results showed that there were no differences in latency of first fixation between emotional and neutral images, suggesting that there was no automatic capture of attention. However, previous similar eye-tracking studies revealed early attentional biases to emotional stimuli (e.g. Calvo & Lang, 2004; Nummenmaa et al., 2006). The discrepancy in results could be explained by differences in task demands. In Humphreys et al.'s study participants judged which of the paired stimuli they preferred, whereas Calvo and Lang's and Nummenmaa et al.'s research required participants to make judgments about affective valence and pleasantness respectively. Therefore, it could be argued that emotional

valence was least relevant in Humphreys et al.'s study as the context of the question emphasised aesthetic qualities as opposed to emotional valence. Van Dongen et al. (2016) reported that the context of picture viewing, as art versus a photograph of a real event, for emotional IAPS images influenced ratings for the image. Preference was increased in the art context, particularly for negative stimuli. The authors concluded that the art context induced implicit emotion regulation, whereby viewers distanced themselves from the images. Although not framed within an art versus reality context, the question in Humphreys et al.'s study could have prompted aesthetic judgements, as opposed to judgements about emotional valence. This could have evoked implicit emotion regulation and prevented early attentional biases to emotional images from occurring.

The current experiment assessed the influence of task demands on attention allocation to emotional stimuli. The study phase from Humphreys et al. (2010) was replicated and modified to allow four task conditions to be tested during the presentation of negative-neutral, positive-neutral and neutral-neutral paired stimuli. Participants were asked to make a preference judgement (cf. Humphreys et al. 2010), a pleasantness judgement (cf. Nummenmaa et al. 2006), or were asked to make a visual judgement (participants were asked to judge which image contained more colour). The colour judgement task was included as it did not require participants to make any judgements about the emotionality of the images, or about their personal preferences for images. A control condition, with no question asked, was employed to investigate attention during naturalistic viewing. Attentional capture was determined using the same eye-tracking measures as Humphreys et al. (time taken to first fixate on a picture, and the number of fixations before first fixation of a picture). However, two further measures were also included: saccade latency before first fixation and probability of

first fixation. The latter measure was included to make direct comparisons with Nummenmaa et al. Total fixation duration was also measured to assess whether emotional images continued to engage attention once fixated. It was predicted that the type of viewing task would modify attention to emotional images. Specifically, it was predicted that attentional biases would be observed for negative and positive images in the pleasantness task condition (in accordance with Nummenmaa et al.), but no such biases would occur in the preference task condition (in accordance with Humphreys et al.).

Method

Participants

A prospective power analysis was conducted using power tables (Power of an F-ratio in Analysis of Variance) provided by Clark-Carter (2018). The between-subjects variable was used to estimate a sample size of eighteen participants per task condition to achieve a Power of 0.8, based on a large effect size ($\eta^2 = 0.138$, Cohen, 1988). Eighty (twenty per task condition) participants (40 males and 40 females) aged 18-65 years old ($M = 32.8$, $SD = 12.49$) participated in the study. Participants were recruited using an online research participation system, SONA, through advertisements around campus, and via internal emails. Participants were a mixture of individuals, including students and staff. Two SONA credits were offered to students requiring such credit for their course; other participants did not receive an incentive for taking part. All participants had normal, or corrected to normal, vision. Full ethical approval was granted by the Faculty of Health Sciences ethics committee at Staffordshire University.

