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1 Attention Orientation to Pleasantness and Depressive 2 Symptomatology Predict Autonomic Reactivity

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14 **Abstract**

15
16 Depression is characterised by attentional bias to emotional information and
17 dysregulated autonomic reactivity. Despite its relevance to understanding depressive
18 mechanisms, the association between attentional bias and autonomic reactivity to emotional
19 information remains poorly characterised. This study compared behavioural and autonomic
20 responses to emotional images in 32 participants in whom subclinical depressive
21 symptomatology was quantified using the Beck Depression Inventory. Pairs of emotional and
22 neutral images (unpleasant-neutral, U-N; pleasant-neutral, P-N; neutral-neutral, N-N) were
23 presented while attentional indices (eye movements) and autonomic activity (skin conductance
24 responses, SCRs; heart rate, HR) were recorded. Results showed that all recorded ocular
25 parameters indicated a preferential orientation and maintenance of attention to emotional
26 images. SCRs were associated with a valence effect on fixation latency: lower fixation latency
27 to pleasant stimuli leads to lower SCRs whereas the opposite was observed for unpleasant
28 stimuli. Finally, stepwise linear regression analysis revealed that latency of fixation to pleasant
29 images and scores of depression predicted SCRs of participants. Thus, our research reveals an
30 association between autonomic reactivity and attentional bias to pleasant information, on the
31 one hand, and depressive symptomatology on the other. Present findings therefore suggest that
32 depressive individuals may benefit from attention training towards pleasant information in
33 association with autonomic biofeedback procedures.

34 **Keywords:** Emotion, Depression, Attention bias, Eye movements, Autonomic responses, skin
35 conductance.

Introduction

37 Healthy individuals mobilise privileged attentional resources toward emotional
38 information (Vuilleumier, 2015) and express associated autonomic and behavioural responses
39 (Damasio, 2000). However, abnormalities in the amount of attention dedicated to emotional
40 information are implicated in the etiology and maintenance of depressive symptomatology
41 (Gotlib and Joormann, 2010). For mood-congruent information, depressed individuals are
42 characterised by biases at all stages of attentional processing (Ingram et al., 1998). Meta-
43 analysis reveals that, in depression, attentional bias toward negative information is observed
44 for verbal and non-verbal stimuli, in both clinical and subclinical populations (Peckham et al.,
45 2010). It is also reported that, in depression, less attention is dedicated to pleasant information
46 (Duque & Vázquez, 2015). This may reflect an absence of the ‘protective bias’ toward positive
47 stimuli that is usually observed in healthy or non-dysphoric individuals (Shane & Peterson,
48 2007). Furthermore, attentional bias to pleasant information is found to correlate negatively
49 with the onset of depressive symptomatology, and is associated with greater trait resilience.
50 Hence, attentional bias to pleasant information can be considered as an index of adaptive
51 emotion regulation (Thoern et al., 2016). Conversely, reduced attentional bias to pleasant
52 material increases vulnerability to stress-related psychopathology (Fox et al., 2010). In brief,
53 individuals with depressive symptomatology show greater orientation and maintenance of
54 attention towards unpleasant stimuli and reduced orientation towards pleasant stimuli (Gotlib
55 and Joormann, 2010).

56 The dot probe task is one established approach for measuring the time course of
57 attentional processes in depression (MacLeod et al., 1986). Here, the participant views a pair
58 of stimuli, usually one emotional and one neutral image, which are immediately followed by
59 a stimulus (‘probe’), which appears at the location of one of two images. The participant is
60 instructed to make a reaction time response to the probe. Emotional attentional bias to it
61 expresses faster responses on trials when the probe is presented in the location of the emotional
62 compared to the neutral image. This task and variations of it has become a gold standard for
63 investigating attentional bias and its time course. However, the use of reaction times does not
64 allow direct measurement of the attention span and has recently been criticised regarding its
65 psychometric properties (Chapman et al., 2019). As an alternative, measures of eye
66 movements can provide a more direct index of attentional deployment. In depressed
67 individuals, they showed an increased attention to negative stimuli and decreased attention to
68 positive stimulation when compared to nondepressed individuals (Armstrong & Olatunji,

69 2012). Eye movements can reflect both orienting (e.g. initial orientation and latency to first
70 fixation) and maintenance (e.g. number of fixations, or total duration of fixation; Duque &
71 Vazquez, 2015) components of attention, as well as attentional reorientation to stimuli.
72 Indeed, unlike reaction times, eye movements allow the continuous measurement of
73 attentional processes and can thus better characterise attention biases to emotional stimuli. A
74 few studies in the literature have investigated the psychometric properties of eye movement
75 indices and most of them used different stimuli, paradigm or sample characteristics (Waechter
76 et al., 2014; Lazarov et al., 2016, Skinner et al., 2018, Sears et al., 2019). Although there are
77 still mixed results for the early attention cues (Skinner et al., 2018), the results for indices of
78 maintenance of attention such as total fixation time and number of fixations appear
79 encouraging concerning psychometrics properties (Sears et al., 2019). Consequently, some
80 authors suggest that eye-tracking measures of attentional bias may have better overall
81 psychometric properties as compared than traditional RT measures of attentional bias for
82 children and adults (Chong & Meyer, 2020).

