

# 1 Lateral presentation alters overall viewing 2 strategy

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## 5 ABSTRACT

6 Eye tracking has been used during face categorisation and identification tasks to identify perceptually  
7 salient facial features and infer underlying cognitive processes. However, viewing patterns are influenced  
8 by a variety of gaze biases, drawing fixations to the centre of a screen and horizontally to the left side of  
9 face images (left-gaze bias). In order to investigate potential interactions between gaze biases uniquely  
10 associated with facial expression processing, and those associated with screen location, face stimuli  
11 were presented in three possible screen positions to the left, right and centre. Comparisons of fixations  
12 between screen locations highlight a significant impact of the screen centre bias, pulling fixations towards  
13 the centre of the screen and modifying gaze biases generally observed during facial categorisation  
14 tasks. A left horizontal bias for fixations was found to be independent of screen position but interacting  
15 with screen centre bias, drawing fixations to the left hemi-face rather than just to the left of the screen.  
16 Implications for eye tracking studies utilising centrally presented faces are discussed.

17 Keywords: eye-tracking, faces, emotion, gaze bias

## 18 INTRODUCTION

19 Eye-movements provide a way of measuring attention and can highlight perceptually salient facial features  
20 for facial identity and expression recognition (Jack et al., 2009). Viewing patterns toward faces have  
21 been well documented. First fixations exhibit a centre-of-face bias which has been interpreted as object  
22 selection (Foulsham and Kingstone, 2013; Levy et al., 2013) and the first stage of expression recognition,  
23 allowing rapid early analysis of expression (Calvo et al., 2008; Eisenbarth and Alpers, 2011; Feldmann-  
24 Wüstefeld et al., 2011; Guo, 2012; Hills et al., 2013; Pollux et al., 2014; Samson et al., 2014). Visual  
25 search tasks have been used to demonstrate that the initial fixation landing position on faces is decided  
26 during pre attentive processing and is used to overtly orient attention and allocate attentional resources  
27 when processing the face (Calvo et al., 2008). The initial central fixation is followed by a strong focus  
28 on the eyes and mouth, which are considered as the most diagnostic facial features for categorisation  
29 of different facial expressions (Calvo et al., 2008; Eisenbarth and Alpers, 2011; Kohler et al., 2004;  
30 Levy et al., 2013; Maurer et al., 2002; Messinger et al., 2012; Rigato and Farroni, 2013; Smyth et al.,  
31 2005; Vassallo et al., 2009; Wang et al., 2011; Xiao et al., 2013) or for identity recognition (Sæther et al.,  
32 2009; van Belle et al., 2010). Preferential feature selection varies between emotions (Eisenbarth and  
33 Alpers, 2011; Pollux et al., 2014) and culture (Jack et al., 2009) but predominantly focuses on the eye  
34 region, which is selected early and frequently for fixations (Eisenbarth and Alpers, 2011; Levy et al.,  
35 2013; Samson et al., 2014). Fixations towards the eyes are independent of their position in the face, as  
36 demonstrated in a study using monsters with non-typical eye locations (Levy et al., 2013). Eyes located in  
37 the centre of a face or peripherally located on limbs were fixated quickly and frequently, showing that  
38 the eyes themselves are the focus of attention and not their relative position on the face. Early selection  
39 of the eyes is not only attributed to emotion categorisation, and is seen as extraction of socially relevant  
40 information from the face (Gobel et al., 2015; Levy et al., 2013).

41 The initial centre-of-face bias in gaze behaviour is commonly observed in studies where face stimuli  
42 are presented in the centre of the screen (Guo, 2012; Levy et al., 2013; Pollux et al., 2014; Rigato and  
43 Farroni, 2013; Samson et al., 2014). However, evidence from natural scenes shows that when presented  
44 with landscapes on a screen, observers generally make the first fixation to the centre of the display  
45 (Bindemann, 2010). This central tendency is not limited to first fixations: Eye movement patterns tend to  
46 exhibit a gravitational pull towards the screen centre throughout the viewing period (Tatler, 2007). Central

47 tendency for fixations is also resistant to the distribution of features in natural scenes (Tatler, 2007) and to  
48 manipulations of the central fixation marker, for example by displaying it peripherally on a screen in any  
49 number of locations (Bindemann, 2010). Similarly, moving the position of the entire screen to the left or  
50 right of an observer's natural viewing position does not eliminate a screen centre bias (Vitu et al., 2004).  
51 The potential role of the central screen bias on gaze patterns during face viewing for emotion expression  
52 categorization has not been investigated systematically. Given the robust nature of this bias, it is not clear  
53 whether the centre-of-face bias, previously associated with rapid extraction of diagnostic facial features  
54 for emotion recognition (Calvo et al., 2008; Eisenbarth and Alpers, 2011; Feldmann-Wüstefeld et al.,  
55 2011; Guo, 2012; Hills et al., 2013; Levy et al., 2013; Pollux et al., 2014; Samson et al., 2014), could be  
56 attributed to the central position of face images on the screen in previous studies (Guo, 2012; Levy et al.,  
57 2013; Pollux et al., 2014; Rigato and Farroni, 2013; Samson et al., 2014).