Design

In accordance with Humphreys et al. (2010), 5 image categories were employed: negative, negative neutral (a neutral image presented with a negative image), positive, positive neutral (a neutral image presented with a positive image) and neutral filler (a neutral image presented with another neutral image). A 5 (Valence: Negative vs. Negative Neutral vs. Positive vs. Positive Neutral vs. Neutral Filler) x 4 (Task Type: Preference vs. Pleasantness vs. Colour vs. Control) mixed factorial design was used with Valence as the repeated measures factor. The negative neutral and positive neutral images were included in the analysis to obtain a detailed picture of how the task influenced attention; the viewing task could modify attention to neutral images presented within the emotional-neutral pairs (as well as attention to emotional images). To replicate Humphreys et al., attentional capture was determined using the following eye-tracking measures: time taken to first fixate on a picture (First Fixation Time) i.e., the time from the onset of the stimulus display up to the point of first fixation upon the picture, and the number of fixations before first fixation of the picture (First Fixation Index) i.e., the number of fixations from the onset of the stimulus display, after the presentation of the fixation cross, up to the point of first fixation upon the picture. However, to gain a more detailed representation of attentional capture, saccade latency before first fixation (the duration of the saccade that led to first fixation upon the picture) was also examined. In addition, to compare the results to Nummenmaa et al. (2006), the probability of fixating on an image was calculated. Nummenmaa et al. compared the probability of fixating on a negative, positive and neutral image that had each been presented with a control image. Therefore, a 3 (Valence: Negative vs. Positive vs. Neutral Filler) x 4 (Task Type: Preference vs. Pleasantness vs. Colour vs. Control) mixed factorial design was used (with Valence as the repeated measures factor) to examine probability of first fixation. To gain an understanding of how

strongly pictures engaged attention once fixated, total fixation duration (the sum of all fixations on the picture, independent of sequence or fixations elsewhere) was also measured.

Stimuli

48 paired IAPS images (Lang et al., 2005), were selected from the study phase of Humphreys et al. (2010) and consisted of 24 emotional-neutral pairings and 24 neutral-neutral pairings. The emotional-neutral pairings consisted of 12 negative-neutral pairings (each containing one negative and one neutral image) and 12 positive-neutral pairings (each containing one positive and one neutral image). The 24 neutral-neutral pairs contained two neutral images. Positive, negative, and neutral images all contained a variety of scenes; some images contained faces/people and some included food/inanimate objects/animals). Importantly, the paired images were matched in terms of content and shape. For example, if the emotional image contained a face with an emotional expression, the neutral image it was paired with would contain a face with a neutral expression (hence the images were paired based on both images having faces/similar shaped objects). Each stimulus display measured 1920 x 1080 pixels with a viewable screen size of 50.8cm x 28.58cm, which equals to 42.69° of horizontal visual angle, and 24.8° of vertical visual angle, at a viewing distance of 65 cm. Within the stimulus display, each image measured 500 x 375 pixels, which equals to a horizontal visual angle of 11.62° , and a vertical visual angle of 8.73° , at a 65cm viewing distance. The innermost edge of each picture was 180 pixels from the central fixation point; the distance between the upper edge of the picture and the top of the screen, and between the lower edge of the picture and the bottom of the screen, was 352.5 pixels. In the emotional-neutral trials, the emotional picture occurred equally on the left and the right-hand side of the screen.

The IAPS ratings (Lang et al., 2005) of the images used, which can range between 1 (most negative) and 9 (most positive), indicate that the valence ratings of the negative images ($M = 2.97$, $SD = 0.74$) are lower than the positive ($M = 6.96$, $SD = .57$), negative neutral ($M = 4.89$, $SD = 0.19$), positive neutral ($M = 5.03$, $SD = 0.27$) and neutral filler ($M = 4.96$, $SD = 0.39$) images. Moreover, the valence ratings of the positive images are higher than the negative neutral, positive neutral, and neutral filler images, and the valence ratings of the negative neutral, positive neutral and neutral filler images do not differ (see Humphreys et al., 2010).

The images used did not differ in terms of their low-level visual features. Low-level visual features were examined in accordance with Nummenmaa et al. (2006), hence the following were calculated for each picture: luminance level, complexity (by examining the number of bytes of the compressed image file size in JPEG format), mean contrast level (measured using root mean square contrast), and colour saturations for the red, green, and blue channels. A series of one-way ANOVAs confirmed that the images did not differ across valence categories for these low-level visual features (see Humphreys et al., 2010).

Apparatus

The stimuli were presented using Experiment Builder© on a PC with a standard colour monitor. Participants' eye movements were recorded via an Eyelink 1000© desktop mount eye tracker system by SR Research. Eye movement data was recorded from the right eye (to replicate Humphreys et al., 2010) using a monocular infra-red desktop camera with the capacity to track eye location every 1ms.

The spatial accuracy of the Eyelink 1000© system is 0.2°-0.4°. Head movements were restricted using a chinrest during stimulus presentation.

