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Attention Orientation to Pleasantness and Depressive Symptomatology Predict Autonomic Reactivity

Stéphane Ranfaing[a]*, Lucas De Zorzi[a]*, Jacques Honoré[a], Hugo Critchley[b,c] and Henrique Sequeira[a,§]

[a] *Univ. Lille, CNRS, UMR 9193 - SCALab - Sciences Cognitives et Sciences Affectives, F-59000 Lille, France*

[b] Clinical Imaging Sciences Centre, Brighton and Sussex Medical School, University of Sussex, United Kingdom

[c] Sackler Centre for Consciousness Science, University of Sussex, United Kingdom; Psychiatry, Brighton and Sussex Medical School, Brighton, United Kingdom.

*These authors contributed equally to this work.

[§] Correspondence to: Henrique.Sequeira@univ-lille.fr

Abstract

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

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

Introduction

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

The dot probe task is one established approach for measuring the time course of attentional processes in depression (MacLeod et al., 1986). Here, the participant views a pair of stimuli, usually one emotional and one neutral image, which are immediately followed by a stimulus ('probe'), which appears at the location of one of two images. The participant is instructed to make a reaction time response to the probe. Emotional attentional bias to it expresses faster responses on trials when the probe is presented in the location of the emotional compared to the neutral image. This task and variations of it has become a gold standard for investigating attentional bias and its time course. However, the use of reaction times does not allow direct measurement of the attention span and has recently been criticised regarding its psychometric properties (Chapman et al., 2019). As an alternative, measures of eye movements can provide a more direct index of attentional deployment. In depressed individuals, they showed an increased attention to negative stimuli and decreased attention to positive stimulation when compared to nondepressed individuals (Armstrong & Olatunji, 2012). Eye movements can reflect both orienting (e.g. initial orientation and latency to first fixation) and maintenance (e.g. number of fixations, or total duration of fixation; Duque & Vazquez, 2015) components of attention, as well as attentional reorientation to stimuli. Indeed, unlike reaction times, eye movements allow the continuous measurement of attentional processes and can thus better characterise attention biases to emotional stimuli. A few studies in the literature have investigated the psychometric properties of eye movement indices and most of them used different stimuli, paradigm or sample characteristics (Waechter et al., 2014; Lazarov et al., 2016, Skinner et al., 2018, Sears et al., 2019). Although there are still mixed results for the early attention cues (Skinner et al., 2018), the results for indices of maintenance of attention such as total fixation time and number of fixations appear encouraging concerning psychometrics properties (Sears et al., 2019). Consequently, some authors suggest that eye-tracking measures of attentional bias may have better overall psychometric properties as compared than traditional RT measures of attentional bias for children and adults (Chong & Meyer, 2020).

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

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

Method

Participants

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

[Insert Table 1 about here]

Stimuli and Apparatus

The stimuli used were pairs of images of emotional or neutral scenes selected from the International Affective Pictures System (IAPS; Lang, Bradley, & Cuthbert, 2008), which provides standardised *a priori* values for each image on valence and arousal dimensions. One value is provided for men, and another for women. Given the recognised differences in gender-based emotional assessments (Bradley, Codispoti, Cuthbert, & Lang, 2001), we performed two image selections adapted to each gender, but resulting in equivalent valence and arousal values. Ninety-six images were selected and used to build three kinds of pairs: 16 unpleasant-neutral pairs (|UN|), 16 pleasant-neutral pairs (|PN|) and 16 neutral-neutral pairs (|NN|). In order to control the salience of the two images that made up each pair, the difference of valence and arousal between the two images constituting each pair were calculated. These within-pairs differences significantly differed between the three kinds of pairs on their *a prioi* valence values (*women*: | U - N | = 2.56, | P - N | = 2.47, | N - N | = 0.54, $F_{1,15} = 290.196$; $p < 0.001$; *men*: | U - N | = 2.65, | P - N | = 2.28, | N - N | = 0.40, $F_{1,15} = 640.406$; $p < 0.001$), and on their arousal *a prioi* values (*women* : | U - N | = 2.74, | P - N | = 2.80, | N - N | = 0.50, $F_{1,15} = 263.916$; $p < 0.001$; and *men:* | U - N | = 2.48, | P - N | = 2.67, | N - N | = 0.54, $F_{1,15} = 232.177$; $p < 0.001$) with higher within-pairs difference for |UN| and |PN| pairs than |NN| ones, but there were no differences between |UN| and |PN| pairs. For each pair of images, no within-pairs differences of valence or arousal was observed between the selections for men and women (all Fs < 0.275 and ps > 0.609). For each image, the angular size (12°x8°), the energy across spatial frequencies (Delplanque, N'diaye, Scherer, & Grandjean, 2007) and the main physical properties were extracted (*ImageJ v1.50 software*), including the luminance and contrasts for the greyscale version and the RGB (red, green and blue) layers. No significant differences were observed between the three sets of images for both genders (all ps > .20). Thus, the image pairs differed only in terms of their emotional dimensions (see table in **Appendix Table S1**).