58 A second gaze bias associated with face viewing is the tendency to preferentially view the left hemi-  
59 face, from an observers perspective (Guo, 2012) or faces presented in the left visual field (Prete et al.,  
60 2015), which has been suggested to specifically benefit categorisations of facial expression. Evidence  
61 of facial muscles portraying emotions more intensely in the left hemi-face (Indersmitten and Gur, 2003)  
62 suggests that more diagnostic information is available on the left, which Indersmitten and Gur (2003)  
63 propose is due to a right hemispheric dominance for emotion processing. The argument is supported by  
64 evidence showing that the left side of the face is less subject to cultural influences, presenting a more  
65 universally recognised display of emotional expressions (Mandal and Ambady, 2004). However, evidence  
66 from natural scenes challenges a face specific left gaze bias, demonstrating a general horizontal bias to  
67 the left visual field (Foulsham et al., 2013; Ossandón et al., 2014). Similarly, when saccading toward  
68 objects, observers typically undershoot their target slightly to the left (Foulsham and Kingstone, 2013).  
69 Methodological factors have also been shown to influence left gaze bias, which is entirely negated for  
70 face viewing during a gender judgement task when faces are presented on either side of an initial fixation  
71 point (Samson et al., 2014). In these conditions, participants preferentially view the hemi-face closest  
72 to the fixation point, suggesting that left gaze bias may be an artefact of central stimulus presentation.  
73 Furthermore, during a free viewing task where time constraints were not introduced, participants did not  
74 demonstrate a bias to either side of the face, an effect the authors propose to be related to long exploration  
75 periods balancing out an initial left processing bias (Eisenbarth and Alpers, 2011).

76 In order to accurately assess viewing patterns attributed to facial expression categorisation we aim to  
77 dissociate generic or methodological gaze biases associated with the use of a screen from face specific  
78 biases, by directly comparing viewing patterns between centrally and laterally presented stimuli. Specific  
79 biases to be investigated include the central gravitational bias for fixations (Bindemann, 2010; Foulsham  
80 et al., 2013; Ossandón et al., 2014; Tatler, 2007), which would result in a higher number of fixations to the  
81 centre of the face only in centrally presented images and to the hemi-face proximal to the screen centre in  
82 laterally presented images. Three emotions will be shown, happy, sad and fear, as the nose regions for  
83 these expressions are generally not considered to be crucially diagnostic for correct categorization (Calvo  
84 et al., 2008; Eisenbarth and Alpers, 2011; Ekman and Friesen, 1978; Kohler et al., 2004; Levy et al.,  
85 2013; Maurer et al., 2002; Messinger et al., 2012; Rigato and Farroni, 2013; Smyth et al., 2005; Vassallo  
86 et al., 2009; Wang et al., 2011; Xiao et al., 2013). Any central fixation biases are therefore more likely  
87 attributable to screen biases. The second bias under investigation is the left gaze bias (Bindemann, 2010;  
88 Foulsham et al., 2013; Guo, 2012). Specifically, the impact of lateral presentation and the absence of  
89 imposed time constraint is expected to diminish or eliminate a bias to the left side of the face (Eisenbarth  
90 and Alpers, 2011) but not to the left side of the screen (Bindemann, 2010; Foulsham et al., 2013).

## 91 **METHODS**

### 92 **Participants**

93 To control for a potential gender bias (Hall, 1978; Vassallo et al., 2009) only female participants were  
94 included who typically perform better at emotion recognition tasks (Wang, 2013); twenty one undergradu-  
95 ate students from the University of Lincoln took part in the experiment (21 female, mean age = 19.19  
96  $\pm$ 1.03). All participants had normal or corrected to normal visual acuity at the time of testing, received no  
97 instructions on eye movements and completed an informed consent form prior to taking part in a single  
98 session lasting approximately 25 minutes. The experiments were granted ethical approval from the School  
99 of psychology research ethics committee at the University of Lincoln.

## 100 **Apparatus**

101 A Tobii T60XL widescreen eye tracker served as eye tracker and monitor displaying at 1280 x 1024 pixels  
102 at a refresh rate of 60Hz, stimuli were presented at a size of 900 x 550 pixels subtending a visual angle of  
103 23.110 and 11.674° respectively. Matlab with Psychtoolbox and the Tobii Matlab Toolbox were used for  
104 visual stimulus control and to run the eye tracker. The gaze precision of the eye tracker is reported at 0.5  
105 visual degrees with binocular sampling at a distance of 65cm. Fixations were computed using a dispersion  
106 algorithm (Salvucci and Goldberg, 2000). Behavioural responses were collected using a Cedrus RB-540  
107 response pad.