Procedure

Participants were randomly assigned to either the preference (n = 20), pleasantness (n = 20), colour (n = 20) or control (n = 20) task condition. Informed consent was obtained, which included highlighting participants' withdrawal rights. A nine-point calibration and validation procedure was completed for the eye-tracking equipment to ensure that all recordings had a mean spatial error of less than 0.5 degrees. A text display then appeared on the computer screen informing participants that they would be presented with paired images, some of which would have an emotional content. Participants in the preference task were asked to indicate which image they preferred; those in the pleasantness condition were asked to decide if the two images are equally pleasant; those in the colour condition were asked to state which picture contained more colour; those in the control task were simply asked to view the images. The display of each image pair was triggered as a result of fixation to an interstimulus cross displayed in the centre of the screen. The stimuli were presented in a random order, and each stimulus was shown for two seconds. Participants eye movements were recorded whilst they viewed the images. A text display appeared on the computer screen after each image pair, which asked participants to click the left or right mouse key in response to the condition statement (for the preference and colour task conditions, participants were instructed to click the left mouse key to choose the left image, and the right mouse key to choose the right image, and for the pleasantness task condition, participants were instructed to click the left mouse key to indicate that images are equally pleasant, and the right mouse key to indicate that the images differ in pleasantness). Participants in the control condition were not required to answer a question about each pair of images, hence after each image pair was presented participants were instructed to view the next trial. Once all the images were presented participants were thanked for their participation and were fully debriefed.

Results

First Fixation Index (FFI), First Fixation Time (FFT), First Fixation Saccade Latency (FFSL), and Total Fixation Duration (TFD) were calculated for each image in each of the task conditions. A 5 (Valence) x 4 (task condition) mixed two-way ANOVA was conducted for each of these eye-tracking measures, with Valence as the within-subjects variable. In addition, the probability of first fixating (PFF) on a negative, positive and neutral filler image was calculated. This was calculated by counting the number of times each type of image was fixated on first within the paired stimuli (for example, the number of times a negative image was fixated first within the negative-neutral pairs), and then dividing this number by the number of trials. A 3 (Valence: Negative vs. Positive vs. Neutral Filler) x 4 (Task Type: Preference vs. Pleasantness vs. Colour vs. Control) mixed factorial design was used (with Valence as the repeated measures factor) to examine probability of first fixation. Effect sizes have been calculated following Clark-Carter's (2018) recommendations for calculating η^2 and d and all confidence intervals (CI) are reported at 95% lower and upper boundaries.

First Fixation Index (FFI)

Positive ($M = 3.09$) and negative ($M = 3.14$) images were viewed after fewer fixations than negative neutral ($M = 3.32$), positive neutral ($M = 3.30$) and neutral filler ($M = 3.26$) images. Moreover, Table 1 indicates that FFI was lowest for positive images in the colour, control, and pleasantness task conditions, whilst FFI was lowest for negative images in the preference task condition. In addition, FFI was increased for all types of images in the control condition compared to the other task conditions. The ANOVA results revealed a significant main effect of valence on FFI, *Greenhouse-Geisser* $F(3.560, 270.558) = 15.344, p < .001, \eta^2 = .056$. Bonferroni post hoc comparisons indicated that FFI was significantly lower for negative images versus

negative neutral images, $p < .001$, mean difference = $-.80$, $CI [-.300, -.061]$, $d = -.47$, positive neutral images, $p = .001$, mean difference = $-.152$, $CI [-.256, -.048]$, $d = -.38$, and neutral fillers $p = .005$, mean difference = $-.119$, $CI [-.214, -.024]$, $d = -.32$. FFI was also significantly lower for positive images versus positive neutral images, $p < .001$, mean difference = $-.212$, $CI [-.335, -.088]$, $d = -.52$, negative neutral images, $p < .001$, mean difference = $-.239$, $CI [-.361, -.117]$, $d = -.61$, and neutral fillers, $p < .001$, mean difference = $-.178$, $CI [-.278, -.078]$, $d = -.47$. However, FFI between negative and positive was comparable, $p = 1$, mean difference = $.059$, $CI [-.058, .177]$, $d = .14$. There was also a significant main effect of task condition on FFI, $F(3, 76) = 3.548$, $p = .018$, $\eta^2 = .079$. Bonferroni post hoc comparisons indicated that FFI was significantly higher for the control condition versus the colour, $p = .036$, mean difference = $.271$, $CI [.012, .530]$, $d = .99$, and preference, $p = .037$, mean difference = $.269$, $CI [.010, .528]$, $d = .99$, conditions.