83 Depressive symptoms are associated with altered patterns of autonomic activity, which
84 has been related to a disengagement from emotional information (Bylsma et al., 2008).
85 Increases in electrodermal activity (Branković, 2008), skin temperature and respiratory
86 frequency (Wenzler et al., 2017) and decreases in heart rate variability (HRV; Kemp et al.,
87 2010) are reported. However, across studies of depression, there is heterogeneity in autonomic
88 reactivity to emotive stimuli, which remains to be clarified. We propose this heterogeneity
89 may reflect individual differences in attentional focus (De Zorzi et al., 2021). For example,
90 depressed individuals show heightened electrodermal reactivity only for stimuli in direct
91 attentional focus (i.e., central vision) and not for stimulation presented in peripheral vision
92 (De Zorzi et al. 2020). More generally, attentional processes are linked to the modulation of
93 autonomic activity. Thus, electrodermal activity, notably the amplitude of sympathetic skin
94 conductance responses (SCRs), is related to attention-orientation behaviours and reflects
95 focused attention to new stimuli and their salience (Boucsein, 2012). Similarly, HRV,
96 reflecting both parasympathetic and sympathetic influences on heart rate, is also considered
97 as an objective indicator of attentional processes. In this context, superior selective or
98 sustained attention is associated with increased HRV, particularly in the dominant high-
99 frequency range (HF-HRV, indexing vagal parasympathetic autonomic activity) (Suess &
100 Porges, 1994). Interoceptive feedback of autonomic bodily signals also influences emotional
101 and attentional processes (Critchley & Harrison, 2013). Altered sensitivity to bodily arousal

102 is observed in depression (Paulus & Stein, 2010). As depressive individuals suffer from
103 attentional disturbance when emotional information is involved, the use of a task allowing to
104 measure attentional processes appears relevant in the study of their autonomic reactivity to
105 emotion.

106 The present study aimed to characterise the association of attentional bias and autonomic
107 reactivity to emotional information in individuals expressing different levels of depression.
108 To this end, in an original paradigm, we presented pairs of emotional and neutral images, at
109 near eccentricities within left (-12°) and right (+12°) visual fields. Eye movements were
110 recorded to enable the tracking of attentional deployment toward one or other images, while
111 we simultaneously measured autonomic variables (SCR and HR). Accordingly, we
112 hypothesised that: 1) Attention will be preferentially directed to emotional images in all
113 participants; 2) attentional bias to emotional information will be associated with autonomic
114 reactivity (SCR and HR responses); 3) depressive symptoms will be associated with greater
115 attention towards unpleasant stimuli and reduced orientation towards pleasant stimuli on the
116 one hand, and with autonomic reactivity on the other hand.

117 **Method**

118 *Participants*

119 Thirty-four healthy unmedicated participants were recruited through an online
120 questionnaire. All were French speakers, right-handed and had normal or corrected-to-normal
121 vision. Individuals with a history of neurological disorders or regular and/or recent illicit drug
122 consumption were not included. Two participants were excluded due to recording problems,
123 giving a sample of 32 participants (24 females and 8 males; **Table 1**). Each participant provided
124 an informed consent statement and received a 20 € compensation for his or her participation.
125 This study was approved by the Ethics Committee of Université de Lille [Référence: 2019-352-
126 S73], and conducted in accordance with the Declaration of Helsinki at Faculté de Medecine,
127 Pôle Recherche, Université de Lille, France.

128 **[Insert Table 1 about here]**

130 *Stimuli and Apparatus*

131 The stimuli used were pairs of images of emotional or neutral scenes selected from the
132 International Affective Pictures System (IAPS; Lang, Bradley, & Cuthbert, 2008), which

133 provides standardised *a priori* values for each image on valence and arousal dimensions. One
134 value is provided for men, and another for women. Given the recognised differences in
135 gender-based emotional assessments (Bradley, Codispoti, Cuthbert, & Lang, 2001), we
136 performed two image selections adapted to each gender, but resulting in equivalent valence
137 and arousal values. Ninety-six images were selected and used to build three kinds of pairs: 16
138 unpleasant-neutral pairs (|UN|), 16 pleasant-neutral pairs (|PN|) and 16 neutral-neutral pairs
139 (|NN|). In order to control the salience of the two images that made up each pair, the difference
140 of valence and arousal between the two images constituting each pair were calculated. These
141 within-pairs differences significantly differed between the three kinds of pairs on their *a priori*
142 valence values (*women*: $|U - N| = 2.56$, $|P - N| = 2.47$, $|N - N| = 0.54$, $F_{1,15} = 290.196$; $p <$
143 0.001 ; *men*: $|U - N| = 2.65$, $|P - N| = 2.28$, $|N - N| = 0.40$, $F_{1,15} = 640.406$; $p < 0.001$), and
144 on their arousal *a priori* values (*women* : $|U - N| = 2.74$, $|P - N| = 2.80$, $|N - N| = 0.50$, $F_{1,15}$
145 $= 263.916$; $p < 0.001$; and *men*: $|U - N| = 2.48$, $|P - N| = 2.67$, $|N - N| = 0.54$, $F_{1,15} =$
146 232.177 ; $p < 0.001$) with higher within-pairs difference for |UN| and |PN| pairs than |NN| ones,
147 but there were no differences between |UN| and |PN| pairs. For each pair of images, no within-
148 pairs differences of valence or arousal was observed between the selections for men and
149 women (all $F_s < 0.275$ and $p_s > 0.609$). For each image, the angular size ($12^\circ \times 8^\circ$), the energy
150 across spatial frequencies (Delplanque, N'diaye, Scherer, & Grandjean, 2007) and the main
151 physical properties were extracted (*ImageJ v1.50 software*), including the luminance and
152 contrasts for the greyscale version and the RGB (red, green and blue) layers. No significant
153 differences were observed between the three sets of images for both genders (all $p_s > .20$).
154 Thus, the image pairs differed only in terms of their emotional dimensions (see table in
155 **Appendix Table S1**).

156 Participants were seated at a fixed viewing distance of 60 cm from the projection screen
157 (30 inches, 256 x 160 ppi, DELL 3007WFP HC), which was connected to a computer (DELL
158 Optiplex 9020, Windows 7 Professional) that managed the presentation of the pairs of images.
159 The images were displayed on a black background and each pair of images was presented
160 pseudo-randomly, based on a Latin squares design, at near visual eccentricities (-12° , $+ 12^\circ$).
161 The presentation of the 48 trials lasted approximately 15 minutes.

162

163 ***Recordings***

164 Anxiety state, trait and depressive scores were measured using French language versions
165 of the State-Trait Anxiety Inventory (STAI-A & B; Spielberger, 1983) and Beck Depressive
166 Inventory (BDI-II; Beck, Steer, & Brown, 1996) respectively.