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

Recordings

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

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

Procedure

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

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

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

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

Data and Statistical Analyses

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

Eye Movements

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

Conductance and Cardiac Activities

SC and ECG variations initially sampled at 200 Hz, were down-sampled at 10 Hz using *LabChart7*. For the SC variations to the presentation of pairs of images, phasic waveforms were derived from the tonic signals with an offline 0.05 Hz high-pass filter using *AcqKnowledge 4.1* software. SCRs were analysed by computing the integrals of SC amplitude variations over time for each condition and participant. One participant with no SCR was excluded from the analysis. For the ECG, the instantaneous heart rate in beats per minute (BPM) was calculated from the R wave intervals and smoothed using the triangular Bartlett window with a 1 s width using *LabChart7*. SC variations in response to stimulation were obtained by subtracting the average over a 3 s pre-stimulus period from the 10 s post-stimulus period data. For each condition and participant, after the baseline correction (-3 to 0 s), we averaged the epochs (-3 to 10 s), time-locked to the stimulus onset. Finally, we analysed the heart rate variability (HRV) during the 2 minutes of baseline and recovery periods. HRV quantification was computed with an in-house customised program *MATLAB* program referring to HRV guidelines (Berntson et al., 1997). The R-R intervals were detrended with a smoothness-prior method in order to remove the slow (< 0.04 Hz) non-stationary trends from the HRV signal. For the frequency domain method, a power spectrum density analysis was performed for the RR interval series using fast Fourier transform method with the low frequency (LF) band set at 0.04-0.15 Hz and a high frequency (HF) band set at 0.15-0.4 Hz. The LF/HF ratio was also computed. For the time domain method, we computed the mean heart rate (HR), the standard deviation of HR (namely the variability of the HR) as well as the root mean square of successive RR intervals differences (RMSSD).

Statistical Analyses

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

The analysis of the factors associated with the autonomic variables was performed by calculating the Pearson correlation coefficient given linear relationships were expected between variables and after inspection of scatterplots. Partial correlations were then assessed controlling for age and gender. The search for predictors of autonomic variables was performed with stepwise linear regression analyses. The multivariate model includes variables for which associations were observed between ocular and autonomic parameters. Thus, the model was constructed by including variables associated with SCRs, but also including covariates such as the age of participants, and their state and trait anxiety (STAI-A and STAI-B scores), regardless of their degree of significance in the univariate analyses. The model selection was based on considerations of the corrected Akaike information criterion (AICc). The validity of the multivariate model was established by a study of the residuals.

Results

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

Eye Movements and Emotional Arousal

Analysis of the contrasts revealed an emotional arousal effect on the initial fixation (QC: $F_{(1.31)}$ = 7.144; p = 0.012 η^2 = 0.187), first fixation latency (QC: $F_{(1.31)}$ = 75.624; $p < 0.001$; η^2 = 0.709), fixation duration (QC: $F_{(1.31)}$ = 107.966; p <0.001; η^2 = 0.777) and number of fixation (QC: $F_{(1.31)}$ = 125,181; p <0.001 ; η^2 = 0.802; **Figure 1**). However, no differences were observed between unpleasant and pleasant for these parameters (initial fixation: LC: $F_{(1.31)}$ = 2.827; p = 0.103 η^2 = 0.084; first fixation latency : LC: $F_{(1.31)}$ = 0.040; p = 0.843; η^2 = 0.001; fixation duration : LC: $F_{(1.31)}$ = 0.92; p = 0.764; η^2 = 0.003 ; number of fixation : LC: $F_{(1.31)}$ = 0.049; p = 0.826 η^2 = 0.002). In sum, eye movements were initially oriented and engaged by emotional images.