There was a significant interaction between valence and task condition, $F(12, 304) = 2.142$, $p = .014$, $\eta^2 = .023$. To explore the interaction four one-way ANOVAs were conducted to examine the effect of valence within each task condition. Alpha was adjusted to 0.0125. There was a significant effect of valence in the colour condition, $F(4, 76) = 10.569$, $p < .001$, $\eta^2 = .107$. Bonferroni post hoc comparisons indicated that FFI was reduced for positive images versus negative neutrals, $p = .028$, mean difference = $-.285$, $CI [-.549, -.022]$, $d = -.65$, and positive neutrals, $p < .001$, mean difference = $-.422$, $CI [-.655, -.188]$, $d = -.92$, and for negative images versus positive neutrals, $p = .003$, mean difference = $-.272$, $CI [-.470, -.074]$, $d = -.62$. FFI was increased for positive neutrals versus neutral fillers, $p = .002$, mean difference = $.228$, $CI [.073, .383]$, $d = .62$. There was a significant effect of valence in the pleasantness condition, $F(4, 76) = 4.165$, $p = .004$, $\eta^2 = .047$. Bonferroni post hoc comparisons indicated that FFI was reduced

for positive images versus neutral fillers, $p = .016$, mean difference = $-.225$, $CI [-.418, -.031]$, $d = -.55$. There was a significant effect of valence in the preference condition, *Greenhouse-Geisser* $F(2.904, 55.167) = 8.170$, $p < 0.001$, $\eta^2 = .187$. Bonferroni post hoc comparisons indicated that FFI was reduced for negative images versus negative neutral images, $p = .005$, mean difference = $-.379$, $CI [-.664, -.094]$, $d = -1.29$, and neutral fillers, $p = .004$, mean difference = $-.214$, $CI [-.371, -.057]$, $d = -.84$. FFI was also reduced for positive images versus negative neutral images, $p = .015$, mean difference = $-.325$, $CI [-.605, -.046]$, $d = -1.2$. There was no significant effect of valence in the control condition, $F(4, 76) = 1.125$, $p = 0.351$, $\eta^2 = .026$.

First Fixation Time (FFT)

Time to first fixation was lower for positive ($M = 527.05$) and negative ($M = 529.52$) images compared to negative neutral ($M = 570.93$), positive neutral ($M = 566.64$) and neutral filler ($M = 565.52$) images. In addition, Table 2 demonstrates that FFT were lower for emotional images in all task conditions. FFT was also generally increased in the control task condition. The ANOVA results revealed a significant main effect of valence on FFT, *Greenhouse-Geisser* $F(3.167, 240.716) = 10.927$, $p < .001$, $\eta^2 = .0347$. Bonferroni post hoc comparisons revealed that FFT was significantly earlier for negative images compared to negative neutral images, $p = .001$, mean difference = -41.412 , $CI [-71.009, -11.816]$, $d = -.4$, positive neutral images, $p = .002$, mean difference = -37.119 , $CI [-64.052, -10.186]$, $d = -.34$, and neutral fillers, $p < 0.001$, mean difference = -36.003 , $CI [-58.270, -13.736]$, $d = -.37$. FFT was also significantly earlier for positive versus positive neutral images, $p = .015$, mean difference = -39.591 , $CI [-74.357, -4.825]$, $d = -.36$, negative neutral images, $p = .001$, mean difference = -43.884 , $CI [-74.119, -13.650]$, $d = -.42$, and neutral fillers, $p < .001$, mean difference = -38.475 , $CI [-60.635, -16.314]$, $d = -.39$. FFT did not differ for negative versus positive

images, $p = 1$, mean difference = 2.472, $CI [-23.550, 28.493]$, $d = .02$. There was a significant main effect of task condition, $F(3, 76) = 3.691$, $p = 0.015$, $\eta^2 = .09$.