167 Regarding behavioural data, the eye movements were recorded using an eye tracker
168 (SMI RED-m Eye Tracking System) connected to the projection computer with *SMI iView*
169 *RED-m 2.11* software for an acquisition at 120 Hz. The skin conductance (SC) and
170 electrocardiogram (ECG) were recorded during two minutes of baseline, during the task and
171 over 2-minute recovery periods, using a BIOPAC MP35 system connected to a second
172 computer (running *BIOPAC Student Pro 3.7* software) for an acquisition at 200 Hz. SC was
173 recorded using bipolar Ag/AgCl surface electrodes (BIOPAC EL507) pre-gelled with an
174 isotonic electrolyte (0.05 molar NaCl) and attached to the palmar side of the middle phalanges
175 of the index and middle fingers of the participant's non-dominant hand. SC was measured
176 with a gain of 5 $\mu\text{S}/\text{V}$ and a 10 Hz low-pass filter. The ECG was recorded using a DI modified
177 bypass placing the Ag/AgCl pre-gelled (BIOPAC EL503, 7% NaCl) surface electrodes on the
178 participant's left and right wrists and with a band-pass filter set between 0.5 and 66.5 Hz. At
179 the end of the experiment, the participant was required to review each of the images and to
180 rate them individually for valence and arousal values using two nine-point SAM scales (Self-
181 Assessment Manikin; Bradley & Lang, 1994), ranging from 1, very unpleasant, to 9, very
182 pleasant, and from 1, very calm, to 9, very arousing. Ratings were recorded with *OpenSesame*
183 (Mathôt et al., 2012).

184

185 ***Procedure***

186 The experimental procedure was divided into three steps. First, the SCR and ECG
187 electrodes were attached and the participant was acclimatised to the experimental environment.
188 The participant completed a psychometric measure of anxiety state (State Anxiety Inventory,
189 STAI-A; Spielberger et al., 1993), then the task was again explained orally in full.

190 Next, autonomic responses were recorded over a task-free 2-minute baseline period.
191 This period was then followed by the main task, with recording of behavioural (eye-tracking)
192 and autonomic responses together. The participant saw 48 pairs of images; 16 pairs of
193 unpleasant-neutral |UN| images, 16 pairs of pleasant-neutral |PN| images and 16 pairs of neutral-

194 neutral |NN| images presented in a pseudo-random order. Each trial had the following sequence:
195 First, a central fixation cross was projected for a duration of 0.5 s then this was replaced by the
196 probe; a digit number (between 1 and 9) replacing the fixing cross for 1 s. The participant was
197 instructed to say this number as quickly as possible. As shown by Duque and Vazquez (2015),
198 this procedure ensured that the participant watched the centre of the screen before the
199 presentation of the stimuli. The procedure also helped maintain the participants' attention
200 during the experimental phase. Following the presentation of the number, a pair of images was
201 presented simultaneously, at -12° and $+12^\circ$ on the projection screen for 3.5 s, followed by a
202 black screen for a random duration between 9 to 13 s. Participants were invited to view the
203 images naturally without any further requirements. The inter-stimulus interval (ISI) varied from
204 10.5 to 14.5 s; an ideal interval to avoid habituation inherent to autonomic responses,
205 particularly electrodermal activity. After the task, we recorded autonomic activity during a 2-
206 minute recovery period.

207 Finally, to validate our selection of images, the participant was asked to rate the valence
208 and arousal dimensions using the two 9-point SAM scales. These subjective ratings correspond
209 to *a posteriori* values of images.

210

211 *Data and Statistical Analyses*

212 All trials containing eye movements before the onset of the image were rejected to
213 exclude trials for which gaze is already directed to a image's side. Across all participants and
214 conditions, 5.14% of the trials were rejected.

215 *Eye Movements*

216 Attentional deployment was assessed based on eye movements
217 (*OpenGazeAndMouseAnalyzer*; Voßkühler et al., 2008). For initial fixation, the percentage of
218 first fixation for each type of image (unpleasant, pleasant and neutral) in pairs (|UN| and |PN|)
219 was calculated for each participant. In addition, total fixation duration, number and latency of
220 fixations were recorded.

221 *Conductance and Cardiac Activities*

222 SC and ECG variations initially sampled at 200 Hz, were down-sampled at 10 Hz using
223 *LabChart7*. For the SC variations to the presentation of pairs of images, phasic waveforms were
224 derived from the tonic signals with an offline 0.05 Hz high-pass filter using *AcqKnowledge 4.1*
225 software. SCRs were analysed by computing the integrals of SC amplitude variations over time

226 for each condition and participant. One participant with no SCR was excluded from the analysis.
227 For the ECG, the instantaneous heart rate in beats per minute (BPM) was calculated from the
228 R wave intervals and smoothed using the triangular Bartlett window with a 1 s width using
229 *LabChart7*. SC variations in response to stimulation were obtained by subtracting the average
230 over a 3 s pre-stimulus period from the 10 s post-stimulus period data. For each condition and
231 participant, after the baseline correction (-3 to 0 s), we averaged the epochs (-3 to 10 s), time-
232 locked to the stimulus onset. Finally, we analysed the heart rate variability (HRV) during the 2
233 minutes of baseline and recovery periods. HRV quantification was computed with an in-house
234 customised program *MATLAB* program referring to HRV guidelines (Berntson et al., 1997).
235 The R-R intervals were detrended with a smoothness-prior method in order to remove the slow
236 (< 0.04 Hz) non-stationary trends from the HRV signal. For the frequency domain method, a
237 power spectrum density analysis was performed for the RR interval series using fast Fourier
238 transform method with the low frequency (LF) band set at 0.04-0.15 Hz and a high frequency
239 (HF) band set at 0.15-0.4 Hz. The LF/HF ratio was also computed. For the time domain method,
240 we computed the mean heart rate (HR), the standard deviation of HR (namely the variability of
241 the HR) as well as the root mean square of successive RR intervals differences (RMSSD).