[Insert FIGURE 1 about here]

Psychometry, Eye Movements and Autonomic Activity

Mean SCRs to pairs of images correlated with depression (r_{32} = 0.475; p = 0.005). Thus, higher SCRs to images were associated with higher depression scores even when age or sex were controlled (respectively r_{30} = 0.476; p = 0.006 and r_{30} = 0.495; p = 0.004). HF-HRV at baseline correlated with the duration of fixation on pleasant images. Thus, higher HF-HRV at baseline was associated with a longer duration of fixation on pleasant images during the task (r_{31} = 0.374; p = 0.035). This association was still observed when age was controlled (r_{29} = 0.375; p = 0.037) and was still marginally significant when controlled for sex (r_{29} = 0.320; p = 0.079). During the task, a correlation was observed between ocular parameters and autonomic reactivity: the difference of fixation latency between pleasant and unpleasant images (valence effect) correlated with mean SCRs (r_{30} = -0.381; p = 0.034) even when age or sex were controlled (respectively $r_{28} = -0.380$; $p = 0.038$ and $r_{28} = -0.438$; $p = 0.015$). No other associations were found between ocular and autonomic variables ($rs > 0.281$; $ps > 0.120$) nor between ocular variables and depression or anxiety ($rs < 0.249$; $ps > 0.170$).

Depression, Eye Movements and Autonomic Reactivity

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

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

[Insert FIGURE 2 about here]

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

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

Discussion

The aim of this study was to investigate potential links between attentional bias and autonomic reactivity to emotional information and the implication of depressive symptomatology on these potential associations. Firstly, all recorded parameters of ocular behaviour indicated a preferential orientation of attention to emotional images. Secondly, higher orientation and maintenance of attention towards pleasant images were associated with lower values of autonomic arousal during baseline (HRV) and during the task (SC). Thirdly, the best model to predict SCRs of participants includes latency of fixation to pleasant images, and scores of depression and anxiety.

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

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

The second result supports specific links between attentional bias to pleasant information and the expression of autonomic arousal both at baseline and during the task. During the baseline, greater HF-HRV was associated with longer fixation on pleasant images. Hence, higher parasympathetic influence, and thus increased HF-HRV, appears linked to maintenance of attention toward pleasant information. The polyvagal theory (Porges, 2007) proposes that baseline cardiac measures of parasympathetic activity can index the capacity to adapt to the environment. More precisely, parasympathetic HRV activity at rest and reactivity are associated with adaptive expression of emotion and self-regulatory skills. Therefore, our observed association between baseline autonomic activity and preferential attention to pleasant information reveals a positive impact of a more parasympathetic psychophysiological state on an upcoming emotional task in the domain of emotional regulation (Beauchaine, 2001). Individuals with higher parasympathetic activation at baseline may be better able to employ the best strategies to respond to stressful emotional challenges by focusing on pleasant information. The present results also reinforce the neurovisceral integration model (Thayer and Lane, 2000), which postulates that cardiac activity, through HRV, is informative about the integrity of brain networks supporting interaction between emotion and cognition. However, this association became marginally significant when sex is controlled. Indeed, sex differences on HRV have been reported with higher HRV in women characterised by a relative dominance of vagal activity (Koenig and Thayer, 2016). Due to the sample size, it seems difficult to conclude on sex differences for HRV and it is therefore advisable to remain cautious about this result. Additional data on the association between attentional and autonomic measurement in relation to sex are necessary and may point out different associations for these parameters for men and women.