Bonferroni post hoc comparisons revealed that FFT was increased in the control condition compared to the preference condition, $p = .010$, mean difference = 86.671, $CI [14.753, 158.588]$, $d = .119$. There was no significant interaction between valence and task condition, $F(12, 304) = 1.687$, $p = .069$, $\eta^2 = .0161$.

First Fixation Saccade Latency (FFSL) and Probability of First Fixation (PFF)

First Fixation Saccade Latency was slightly higher for negative ($M = 62.54$) compared to negative neutral ($M = 61.26$), positive ($M = 59.89$), positive neutral ($M = 61.61$) and neutral filler ($M = 61.07$) images. In addition, Table 3 demonstrates that the preference task resulted in the greatest variability in FFSL between the valence categories, with FFSL being lowest for positive images and highest for negative images. However, there was a very large variability in FFSL for negative images within the preference task condition, which was due to an outlier within the data. A sensitivity analysis was performed, following Clark-Carter's (2018) recommendations, whereby the ANOVA was conducted both with and without the outlier. Both ANOVAs revealed non-significant results, indicating that the outlier did not impact the results. Therefore, the outlier was not removed from the data and is included in the following results. There was no significant main effect of valence, *Greenhouse-Geisser* $F(1.653, 125.628) = .473$, $p = .588$, $\eta^2 = .0037$, no significant main effect of task, $F(3, 76) = .543$, $p = .654$, $\eta^2 = .0078$, and no interaction between valence and task, $F(12, 304) = 1.255$, $p = .245$, $\eta^2 = .029$, on FFSL. Probability of First Fixation was slightly higher for negative ($M = .52$) compared to positive ($M = .517$) and neutral ($M = .50$) images. Also, Table 4 demonstrates that PFF was highest for negative images in all task conditions, except for the colour task condition, where PFF was highest for positive images. The ANOVA did

not indicate any significant findings. There was no significant main effect of valence, $F(2, 152) = 1.493, p = .228, \eta^2 = .089$, no significant main effect of task, $F(3,76) = 2.279, p = .086, \eta^2 = .016$, and no interaction between valence and task, $F(6, 152) = 1.421, p = .210, \eta^2 = .257$, on PFF.

Total Fixation Duration (TFD)

Negative neutral ($M = 804.66$) and positive ($M = 794.27$) images received more fixation time than neutral filler ($M = 771.09$), positive neutral ($M = 763.07$) and negative ($M = 762.54$) images. In addition, Table 5 indicates that TFD was highest for positive images in the colour and control task conditions, whilst in the pleasantness task TFD was highest for positive neutral images. Furthermore, TFD was highest for negative neutral images, and lowest for negative images, in the preference task condition. There was a significant main effect of valence on TFD, *Greenhouse-Geisser* $F(1.994, 151.577) = 4.261, p = .016, \eta^2 = .042$. Bonferroni post hoc comparisons revealed that TFD was increased for negative neutral pictures compared to neutral fillers, $p = .008$, mean difference = 33.572, $CI [5.750, 61.393]$, $d = .50$. There was also a significant interaction between valence and task condition, $F(12, 304) = 2.659, p = .002, \eta^2 = .079$. To explore the interaction four one-way ANOVAs were conducted to examine the effect of valence within each task condition. Alpha was adjusted to 0.0125. There was a significant effect of valence in the preference condition, *Greenhouse-Geisser* $F(2.013, 38.252) = 6.817, p = .003, \eta^2 = .244$. Bonferroni post hoc comparisons revealed that positive images received greater fixation time than negative images, $p = .021$, mean difference = 98.487, $CI [10.751, 186.224]$, $d = 1.09$. There was no significant effect of valence in the pleasantness condition, *Greenhouse-Geisser* $F(1.493, 28.373) = 2.868, p = .087, \eta^2 = .117$, colour condition, *Greenhouse-Geisser* F

(2.029, 38.557) = 1.501, $p = .236$, $\eta^2 = .062$, nor in the control condition, Greenhouse-Geisser $F(1.889, 35.896) = 1.246$, $p = .298$, $\eta^2 = .053$. There was no significant main effect of task condition on TFD, $F(3, 76) = 1.702$, $p = 0.174$, $\eta^2 = .0079$.