## 108 **Stimuli**

109 Stimuli were generated using the Karolinska Directed Emotional Faces database (Lundqvist et al., 1998).  
110 Two male (AM10, AM23) and two female models (AF01, AF09) were chosen displaying prototypical  
111 expressions of happy, sad and fear. Images were converted to grey-scale and balanced for contrast and  
112 brightness; extraneous features such as hair, ears and neck were removed by placing an oval frame around  
113 the face. In order to manipulate task demand and avoid ceiling performance, emotions were morphed  
114 between neutral and emotional using the Morpheus Photomorphing Suite, creating eleven intensity stages,  
115 labelled from neutral to 100%. Based on previous findings of improvements in expression recognition  
116 only at low intensities and no further significant improvement beyond 50-60% (Gao and Maurer, 2010;  
117 Pollux et al., 2014; Pollux, 2016) neutral and intensities of 70, 80 and 90% were removed, 100% was  
118 included as a control measure leaving a total of 84 images used in the study.

## 119 **Procedure**

120 Stimuli were presented three times, once per location on screen; possible screen locations were to the left,  
121 right or centre. Screen locations were centered on quartile pixel calculations of the x axes of the screen, for  
122 example left presented faces centered on pixel 320 ( $\frac{1280}{4}$ ). Participants were seated 65 cm away from the  
123 monitor and used their preferred hand to make responses; calibration required participants to focus on the  
124 centre of a shrinking dot randomly presented in sequence using a 5 point calibration array. The main task  
125 required participants to quickly and accurately categorise displayed facial expressions according to three  
126 possible responses, happy, sad or fear, though no time limit was imposed. Each trial's screen position was  
127 randomly chosen and stimuli were presented in a random order based on selected screen position; each  
128 stimulus appeared once per location. After an instruction screen, each trial commenced with a fixation  
129 cross presented centrally for 500ms, followed by a facial stimulus at one of the three locations. The  
130 stimulus remained on screen until a participant pressed any response key to indicate that they recognized  
131 the emotion. After this key press, a choice selection screen detailing the possible responses and the  
132 corresponding keys. This procedure was chosen due to the number of possible responses, to eliminate  
133 button selection time from the viewing period.

## 134 **RESULTS**

135 Initial analysis included comparisons for stimuli gender and participant ocular dominance, measured  
136 using the Dolman method (Cheng et al., 2004). However, no effect was found on proportion correct  
137 responses or eye movements. Therefore, these factors were not included in further analysis.

138 Reaction times (RT's) were analysed by entering average RT's into a 3 x 3 x 7 Repeated Measures  
139 ANOVA (Emotion x Screen position x Intensity). Bonferroni corrected pairwise comparisons were used  
140 to compare main effects and Greenhouse Geisser adjustment was used where appropriate. Results showed  
141 no significant differences in RT's between each of the possible screen positions [ $F(2,40) = 0.359$ ,  $p = 0.701$ ,  
142  $\eta p^2 = 0.018$ ], however the main effect of emotion [ $F(2,40) = 6.754$ ,  $p = 0.003$ ,  $\eta p^2 = 0.252$ ] was significant  
143 due to fear expressions being responded to faster (mean 1454ms) compared to sad expressions (mean  
144 1660ms,  $p = 0.010$ ). Intensity was also significant [ $F(6,120) = 9.582$ ,  $p < 0.001$ ,  $\eta p^2 = 0.324$ ] as lower  
145 intensities were responded to slower than higher intensities. 10% intensity (mean 1866ms) was responded  
146 to significantly slower than 100% (mean 1241ms,  $p = 0.045$ ), 20% (mean 1780ms) was responded to  
147 significantly slower than 60% (mean = 1375ms,  $p = 0.042$ ) or 100% ( $p = 0.041$ ) and 40% intensity (mean  
148 1575ms) was responded to significantly slower than 50% (mean = 1399ms,  $p = 0.043$ ), 60% ( $p = 0.037$ )  
149 and 100% ( $p = 0.006$ ).

150 Accuracy was analysed by entering percentage correct responses for each screen position into a 3  
151 x 3 x 7 Repeated Measures ANOVA (Emotion x Screen position x Intensity). Bonferroni corrected

152 pairwise comparisons were used to compare main effects and Greenhouse Geisser adjustment was used  
153 where appropriate. Results showed no significant differences in accuracy between each of the three  
154 Screen positions [ $F(2,40) = 0.596$ ,  $p = 0.556$ ,  $\eta p^2 = 0.029$ ]; average correct response across all three  
155 screen positions was  $74 \pm 1\%$ . Emotion did have a significant effect on accuracy [ $F(2,40) = 40.191$ ,  $p <$   
156  $0.001$ ,  $\eta p^2 = 0.668$ ] which was due to sad expressions being correctly categorised (mean = 89%) more  
157 than happy (mean = 71%) or fear (mean = 63%,  $p$ 's  $< 0.001$ ). Intensity was also significant [ $F(6,120)$   
158  $= 27.615$ ,  $p < 0.001$ ,  $\eta p^2 = 0.580$ ], improvements in categorisation performance were seen from 10%  
159 intensity (mean 50% correct) to 20% (mean 61%), and 30% (mean 71%) to 40% (mean 79%). At  
160 high intensities there were no significant differences of categorisation performance, though the trend to  
161 increase performance continued (10% < 20%/30% < 40%/50%/60%/100%,  $p$ 's  $< 0.011$ ). Finally, emotion  
162 and intensity interacted [ $F(12,240) = 11.515$ ,  $p < 0.001$ ,  $\eta p^2 = 0.365$ ]. Compared to sad (range = 7%,  
163  $p$ 's  $> 0.913$ ), for which accuracy did not change significantly from low intensity to high intensity, fear  
164 (range = 60%, 10% < 20%/30% < 40%/50%/60%/100%,  $p$ 's  $< 0.004$ ) and happy (range = 48%, 10% <  
165 40%/50%/60%/100%,  $p$ 's  $< 0.022$ ) had larger improvements from low intensity to high intensity.