242 *Statistical Analyses*

243 Regarding emotion and in accordance with its dimensional theory (Lang et al., 1993), we
244 tested for two emotional effects: 1) A valence effect (Unpleasant vs. Pleasant), being modelled
245 by a first degree polynomial contrast (*Linear Contrast*, $LC = |PN| - |UN|$; and 2) an arousal
246 effect (Emotion vs. Neutral) being modelled by a second degree polynomial contrast (*Quadratic*
247 *Contrast*, $QC = (|UN| + |PN|) / 2 - |NN|$). These contrasts were assessed with a repeated
248 measure analysis of variance (ANOVA), applied to the individual subjective image
249 assessments, eye movements, electrodermal and cardiac measurements with emotion (type of
250 pairs: $|UN|$, $|NN|$, $|PN|$) as intra-subject factors.

251 The analysis of the factors associated with the autonomic variables was performed by
252 calculating the Pearson correlation coefficient given linear relationships were expected between
253 variables and after inspection of scatterplots. Partial correlations were then assessed controlling
254 for age and gender. The search for predictors of autonomic variables was performed with
255 stepwise linear regression analyses. The multivariate model includes variables for which
256 associations were observed between ocular and autonomic parameters. Thus, the model was
257 constructed by including variables associated with SCRs, but also including covariates such as
258 the age of participants, and their state and trait anxiety (STAI-A and STAI-B scores), regardless

259 of their degree of significance in the univariate analyses. The model selection was based on
260 considerations of the corrected Akaike information criterion (AICc). The validity of the
261 multivariate model was established by a study of the residuals.

262 **Results**

263 Concerning psychometry, STAI-B (trait anxiety) scores correlated with BDI (depression)
264 ($r_{33} = 0.810$; $p < 0.001$) and STAI-A (state anxiety) scores ($r_{33} = 0.631$; $p < 0.001$). BDI scores
265 correlated with STAI-A scores ($r_{33} = 0.651$; $p < 0.001$).

266 *Eye Movements and Emotional Arousal*

267 Analysis of the contrasts revealed an emotional arousal effect on the initial fixation (QC:
268 $F_{(1,31)} = 7.144$; $p = 0.012$ $\eta^2 = 0.187$), first fixation latency (QC: $F_{(1,31)} = 75.624$; $p < 0.001$; η^2
269 $= 0.709$), fixation duration (QC: $F_{(1,31)} = 107.966$; $p < 0.001$; $\eta^2 = 0.777$) and number of fixation
270 (QC: $F_{(1,31)} = 125,181$; $p < 0.001$; $\eta^2 = 0.802$; **Figure 1**). However, no differences were observed
271 between unpleasant and pleasant for these parameters (initial fixation: LC: $F_{(1,31)} = 2.827$; $p =$
272 0.103 $\eta^2 = 0.084$; first fixation latency : LC: $F_{(1,31)} = 0.040$; $p = 0.843$; $\eta^2 = 0.001$; fixation
273 duration : LC: $F_{(1,31)} = 0.92$; $p = 0.764$; $\eta^2 = 0.003$; number of fixation : LC: $F_{(1,31)} = 0.049$; p
274 $= 0.826$ $\eta^2 = 0.002$). In sum, eye movements were initially oriented and engaged by emotional
275 images.

276 **[Insert FIGURE 1 about here]**

277

278 *Psychometry, Eye Movements and Autonomic Activity*

279 Mean SCRs to pairs of images correlated with depression ($r_{32} = 0.475$; $p = 0.005$). Thus,
280 higher SCRs to images were associated with higher depression scores even when age or sex
281 were controlled (respectively $r_{30} = 0.476$; $p = 0.006$ and $r_{30} = 0.495$; $p = 0.004$). HF-HRV at
282 baseline correlated with the duration of fixation on pleasant images. Thus, higher HF-HRV at
283 baseline was associated with a longer duration of fixation on pleasant images during the task
284 ($r_{31} = 0.374$; $p = 0.035$). This association was still observed when age was controlled ($r_{29} =$
285 0.375 ; $p = 0.037$) and was still marginally significant when controlled for sex ($r_{29} = 0.320$; $p =$
286 0.079). During the task, a correlation was observed between ocular parameters and autonomic
287 reactivity: the difference of fixation latency between pleasant and unpleasant images (valence
288 effect) correlated with mean SCRs ($r_{30} = -0.381$; $p = 0.034$) even when age or sex were

289 controlled (respectively $r_{28} = -0.380$; $p = 0.038$ and $r_{28} = -0.438$; $p = 0.015$). No other
290 associations were found between ocular and autonomic variables ($r_s > 0.281$; $p_s > 0.120$) nor
291 between ocular variables and depression or anxiety ($r_s < 0.249$; $p_s > 0.170$).

292 *Depression, Eye Movements and Autonomic Reactivity*

293 As SCRs correlated with depression scores and with the valence effect on the fixation
294 latency, the stepwise linear regression model was performed by including depression (BDI
295 scores) and the latency of fixing pleasant and unpleasant images, the age of participants, and
296 their state and trait anxiety (STAI-A and STAI-B scores).

297 On the basis of the corrected Akaike information criterion (AICc), the selected model
298 for predicting SCRs was found to explain 21% of the variance in the integral of SCR ($F_{3,29} =$
299 3.60 , $p = 0.027$) and include the depression scores (BDI), the latency to fix pleasant images and
300 the trait-anxiety scores (STAI-B) as predictors. The measures found did not point to the
301 existence of significant collinearity between the predictors, minimal tolerance = 0.429 and
302 maximal variance inflation factor (VIF) = 2.33 (**Figure 2 A1**).