Discussion

The current study investigated the role of task demands in mediating attention to emotional images. Results showed that emotional images attracted attention earlier (were fixated on in less time and after fewer fixations) within the emotional-neutral pairings, and in comparison, to neutral images presented within the neutral-neutral pairings. However, early attentional biases to emotional images were not observed through first fixation saccade latencies, or through the probability of first fixation. These non-significant results could be due to the variety of image types used in the current study (which included faces/people, but also other types of scenes). In contrast, in Nummenmaa et al.'s (2006) study, the emotional target images always contained faces. Hence, it is possible that there is reduced evidence for attentional biases in the current study, compared to Nummenmaa et al., as the images did not simply consist of faces. It is also worth noting that in the current study participants made several fixations prior to fixating on an image (almost all the FFI values were over 3), which suggests that all types of images did not strongly capture attention. Given the time taken to first look at an image, which was approximately 550ms, these fixations that occurred prior to first fixation were quite short, hence indicating fast processing. Taken together, the results suggest that emotional images were looked at earlier, providing some evidence that there are pre-attentive biases to emotional images (e.g. Mogg et al., 2000; Öhman et al, 2001; Nummenmaa et al., 2006; 2009), but the results do not suggest that emotional images strongly captured attention. The effect of emotional valence on total fixation duration was also examined to assess whether emotional images continued to

attract attention once they had been fixated. The results showed that, when the type of viewing task was not considered, emotional images did not continue to engage attention. Conversely, total fixation duration was increased throughout the trial for neutral images presented with negative images, compared to neutral images presented within the neutral-neutral pairings. This increased attention to neutral images within the negative-neutral pairings could indicate an avoidance response for negative images once they have been fixated.

Importantly, the results of the current study showed that attention patterns were dependent upon the task given during image viewing. Whilst positive and negative images were looked at earlier in the preference and colour task conditions, only positive images were looked at earlier in the pleasantness task condition, and no early attentional biases were observed in the control task condition. These results support previous research showing that the effect of emotion on early attention can be moderated by top-down task demands (e.g. Stein et al., 2009; Vogt et al., 2013; Vromen et al., 2015). The results also showed that later attentional engagement to positive images was modified by the type of task; in the preference task positive images received greater fixation duration compared to negative images, yet this effect did not occur in the other task conditions. This increased attention to positive images in the preference task condition is consistent with Humphreys et al. (2010), who found that positive images obtained increased inspection time using the same images and task instructions.

Despite the attentional engagement measure replicating Humphreys et al. (2010), the measures of early attention do not replicate the original 2010 study. Whilst Humphreys et al. did not observe any early attentional biases, the current study showed some evidence of early attentional biases to emotional images using the same task instructions and images. These results refute the argument that Humphreys et al. failed

to observe early attentional biases to emotional images due to the preference task used. It is worth noting that the negative and positive images used (in the current study and in Humphreys et al.'s study) are lower in negativity and positivity, respectively, compared to previous studies in the literature (Calvo & Lang, 2004; Nummenmaa et al., 2006). Therefore, it is possible that the emotional images did not elicit sufficient negativity or positivity for consistent replication of early attentional biases to be observed across the two studies. Nevertheless, it is surprising that the current study did not replicate Humphreys et al., given that the same images and task instructions were used. It could be argued that the current study provides more reliable results than Humphreys et al., given that the sample size is larger (80 participants in the current study compared to 18 in Humphreys et al.). It is also important to note that in the current study the number of fixations prior to fixation on an image was greater than in Humphreys et al., and although emotional images were looked at earlier, the data does not suggest strong capture of attention.