166 Face viewing was measured by defining three regions of interest (ROI); the eyes, the nose and the  
167 mouth. The eyes ROI included the brows, upper and lower lids and a surrounding area of approximately  
168 2 visual degrees. The nose ROI included the bridge, nasal root and a surrounding area up to 2 visual  
169 degrees where this did not impact on other ROI's. Finally the mouth ROI included the lips, mentolabial  
170 sulcus and philtrum and a surrounding area of 2 visual degrees. Each ROI was designed to encompass  
171 the face accurately for any expression at all intensities so that gaze biases introduced by the screen or  
172 stimulus position would not impact on analyses between expressions. Fixations that were not within the  
173 boundaries of the displayed image (900 x 550 pixels) were removed from analysis, however, fixations  
174 within the image but not within any ROI (eyes, nose or mouth) were included in total fixation calculations.  
175 Therefore, the total number of fixations for each stimulus were comprised of fixations to the three ROI's  
176 being analysed, as well as fixations to any other area of the face.

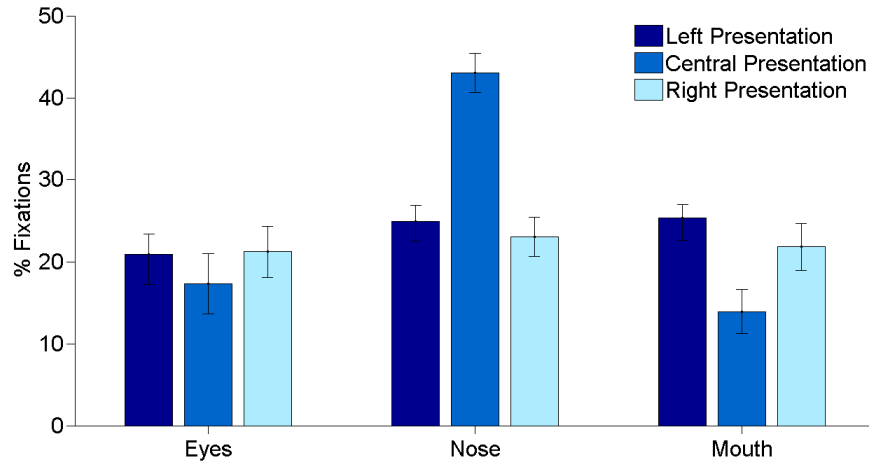
### 177 Central Bias

178 Due to the free viewing method each stimulus received a variable total number of fixations, therefore these  
179 were converted to percentage of total fixations for comparisons between participants and across stimuli,  
180 percentage fixations were then averaged across the four models. To analyse the effect of screen position  
181 (3), emotion (3) and intensity level (7) on the linear combination of 'Percentage Fixations' (on mouth,  
182 eyes and nose), these percentages were entered in a 3 (Screen position)  $\times$  3 (Emotion)  $\times$  7 (Intensity)  
183 Repeated Measures MANOVA.

184 Multivariate analysis revealed that screen position was significant [Wilk's  $\lambda = 0.107$ ,  $F(6,76) = 26.575$ ,  
185  $p < 0.001$ ,  $\eta p^2 = 0.677$ ] and univariate analysis showed that the percentage of fixations to eyes [ $F(2,40)$   
186  $= 5.64$ ,  $p = 0.007$ ,  $\eta p^2 = 0.220$ ], nose [ $F(2,40) = 100.98$ ,  $p < 0.001$ ,  $\eta p^2 = 0.835$ ] and mouth [ $F(2,40) = 35.29$ ,  
187  $p < 0.001$ ,  $\eta p^2 = 0.638$ ] all varied significantly dependent on screen position.