303 **[Insert FIGURE 2 about here]**

304 In the model, depression scores ($t = 2.22$, $p = 0.035$) and the latency to fix pleasant
305 images ($t = 2.33$, $p = 0.028$) significantly contributed to a better prediction of the SCRs while
306 the trait-anxiety scores ($t = -1.92$, $p = 0.066$) did not significantly contribute to the predictive
307 power of the model. Hence, greater SCRs were associated with higher depression, with a
308 coefficient of 1.30, and higher latency to fix pleasant images, with a coefficient of 0.05.
309 Interestingly, contrary to what has been observed for depression scores and the latency to fix
310 pleasant images, the coefficient describing the direction of the relation between STAI-B scores
311 and SCRs was negative.

312 In sum, the best model to predict SCRs integrate latency of fixation to pleasant images,
313 depression and anxious scores such higher depression level and lower orientation to pleasant
314 stimuli were expected to predict higher SCRs, after controlling for the other variables.

315 **Discussion**

316 The aim of this study was to investigate potential links between attentional bias and
317 autonomic reactivity to emotional information and the implication of depressive
318 symptomatology on these potential associations. Firstly, all recorded parameters of ocular

319 behaviour indicated a preferential orientation of attention to emotional images. Secondly,
320 higher orientation and maintenance of attention towards pleasant images were associated with
321 lower values of autonomic arousal during baseline (HRV) and during the task (SC). Thirdly,
322 the best model to predict SCRs of participants includes latency of fixation to pleasant images,
323 and scores of depression and anxiety.

324 The first result, showing a preferential orientation and maintenance of attention toward
325 emotional contents, reflected by the initial fixation and the shorter latency to fixate upon
326 emotional images, extends data from previous eye-tracking studies demonstrating that
327 emotional stimuli benefit from enhanced perceptual processing, with more fixations, especially
328 during the first saccades (Niu et al., 2012). In terms of unpleasant and pleasant value of images,
329 no attentional preference was observed for one over the other, suggesting that attentional bias
330 depends only on the arousal dimension of emotion.

331 Depressive symptomatology was not correlated with any ocular parameter which is
332 consistent with few studies that failed to report bias for emotion in people with depression or
333 dysphoria (Koster et al., 2006; Elgersma et al., 2018). Moreover, data from the literature report
334 an attentional bias in depression towards “mood-congruent” or “dysphoric” information, using
335 discrete emotional stimuli, and mainly for attention maintenance indicators (Armstrong &
336 Olatunji, 2012). The present study did not use mood-congruent stimuli but natural scene based
337 on dimensional theory of emotion, which could explain that such correlation was not observed.
338 Besides, in the present study, the images’ selection was carried out in order to ensure
339 homogenised arousal differences between the two images constituting the pairs. Thereby,
340 attention may have been captured by the emotional image regardless of symptomatology for all
341 participants.

342 The second result supports specific links between attentional bias to pleasant
343 information and the expression of autonomic arousal both at baseline and during the task.
344 During the baseline, greater HF-HRV was associated with longer fixation on pleasant images.
345 Hence, higher parasympathetic influence, and thus increased HF-HRV, appears linked to
346 maintenance of attention toward pleasant information. The polyvagal theory (Porges, 2007)
347 proposes that baseline cardiac measures of parasympathetic activity can index the capacity to
348 adapt to the environment. More precisely, parasympathetic HRV activity at rest and reactivity
349 are associated with adaptive expression of emotion and self-regulatory skills. Therefore, our
350 observed association between baseline autonomic activity and preferential attention to pleasant
351 information reveals a positive impact of a more parasympathetic psychophysiological state on

352 an upcoming emotional task in the domain of emotional regulation (Beauchaine, 2001).
353 Individuals with higher parasympathetic activation at baseline may be better able to employ the
354 best strategies to respond to stressful emotional challenges by focusing on pleasant information.
355 The present results also reinforce the neurovisceral integration model (Thayer and Lane, 2000),
356 which postulates that cardiac activity, through HRV, is informative about the integrity of brain
357 networks supporting interaction between emotion and cognition. However, this association
358 became marginally significant when sex is controlled. Indeed, sex differences on HRV have
359 been reported with higher HRV in women characterised by a relative dominance of vagal
360 activity (Koenig and Thayer, 2016). Due to the sample size, it seems difficult to conclude on
361 sex differences for HRV and it is therefore advisable to remain cautious about this result.
362 Additional data on the association between attentional and autonomic measurement in relation
363 to sex are necessary and may point out different associations for these parameters for men and
364 women.

365 During the task, a valence effect on the fixation latency was associated with autonomic
366 reactivity. Individuals who fixated upon pleasant stimuli more quickly showed lower SC to the
367 pairs of images whereas the reverse was observed for fixation on unpleasant stimuli. This
368 positivity bias, described in the attentional literature (Troller-Renfree et al., 2017) bears witness
369 to a regulatory interaction between the capture of information and autonomic adaptation.

370 The third result showed that the best model to predict SCRs integrate latency of fixation
371 to pleasant information with depression and trait-anxiety scores. At psychometric level, higher
372 depression predicted greater SCRs in response to pair of images while trait anxiety did not
373 significantly contribute to the prediction of SCRs. At attentional level, measured by images'
374 fixation latency, a lower attentional orientation towards the pleasant images was associated with
375 greater SCRs. This association between pleasant orientation and autonomic reactivity is
376 particularly interesting since depressed individuals appear to lack positive attentional bias
377 (Duque & Vazquez, 2015) and are characterised by autonomic dysfunctions sometimes reported
378 as increased autonomic activity (Branković, 2008; Wenzler et al., 2017). Consequently,
379 attempts to reinforce such bias could help to attenuate autonomic activation and potentially
380 serve as a protective homeostatic adaptation or a coping strategy. In the same vein, similar
381 autonomic hyporeactivity to emotional challenges has already been reported, and interpreted as
382 the expression of a coping strategy engaged to improve performance of a behavioural task
383 (Naveteur et al., 2005). In this context, an intervention to attenuate autonomic reactivity could
384 increase capacity to orient attention towards pleasant information which may be beneficial

385 especially for depressed individuals. Therefore, these results suggest that the pleasantness bias
386 could constitute a cognitive marker of behavioural and autonomic adaptations to emotion.