In contrast to the early attentional biases for positive and negative images in the preference task, in the pleasantness task early attentional biases only occurred for positive images. This increased early attention to positive images in the pleasantness task could have occurred because the instructions primed participants to focus on images of positive valence. This supports previous research showing that the capture of attention by emotional stimuli is dependent upon whether the viewing task primes participants towards such stimuli (Stein, et al., 2009; Vogt et al., 2013; Vromen et al., 2015). In addition to the negative-only stimuli presented in previous research, the current study demonstrates that positive stimuli will capture attention when the task is primed towards positive valence. As the phrasing of the pleasantness task (which asked participants to decide whether two images are equally pleasant), resulted in biases

towards positive images, future research should examine whether changing the phrasing modifies these biases; if participants are asked to decide whether two images are equally unpleasant, does this result in biases towards negative images? It is also possible that the different pattern of results in the pleasantness task could have occurred because the question required participants to compare the two images presented, whereas the preference and colour tasks required participants to choose one of the images from each pair. Specifically, in the pleasantness task participants were required to either state whether the images are equally pleasant, or if the images differ in pleasantness, whilst in the preference task participants were asked to choose the image they prefer, and in the colour task, they were asked to select the image that contains more colour. These results highlight how the question posed during picture viewing can alter attention patterns.

Despite the interesting pattern of results in the pleasantness task condition, the findings were not anticipated; Nummenmaa et al. (2006) observed early attentional biases to both positive and negative images using the same task instructions. Therefore, whilst the task used in both studies primed participants to focus on images of positive valence, this resulted in early attentional biases solely to positive images in the current study; in Nummenmaa et al.'s study negative images still captured attention. In addition, whilst Nummenmaa et al. found that the probability of first fixation was increased for emotional images, the current study did not observe any differences for this measure. As discussed previously, the increased evidence for attentional biases in Nummenmaa et al.'s study could be due to the target always containing faces. It is also important to note that in Nummenmaa et al.'s study, the images within each pairing were different types of images (images of people versus inanimate objects), yet in the

current study the paired images were matched for content and shape (for example, a happy face was paired with a neutral face). Therefore, participants in Nummenmaa et al.'s study could have been biased towards the target images; thus, the current results could be considered as more reliable. In addition, as stated previously, the negative images used by Nummenmaa et al. were higher in negativity compared to the current study. It is possible that in the current study the negative images did not have sufficient negativity to capture attention, given that the task placed emphasis on images from the opposite end of the emotional valence spectrum. In contrast, in Nummenmaa et al.'s study, because the images used were higher in negativity, these could not be ignored despite the demands of the task. To examine this argument future research should examine the influence of task demands using images with varying levels of emotional valence.

The finding that emotional images were looked at earlier than neutral images in the colour task condition, highlights that early attentional biases to emotional images can occur even when emotion is not task relevant. Therefore, emotion does not always need to be relevant to the task for early attentional biases to occur, as some studies suggest (Stein et al., 2009; Vogt et al., 2013; Vromen et al., 2015). Finally, the lack of pre-attentive biases in the control task condition suggests that the absence of a viewing purpose can remove early attentional biases to emotional stimuli. The data suggested that the control task generally delayed attention to images: FFI was increased in the control condition compared to the colour and preference conditions, and FFT was increased in the control condition compared to the preference condition. Therefore, viewing images without a specific purpose delays initial attention, and eradicates the capture of attention by emotional images. These findings support the argument that

there is some top-down control over early attention allocation (e.g. Acunzo & Henderson, 2011; Pessoa, 2005).

Despite the useful findings highlighted within the current paper, there are several issues that should be addressed in future research. Firstly, the variety of items across scenes (for example, faces and inanimate objects), could have influenced attention (although it was important that the current study used the same images as Humphreys et al. (2010), to make direct comparisons). Given that research suggests that fixation patterns can differ across images containing different semantic objects (Haas et al., 2019), future research should examine the interaction between task demands and the semantic categories of images. Secondly, future research should also control for the cognitive load of the different viewing tasks, as it is possible that this was not comparable across tasks. In addition, it would also be useful to examine whether cognitive load is comparable across valence conditions within a task (for example, is it easier to give a preference judgement for emotional-neutral pairs compared to neutral-neutral pairs?). Future research should also obtain participant valence and arousal ratings as it is possible that these ratings could differ to the IAPS published normative ratings. Indeed, variations in valence and arousal ratings have been related to several factors including cognitive processing (Liu et al., 2015) and cultural differences in emotional expression (Hareli et al., 2015). The current study did not record participant valence and arousal ratings because the primary aim was to make direct comparisons to Humphreys et al.'s study, which did not record participant ratings. Nevertheless, future research would benefit from this additional measure. Lastly, future research should examine the relationship between performance on the behavioural tasks and the eye-tracking measures. Performance on the behavioural tasks was not recorded because the focus of the current study was to examine whether task instructions could influence

early attentional biases, rather than the decisions made following such tasks. Future research could also incorporate think aloud measures to add to the context of why a particular image was chosen.