188 Bonferroni corrected pairwise comparisons were used to analyse main and interaction effects. The  
189 effect of Screen position was compared separately for each ROI (see Figure 1). Percentage fixations to the  
190 eyes varied significantly between faces presented in the centre and to the right ( $p$ 's  $<$  or equal to 0.003)  
191 of the screen. The nose was fixated less when faces were presented to the right and left compared to  
192 those presented centrally in the screen ( $p$ 's  $< 0.001$ ). Percentage fixations to the mouth were significantly  
193 different for all three screen positions (for all comparisons,  $p$ 's  $< 0.05$ ). A multivariate interaction between  
194 Screen position and Intensity [Wilk's  $\lambda = 0.713$ ,  $F(36,703.925) = 2.373$ ,  $p < 0.001$ ,  $\eta p^2 = 0.107$ ], which  
195 was accounted for by the univariate interaction between Screen position and Intensity for the nose region  
196 [ $F(12,240) = 3.870$ ,  $p < 0.001$ ,  $\eta p^2 = 0.162$ ] and the mouth region [ $F(12,240) = 2.411$ ,  $p = 0.006$ ,  $\eta p^2$   
197  $= 0.108$ ], suggest that the effect of screen position for nose and mouth in Figure 1 was not exactly the same  
198 at all intensity levels. Most pairwise comparisons confirmed the effects illustrated in Figure 1: There were  
199 more fixations to the nose in centrally presented faces at all intensities compared to left ( $p$ 's  $< 0.001$ ) or  
200 right ( $p$ 's  $< 0.001$ ) presented faces and centrally presented faces had fewer fixations to the mouth at all  
201 intensities compared to left ( $p$ 's  $< 0.001$ ) or right presentations ( $p$ 's  $< 0.038$ ). However, when left and  
202 right screen positions are directly compared, the nose was fixated more in left compared to right presented  
203 faces at 100% intensity ( $p = 0.049$ ) and the mouth was viewed more in left compared to right presented  
204 faces at intensity levels 30% ( $p = 0.001$ ) and 100% intensities ( $p = 0.020$ ).

205 A significant multivariate effect of emotion [Wilk's  $\lambda = 0.527$ ,  $F(6,18) = 4.775$ ,  $p < 0.001$ ,  $\eta p^2 = 0.274$ ]



**Figure 1.** Percentage fixations to predefined regions of interest, eyes, nose and mouth dependant on face presentation position on screen, left centre or right.

206 was accounted for by a significant univariate effect of emotion for percentage fixations to the mouth  
 207 only [F(2,76) = 15.96,  $p < 0.001$ ,  $\eta^2 = 0.444$ ]. Pairwise comparisons showed this was due to significant  
 208 differences between all three emotions, with happy receiving the highest percentage of fixations to the  
 209 mouth (mean = 22.253), fear receiving fewer (mean = 20.627) and sad receiving the lowest percentage  
 210 (mean = 18.1191, all  $p$ 's < 0.020). Furthermore the multivariate effect of Intensity [Wilk's  $\lambda = 0.691$ ,  
 211 F(18,334.240) = 2.588,  $p < 0.001$ ,  $\eta^2 = 0.116$ ] was accounted for by the univariate effect of Intensity on  
 212 percentage fixation toward the eyes [F(6,120) = 4.539,  $p < 0.001$ ,  $\eta^2 = 0.185$ ]. Pairwise comparisons  
 213 showed that fixations towards the eyes were higher at intensity 10% (mean = 21.80) compared to 30%  
 214 (mean = 19.00,  $p = 0.016$ ) or 60% (mean = 18.10,  $p = 0.018$ ).

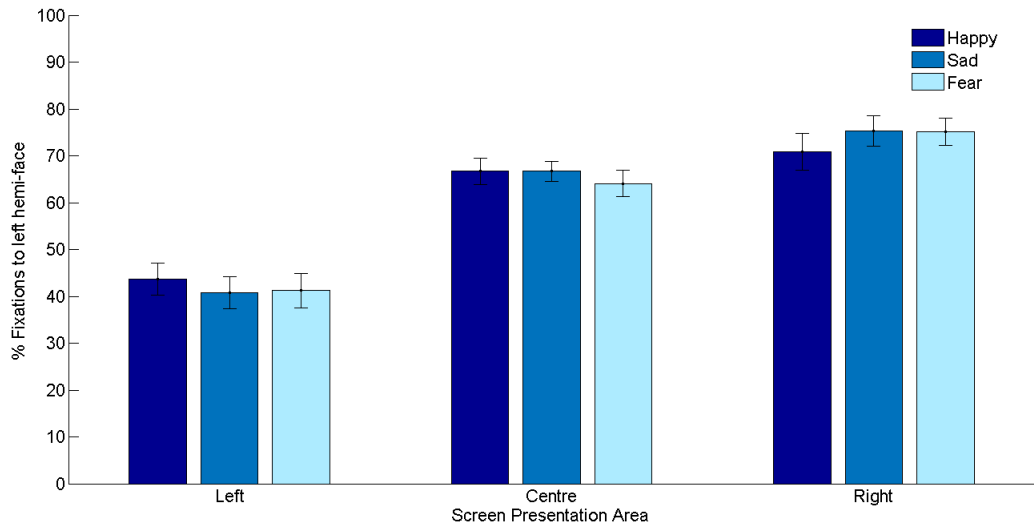
215 A significant multivariate interaction effect between Screen position and Emotion [Wilk's  $\lambda = 0.648$ ,  
 216 F(12, 206.660) = 3.066,  $p = 0.001$ ,  $\eta^2 = 0.135$ ] was found, which was accounted for by a significant  
 217 interaction between Screen Position and Emotion for the eye-region only [F(4,80) = 5.264,  $p = 0.001$ ,  $\eta^2$   
 218 = 0.208]. Pairwise comparison found fewer fixations to the eyes of fear expressions that were centrally  
 219 presented compared to right presentations ( $p = 0.043$ ). Similarly, sad expressions received fewer fixations  
 220 to the eyes when centrally presented, compared to right ( $p = 0.001$ ) presentations. Comparing emotions  
 221 within each screen position pairwise comparisons found that fear expressions had more fixations to the  
 222 eyes (mean = 23%) than happy (mean = 20%,  $p = 0.004$ ) or sad expressions (mean = 20%) only when  
 223 faces were presented to the right of the screen, all other comparisons were not significant.