387 Finally, this study has several methodological strengths. First, we carefully considered
388 influences of physical saliency of images on visual search and attention (Lucas & Vuilleumier,
389 2008) and gender differences in emotional assessment and reactivity (Bradley et al., 2001).
390 Thus, we carried out a rigorous selection of stimuli for each type of pair of images (see
391 **Appendix 1; Table S1**). Second, this study was enriched by taking into account both facets of
392 the autonomic nervous system, sympathetic and parasympathetic, which potentially have
393 distinct contributions to attentional and emotional processes. Third, the integration of
394 behavioural and autonomic parameters, encompassing their reciprocal influences, allowed us
395 to clarify the relationship between attentional bias and autonomic reactivity and the relation
396 with depressive symptomatology. The study also had some limitations, notably the sex-ratio of
397 participants. Indeed, even if images selection was homogenised between women and men, sex
398 of participants seems to influence some of the association observed (e.g. HRV) and the sample
399 size for men do not allow to examine potential sex differences properly on these associations.
400 Therefore, additional researches are needed to determine potential implication of this variable
401 on interaction between attention and autonomic expression. Moreover, the choice of a non-
402 clinical population constrains the scope of our results to moderate levels of depression. Indeed,
403 participants are not clinically depressed in our sample. Nonetheless, even when considering
404 lower depression levels, prominent effects were observed. Moreover, findings remain relevant
405 since attentional bias is considered to be implicated in the development of clinical depression
406 (Gotlib and Joorman, 2010).

407 In conclusion, our characterisation of the association between attentional processes and
408 specific patterns of autonomic reactivity extends a growing literature, and points in the direction
409 of reciprocal influences of both systems that can lead to the personalisation of clinical
410 remediation and rehabilitation procedures, including attentional training and/or biofeedback
411 therapies. Furthermore, the data obtained in this work argue in favour of evidence-based
412 interventions using attentional training towards pleasant information. Consequently,
413 considering the lack of orientation to pleasant information and autonomic dysfunction in
414 depression, two strategies can emerge from these results. On the one hand, in depressed
415 individuals who lack strong attentional bias toward pleasantness, attentional training towards
416 emotionally positive information may be beneficial in reducing autonomic hyperarousal and
417 reactivity to emotional information. On the other hand, in depressed individuals who show
418 autonomic hyperarousal, biofeedback procedures based on HRV may be therapeutically

419 beneficial, in part by fostering enhanced attentional bias toward pleasant information. Finally,
420 our research supports an approach integrating both cognition and physiology to better
421 understand their interdependence in healthy and pathological expressions of emotion.

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427 **Disclosure statement**

428 No potential conflicts of interest were reported by the author(s).

429

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437

438

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547

548 *Table and Figures*

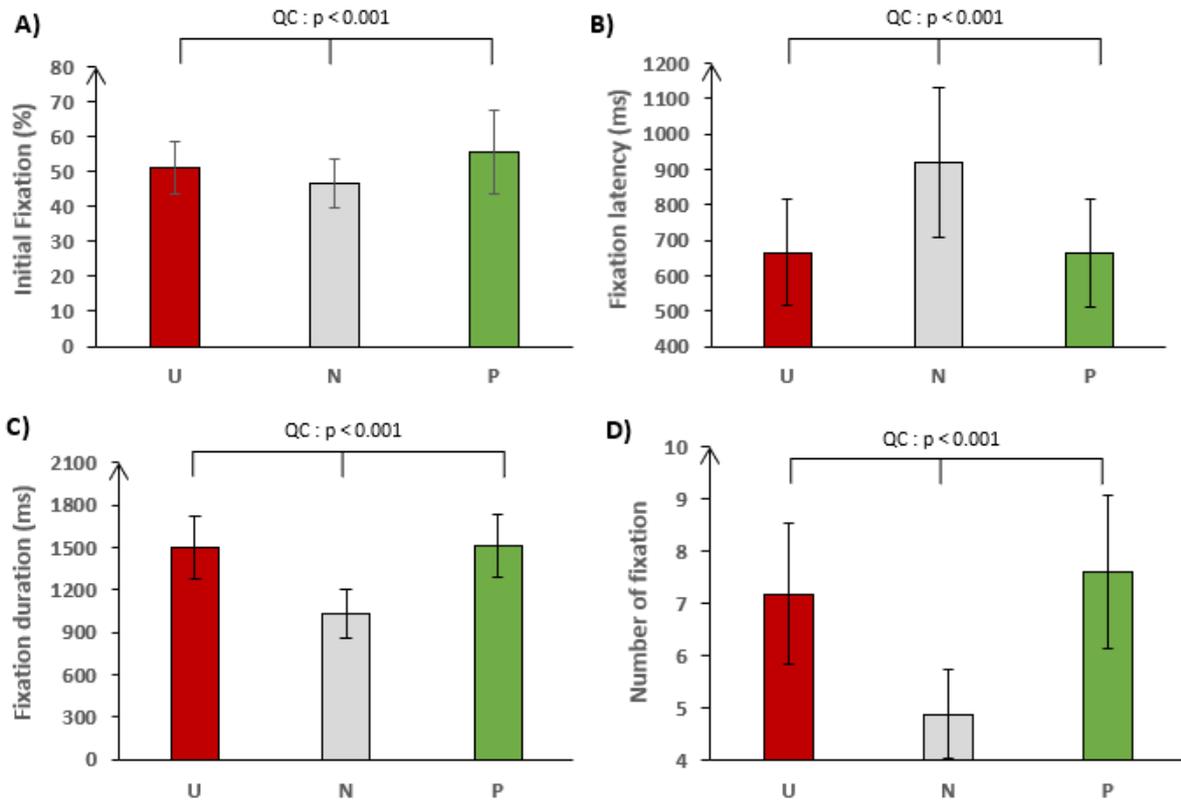
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Sample (N = 32)			
	Mean	SD	(Min – Max)
Age	21	2	(18 – 24)
STAI-A	30.4	9.7	(20 – 58)
STAI-B	47.1	12.8	(25 – 71)
BDI-II	13.3	10.4	(1 – 41)

550

Table 1. Demographic and psychometric characteristics of participants.