In summary, the current study has provided further evidence for early attentional biases to emotional stimuli, as emotional images were looked at earlier than neutral images. However, the different eye-tracking measures recorded do not present a strong indication of attentional capture. Importantly, the current results demonstrate that attention patterns can vary with different task demands. However, future research needs to control for the cognitive load of the tasks, and for the content of the images used. In addition, future studies should obtain participant valence and arousal ratings, and should explore how performance on the behavioural tasks impact attention.

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Table 1. Mean First Fixation Index for each valence category in the different task conditions (standard deviations in parentheses).

	Colour Task	Control Task	Pleasantness Task	Preference Task
Negative	3.07 (.47)	3.39 (.38)	3.16 (.40)	2.96 (.25)
Negative neutral	3.20 (.36)	3.48 (.30)	3.28 (.39)	3.34 (.33)
Positive	2.92 (.50)	3.30 (.42)	3.10 (.45)	3.01 (.19)
Positive neutral	3.34 (.42)	3.39 (.39)	3.29 (.35)	3.17 (.37)
Neutral filler	3.11 (.31)	3.44 (.33)	3.33 (.36)	3.17 (.26)

Table 2. Mean First Fixation Time (milliseconds) for each valence category in the different task conditions (standard deviations in parentheses).

	Colour Task	Control Task	Pleasantness Task	Preference Task
Negative	514.56 (93.64)	584.45 (93.41)	533.44 (90.75)	485.62 (125.52)
Negative neutral	552.42 (97.03)	622.23 (106.87)	555.66 (95.69)	553.41 (98.02)
Positive	504.26 (130.81)	585.80 (86.33)	533.78 (99.69)	484.35 (89.37)
Positive neutral	596.20 (94.26)	596.17 (106.81)	554.56 (72.91)	519.62 (140.02)
Neutral filler	546.06 (82.15)	614.71 (71.73)	574.30 (76.65)	527.01 (97.72)

Table 3. Mean First Fixation Saccade Latency (milliseconds) for each valence category in the different task conditions (standard deviations in parentheses).

	Colour Task	Control Task	Pleasantness Task	Preference Task
Negative	58.95 (4.54)	60.04 (7.77)	61.45 (11.67)	69.72 (46.94)
Negative neutral	60.40 (8.38)	60.46 (8.45)	64.38 (15.61)	59.77 (5.79)
Positive	57.12 (6.95)	61.04 (8.94)	64.18 (18.19)	57.23 (4.67)
Positive neutral	61.47 (5.49)	64.31 (17.60)	62.45 (8.98)	58.20 (6.03)
Neutral filler	59.81 (5.33)	62.61 (9.10)	62.37 (8.78)	59.51 (5.06)

Table 4. Mean Probability of First Fixation for targets in the different task conditions (standard deviations in parentheses).

	Colour Task	Control Task	Pleasantness Task	Preference Task
Negative	.52 (.09)	.51 (.07)	.51 (.04)	.54 (.08)
Positive	.56 (.09)	.50 (.08)	.49 (.04)	.52 (.06)
Neutral filler	.51 (.10)	.50 (.03)	.50 (.06)	.49 (.07)

Table 5. Mean Total fixation duration (milliseconds) for each valence category in the different task conditions (standard deviations in parentheses).

	Colour Task	Control Task	Pleasantness Task	Preference Task
Negative	758.68 (70.08)	789.79 (97.96)	780.24 (77.91)	721.47 (95.04)
Negative neutral	782.04 (61.25)	794.85 (96.53)	798.93 (86.48)	842.82 (89.31)
Positive	788.75 (82.20)	822.06 (113.55)	746.31 (60.52)	819.95 (86.28)
Positive neutral	741.63 (80.01)	752.02 (123.28)	813.54 (54.86)	745.07 (90.28)
Neutral filler	762.07 (30.46)	772.93 (66.52)	773.09 (27.82)	776.26 (27.10)