### 224 Left Horizontal Bias

225 To investigate left or right face or screen biases, percentage fixations within the face were calculated as  
 226 percentages of those to the left hemi-face and those to the right hemi-face in each of the three screen  
 227 positions, with left and right hemi-face fixations equalling the total number of fixations made during  
 228 stimulus presentation. Percentage of fixations to the left and to the right hemi-faces were averaged across  
 229 the four models shown for each emotion and intensity, then these average percentages were entered into  
 230 two 3 (Screen position)  $\times$  3 (Emotion)  $\times$  7 (Intensity) Repeated Measures ANOVAs, for separate analyses  
 231 of percentage fixations to the left side and right side of the face. Due to the highly correlated nature of left  
 232 and right face fixations they could not be included in a single analysis.

233 A significant effect of Screen position was found for fixations to the left hemi-face [F(2,40) = 100.067,  
 234  $p < 0.001$ ,  $\eta^2 = 0.833$ ] and to the right hemi-face [F(2,40) = 135.155,  $p < 0.001$ ,  $\eta^2 = 0.871$ ]. Figure 2  
 235 shows that the number of fixations to the left hemi-face increased as the image screen position changed to  
 236 the right of the screen and therefore conversely that the number of fixations to the right hemi-face reduced.  
 237 Pairwise comparisons showed significant differences between all three screen positions, for fixations to  
 238 both the left ( $p$ 's < 0.001) and right hemi-face ( $p$ 's < 0.001).

239 Significant interaction effects were further found between Screen position and Emotion [left hemi-face:



**Figure 2.** Percentage fixations to the left of a displayed face (left hemi-face) in each of the three screen presentation areas, left, centre and right for each emotion, happy, sad and fear.

240  $F(4,80) = 4.337, p=0.003, \eta p^2=0.178$ . right hemi-face:  $F(4,80) = 4.684, p=0.002, \eta p^2=0.190$ ]. Fixations  
 241 to the left hemi-face were significantly lower for fear expressions presented on the left compared to the  
 242 right or centre ( $p$ 's < 0.001). For both happy and sad expressions, fixations to the left hemi-face were  
 243 lower on faces presented to the left compared to the centre ( $p$ 's < 0.001) and higher on faces presented  
 244 to the right compared to centre ( $p$ 's < or equal 0.003, see Figure 2). Conversely fixations to the right  
 245 hemi-face were lowest for all emotions when faces were presented to the right compared to centrally or  
 246 to the left, and highest for faces presented to the left compared to the centre or right (all  $p$ 's < 0.001).  
 247 Within each screen position, fixations to the left hemi-face varied significantly only between happy (mean  
 248 = 43%) and fearful expressions (mean = 41%,  $p = 0.046$ ) in left presentations and happy (mean = 70%)  
 249 and sad (mean = 75%,  $p = 0.008$ ) and happy and fearful (mean = 75%,  $p = 0.021$ ) expressions in right  
 250 presentations. Fixations to the right hemi-face when stimuli were presented in the centre of the screen  
 251 were higher for sad expressions (mean = 23%) compared to happy (mean = 21%,  $p = 0.018$ ) or fearful  
 252 expressions (mean = 20%,  $p < 0.001$ ) but when stimuli were presented to the left fearful expressions  
 253 received more fixations to the right hemi-face (mean = 46%) than happy expressions (mean = 43%,  $p =$   
 254 0.046). Finally, right hemi-face fixations were lower for sad expressions when stimuli were presented on  
 255 the right of the screen (mean = 11%) compared to happy (mean = 13%,  $p = 0.008$ ) or fearful expressions  
 256 (mean = 13  $p = 0.006$ ). Emotion and Intensity [left hemi-face:  $F(12,240) = 2.988, p=0.017, \eta p^2=0.130$ ,  
 257 right hemi-face:  $F(12,240) = 2.815, p=0.001, \eta p^2=0.123$ ] revealed that at 40% intensity, sad expressions  
 258 had more fixations to the right hemi-face than fear ( $p = 0.006$ ) and fewer fixations to the left hemi-face  
 259 compared to happy ( $p = 0.031$ ); happy expressions had fewer right hemi-face fixations compared to fear  
 260 at 10% intensity ( $p = 0.003$ ).