551



552 **Figure 1. Initial fixation and fixation latency (A-B) and total fixation duration and number of fixations (C-D) to image**
 553 **emotion in |UN| and |PN| pairs. U: Unpleasant; N: Neutral; P: Pleasant; QC: Quadratic contrast.**

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A1)

Predictors	Slope	β	t	Sig.	VIF
STAI-B	-0.842	-0.484	-1.922	0.066	2.329
BDI	1.302	0.559	2.220	0.035	2.332
Latency to fix pleasant	0.050	0.384	2.325	0.028	1.003

One participant was excluded (N = 30) due to a Cook's distance value greater than 0.2.

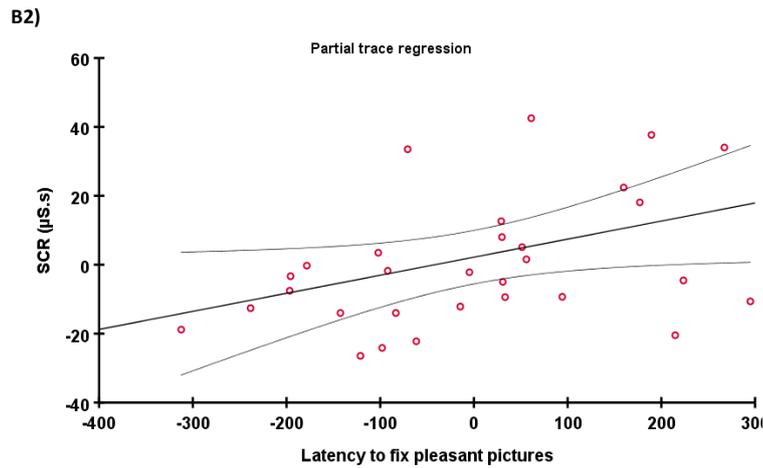
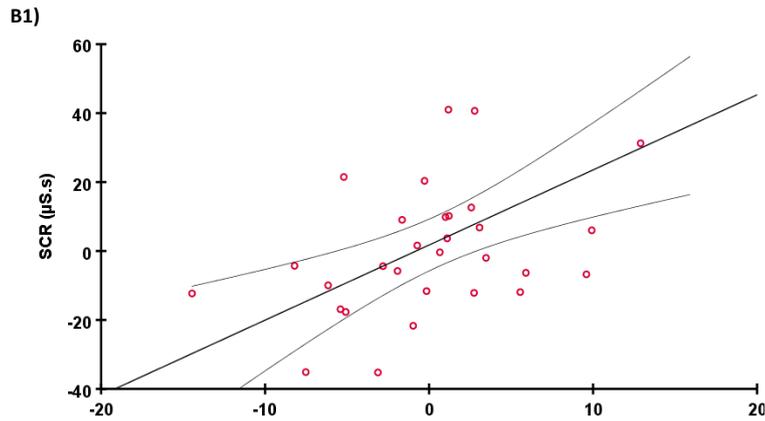
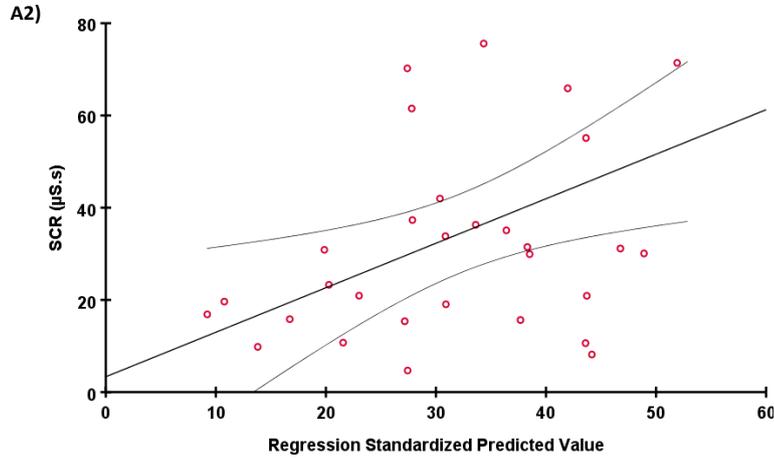


Figure 2. A. Multiple linear regression model to predict SCRs. VIF: maximal variance inflation factor, index allowing to verify the premise of multicollinearity (A1) and representation of the model (A2) B. Partial trace regression with intervals of confidence for BDI scores (B1) and for latency of fixation to pleasant images (B2).

	Women				Men				W/M
	U-N	N-N	P-N	p	U-N	N-N	P-N	p	p
Valence	2,563 (0,829)	0,548 (0,407)	2,473 (0,668)	> 0,001	2,652 (0,621)	0,401 (0,241)	2,281 (0,663)	> 0,001	0.502
Activation	2,746 (0,949)	0,501 (0,344)	2,805 (0,984)	> 0,001	2,485 (0,937)	0,547 (0,349)	2,678 (1,066)	> 0,001	0.502
Luminance	42,973 (37,520)	37,069 (25,382)	41,300 (34,078)	0,871	41,292 (24,261)	41,985 (30,566)	45,121 (27,293)	0,916	0.704
Contrast	19,411 (13,826)	21,620 (12,766)	18,570 (12,383)	0,792	15,798 (11,064)	17,726 (9,295)	16,286 (14,325)	0,890	0.200
Luminance (R)	42,846 (35,427)	36,542 (22,893)	46,769 (35,522)	0,659	45,321 (35,155)	45,965 (29,572)	48,051 (32,176)	0,969	0.504
Contrast (R)	19,717 (13,838)	22,692 (15,125)	18,869 (12,797)	0,720	20,565 (14,880)	16,888 (10,719)	17,884 (11,968)	0,698	0.468
Luminance (G)	41,892 (38,487)	39,115 (32,486)	43,611 (34,817)	0,936	44,000 (26,756)	44,386 (31,426)	47,708 (31,503)	0,929	0.569
Contrast (G)	18,969 (14,722)	21,646 (15,968)	19,000 (12,785)	0,837	16,549 (13,788)	16,536 (12,298)	16,997 (14,822)	0,994	0.273
Luminance (B)	54,553 (41,430)	44,421 (30,608)	53,355 (41,504)	0,716	47,938 (18,047)	52,475 (37,773)	48,761 (28,520)	0,897	0.880
Contrast (B)	23,999 (14,607)	27,288 (17,579)	23,142 (18,017)	0,763	17,734 (14,854)	21,057 (17,558)	26,196 (21,305)	0,419	0.380
Low frequencies (Grey)	6,775 (6,253)	9,781 (11,364)	6,164 (3,779)	0,381	6,148 (9,917)	8,0253 (7,804)	6,3499 (3,820)	0,747	0.643
High frequencies (Grey)	1,152 (1,387)	1,479 (2,568)	0,925 (0,812)	0,669	1,380 (2,560)	1,479 (1,762)	0,975 (0,804)	0,719	0.801
Low frequencies (R)	6,149 (4,876)	8,315 (9,291)	6,220 (3,798)	0,562	7,133 (8,703)	5,921 (6,927)	4,930 (3,348)	0,651	0.504
High frequencies (R)	0,999 (0,997)	1,698 (3,140)	0,9172 (0,764)	0,468	1,363 (2,586)	1,705 (2,357)	0,944 (0,727)	0,583	0.748
Low frequencies (G)	6,020 (5,721)	9,132 (11,022)	5,576 (3,305)	0,345	5,193 (8,357)	7,280 (8,227)	5,560 (3,812)	0,678	0.546
High frequencies (G)	1,048 (1,133)	1,583 (2,716)	0,929 (0,756)	0,537	1,319 (2,591)	1,579 (1,767)	0,861 (0,751)	0,548	0.858
Low frequencies (B)	7,178 (5,619)	10,506 (14,983)	4,958 (4,328)	0,267	6,911 (10,878)	7,728 (10,712)	6,085 (5,361)	0,884	0.741
High frequencies (B)	1,110 (1,309)	1,286 (1,790)	0,949 (0,935)	0,792	1,053 (1,653)	1,479 (1,523)	0,994 (1,037)	0,582	0.834

569

570

Table S1. Physical properties from the pairs of images selected. Mean value and standard deviation of

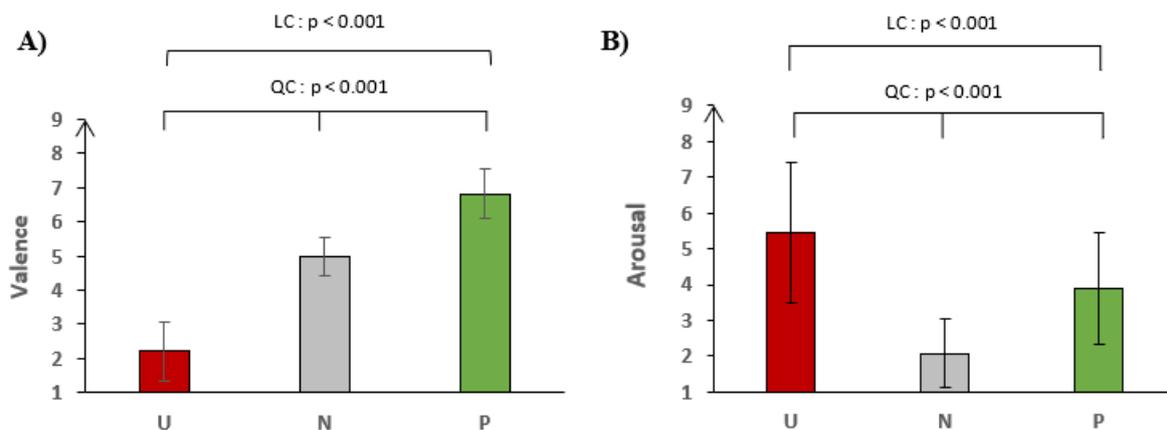
571 differences between the two images composing each pair concerning valence, activation and physical properties for women

572 and men and for unpleasant-neutral (U-N), neutral-neutral (N-N) and pleasant-neutral (P-N) conditions. R = red, B = blue, G

573 = green, p = p value of multivariate analyses for each sex, W/M = comparisons between women and men.

574 *Appendix 2: Subjective assessment of images*

575 As expected, the valence assessment by the participants differed according to the
576 emotional category ($F_{1,41,46.67} = 322.085$; $p < 0.01$; $\eta^2 = 0.907$; $U = 2.21$, $N = 4.98$, $P = 6.82$).
577 Thus, participants rated unpleasant images with a lower valence than pleasant ones (LC: $F_{1,33} =$
578 387.70 ; $p < 0.001$; $\eta^2 = 0.922$) but the valence gap with neutral images was more important for
579 unpleasant images (QC: $F_{1,33} = 24.113$; $p < 0.001$; $\eta^2 = 0.422$; **Figure S1.A**). The arousal
580 assessment by the participants also differed according to the emotional category ($F_{1,67,55.34} =$
581 109.110 ; $p < 0.001$; $\eta^2 = 0.768$; $U = 5.45$, $N = 2.07$, $P = 3.89$). Participants rated emotional
582 images with a greater arousal than neutral ones (QC: $F_{1,33} = 217.006$; $p < 0.001$; $\eta^2 = 0.868$) but
583 they evaluated unpleasant images as more arousing than pleasant ones (LC: $F_{1,33} = 38.370$; p
584 < 0.001 ; $\eta^2 = 0.868$ **Figure S1.B**).



585 **Figure S1. Subjective assessment of valence (A) and arousal (B).** U: Unpleasant; N: Neutral; P: Pleasant; LC: Linear
586 contrast; QC: Quadratic contrast.