261 Finally, Screen position, Emotion and Intensity was significant for fixations to the left hemi-face only  
 262 [ $F(24,480) = 3.762, p=0.003, \eta p^2=0.158$ ]. Pairwise comparison showed that when presented centrally,  
 263 all emotions at all intensities had more left hemi-face fixations than when presented on the left ( $p$ 's <  
 264 or equal 0.048). Faces presented on the right of the screen also had more left hemi-face fixations than  
 265 those presented to the left ( $p$ 's < or equal 0.021) except fear at 30% which did not vary significantly  
 266 between right and left presentations. Right presented faces typically had more left hemi-face fixations  
 267 than centrally presented faces, this was significant for fear expressions at 40% intensity ( $p = 0.002$ ), happy  
 268 expressions at 20% ( $p = 0.002$ ), 30% ( $p = 0.014$ ), 50% ( $p = 0.006$ ) and 60% intensity ( $p = 0.029$ ) and  
 269 finally, for sad expressions at 20% ( $p = 0.003$ ), 30% ( $p = 0.002$ ) and 50% ( $p < 0.001$ ) intensity. Next,  
 270 when faces were presented in the centre of the screen happy expressions received more left hemi-face  
 271 fixations than fearful expressions at 10% and 30% intensities ( $p$ 's < 0.036) and happy expressions also had  
 272 more left hemi-face fixations than sad faces at 20% and 30% intensities ( $p$ 's < 0.048). Sad expressions

273 also received more left hemi-face fixations than fearful expressions at 20% and 40% intensities ( $p$ 's <  
274 0.028). When faces were presented to the left of the screen happy expressions had more left hemi-face  
275 fixations than sad at 30% and 50% intensities ( $p$ 's < 0.049) and fear at 30% ( $p$  = 0.018). Sad expressions  
276 also had more left face fixations than fear at 20% and 50% ( $p$ 's < 0.045) but fewer fixations than fear at  
277 60% intensity ( $p$  = 0.049). Lastly, when faces were presented to the right of the screen happy expressions  
278 had fewer left hemi-face fixations than sad at 10%, 20%, 50% and 100% ( $p$ 's < 0.030) but more left  
279 hemi-face fixations than sad at 40% ( $p$  = 0.033). Happy expressions also had fewer left face fixations  
280 than fear at 20% and 30% ( $p$ 's < 0.009) but more left face fixations than fear at 60% ( $p$  = 0.032), sad  
281 expressions only had more left face fixations than fear at 60% intensity ( $p$  = 0.018).

## 282 **DISCUSSION**

283 The present study was designed to differentiate general screen biases in viewing from those associated  
284 specifically to faces during categorisation tasks, in particular a tendency for fixations to focus around the  
285 centre of the face (Guo, 2012; Levy et al., 2013; Pollux et al., 2014; Rigato and Farroni, 2013; Samson  
286 et al., 2014) and for fixations to land on the left hemi-face (Guo, 2012). Stimulus screen position had a  
287 significant impact on participants fixation patterns toward faces, specifically, laterally presenting faces on  
288 either side of a screen resulted in a large reduction in overall fixations towards the centre of the face when  
289 compared to centrally presented faces. Furthermore, the gravitational effect of screen centre on fixations  
290 (Tatler, 2007) was demonstrated by an increase in fixations to the hemi-face closest to screen centre even  
291 in laterally presented stimuli. This suggests that the centre of screen bias observed in studies using natural  
292 scenes (Bindemann, 2010; Tatler, 2007; Vitu et al., 2004) extends to face viewing and that the previously  
293 observed preference for face centre throughout viewing (Guo, 2012; Levy et al., 2013; Pollux et al., 2014;  
294 Rigato and Farroni, 2013; Samson et al., 2014) could be attributed to a general viewing bias introduced  
295 by the screen. In contrast, the left-gaze bias for faces (Guo, 2012) was not solely attributable to general  
296 screen biases as left-gaze persisted regardless of stimulus screen position, though this interacted with  
297 the centre of screen bias resulting in even fixations to each hemi-face in stimuli presented to the left  
298 of the screen. This finding is in contrast with previous evidence showing elimination of the left-gaze  
299 bias when faces are displayed laterally (Samson et al., 2014) and extended viewing periods are allowed  
300 (Eisenbarth and Alpers, 2011) but is compatible with a tendency to preferentially select the left side of  
301 objects (Foulsham and Kingstone, 2013) or faces presented to the left (Prete et al., 2015).

302 Displayed emotions were chosen specifically to contain little or no informative facial characteristics in  
303 the nose region, with fear displaying primarily in the eyes and happiness and sadness displaying primarily  
304 in the eyes and mouth (Calvo et al., 2008; Eisenbarth and Alpers, 2011; Ekman and Friesen, 1978; Kohler  
305 et al., 2004; Levy et al., 2013; Maurer et al., 2002; Messinger et al., 2012; Rigato and Farroni, 2013;  
306 Smyth et al., 2005; Vassallo et al., 2009; Wang et al., 2011; Xiao et al., 2013). The screen centre bias  
307 for landscapes and objects is suggested to arise from perceiving the screen itself as an object, which are  
308 also typically fixated at the centre (Bindemann, 2010; Foulsham and Kingstone, 2013). Our finding of a  
309 strong centre of screen bias, shown by fixations to the nose in centrally presented stimuli and fixations  
310 to the hemi-face closest to screen centre, supports the screen being perceived as an object (Foulsham  
311 and Kingstone, 2013) where fixations are typically drawn to the centre of the object being viewed. The  
312 central bias was reduced considerably when faces were laterally presented, reflected in a more balanced  
313 percentage of fixations across the three defined regions of interest. However, fixations toward the nose  
314 were not eliminated entirely, suggesting that details in the nose region were informative for categorization  
315 responses. Alternatively, fixations in this region may have been associated predominantly with early stages  
316 of face-viewing and could have been a reflection of a centre-of-face bias, aiding rapid early expression  
317 analysis. (Calvo et al., 2008; Eisenbarth and Alpers, 2011; Feldmann-Wüstefeld et al., 2011; Guo, 2012;  
318 Hills et al., 2013; Pollux et al., 2014; Samson et al., 2014). Future studies will be required to explore  
319 whether different viewing biases exert stronger influences at early and later stages of face viewing for  
320 expression categorization.

321 Our data shows that a screen centre bias, reflected in preferential attending of the hemi-face closest to  
322 screen centre, co-occurs with left hemi-face bias. Faces presented to the left of the screen had a similar  
323 percentage of fixations to the left hemi-face and right hemi-face, whereas faces presented to the right of the  
324 screen received around six times more fixations to the left hemi-face compared to the right hemi-face. Due  
325 to the influence of a screen centre gravitational effect (Tatler, 2007), fixations to faces presented on the left  
326 would be expected to fall primarily on the right hemi-face as previously observed (Samson et al., 2014).

327 However, participants viewed both hemi-faces equally during left presentation, showing the influence of  
328 the left hemi-face bias drawing fixations to the left hemi-face whilst the screen centre bias concurrently  
329 draws fixations to the right hemi-face. In contrast, the two biases significantly increase fixations to the left  
330 hemi-face in right screen presentations. Samson et al. (2014) utilised restricted viewing time to control the  
331 total number of saccades participants could make, whereas here we utilised a free viewing task allowing  
332 unlimited visual exploration of the face. In both instances, a screen centre bias was observed, drawing  
333 fixations to the hemi-face closest to screen centre. Unlike Samson et al. (2014) we also observed a left  
334 hemi-face bias, drawing fixations to the left side of the face. Differences between our findings and those  
335 of Samson et al. (2014) may be due to viewing time, as previous studies have demonstrated both that  
336 free viewing can eliminate a bias to the left hemi-face (Eisenbarth and Alpers, 2011) but also facilitate it  
337 (Levy et al., 1983). However, a meta analysis of leftward biases suggests that the use of emotive faces and  
338 time restrictions results in the largest effect sizes (Voyer et al., 2012), therefore, the appearance of left  
339 gaze bias in our task is more likely a characteristic of emotion categorisation, as Eisenbarth and Alpers  
340 (2011) utilised valence and arousal rating scales rather than emotion categories and Samson et al. (2014)  
341 utilised a gender judgement task while Levy et al. (1983) asked participants to judge happiness in pairs of  
342 chimeric faces.

343 In addition to centre-of-screen and left hemi-face gaze biases, the results of the present study seem to  
344 suggest that a small bias towards the left compared to the right side of screen may have influenced gaze  
345 patterns, although this effect was small and only observed for the nose and mouth and was restricted to only  
346 a few intensity levels. However, this trend is consistent with the horizontal left bias previously reported in  
347 free viewing of natural scenes (Foulsham et al., 2013; Foulsham and Kingstone, 2013; Ossandón et al.,  
348 2014) and faces (Prete et al., 2015) and may warrant further exploration in future studies. If, as suggested  
349 in the present study, this bias is relatively small compared to the centre-of-screen and left hemi-face bias,  
350 then it may require experiments with a larger number of trials per intensity level to reveal the nature of  
351 this bias in facial expression recognition experiments.

352 In summary, a bias to the left hemi-face for fixations was dissociable from a general left horizontal  
353 bias (Foulsham et al., 2013; Prete et al., 2015) specifically as a characteristic of emotion categorisation  
354 tasks. The left hemi-face bias co-occurred with a screen centre bias (Bindemann, 2010; Ossandón et al.,  
355 2014; Tatler, 2007), drawing fixations gravitationally towards the centre of the display screen whilst  
356 simultaneously drawing fixations to the left hemi-face. Lateral presentation reduced the effect of a central  
357 bias, but did not eliminate the left hemi-face bias, resulting in more evident emotion specific viewing  
358 patterns and greater visual exploration of the face. Future work utilising eye tracking methodology with  
359 facial categorisation may consider carefully the impact of stimulus screen position and the effect of screen  
360 centre or left hemi-face biases.

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