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

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

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

In conclusion, our characterisation of the association between attentional processes and specific patterns of autonomic reactivity extends a growing literature, and points in the direction of reciprocal influences of both systems that can lead to the personalisation of clinical remediation and rehabilitation procedures, including attentional training and/or biofeedback therapies. Furthermore, the data obtained in this work argue in favour of evidence-based interventions using attentional training towards pleasant information. Consequently, considering the lack of orientation to pleasant information and autonomic dysfunction in depression, two strategies can emerge from these results. On the one hand, in depressed individuals who lack strong attentional bias toward pleasantness, attentional training towards emotionally positive information may be beneficial in reducing autonomic hyperarousal and reactivity to emotional information. On the other hand, in depressed individuals who show autonomic hyperarousal, biofeedback procedures based on HRV may be therapeutically beneficial, in part by fostering enhanced attentional bias toward pleasant information. Finally, our research supports an approach integrating both cognition and physiology to better understand their interdependence in healthy and pathological expressions of emotion.

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Table and Figures

	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)

Table 1. Demographic and psychometric characteristics of participants.

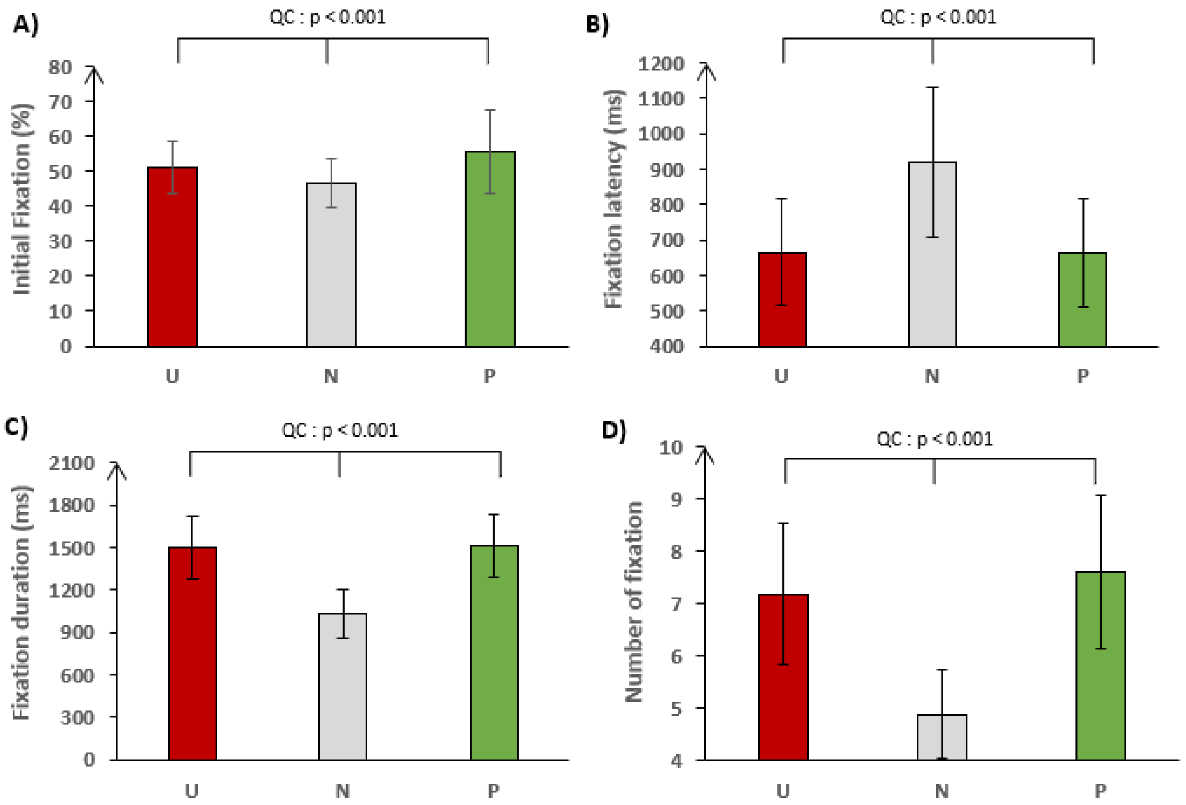

Figure 1. Initial fixation and fixation latency (A-B) and total fixation duration and number of fixations (C-D) to image emotion in |UN| and |PN| pairs. U: Unpleasant; N: Neutral; P: Pleasant; QC: Quadratic contrast.

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.

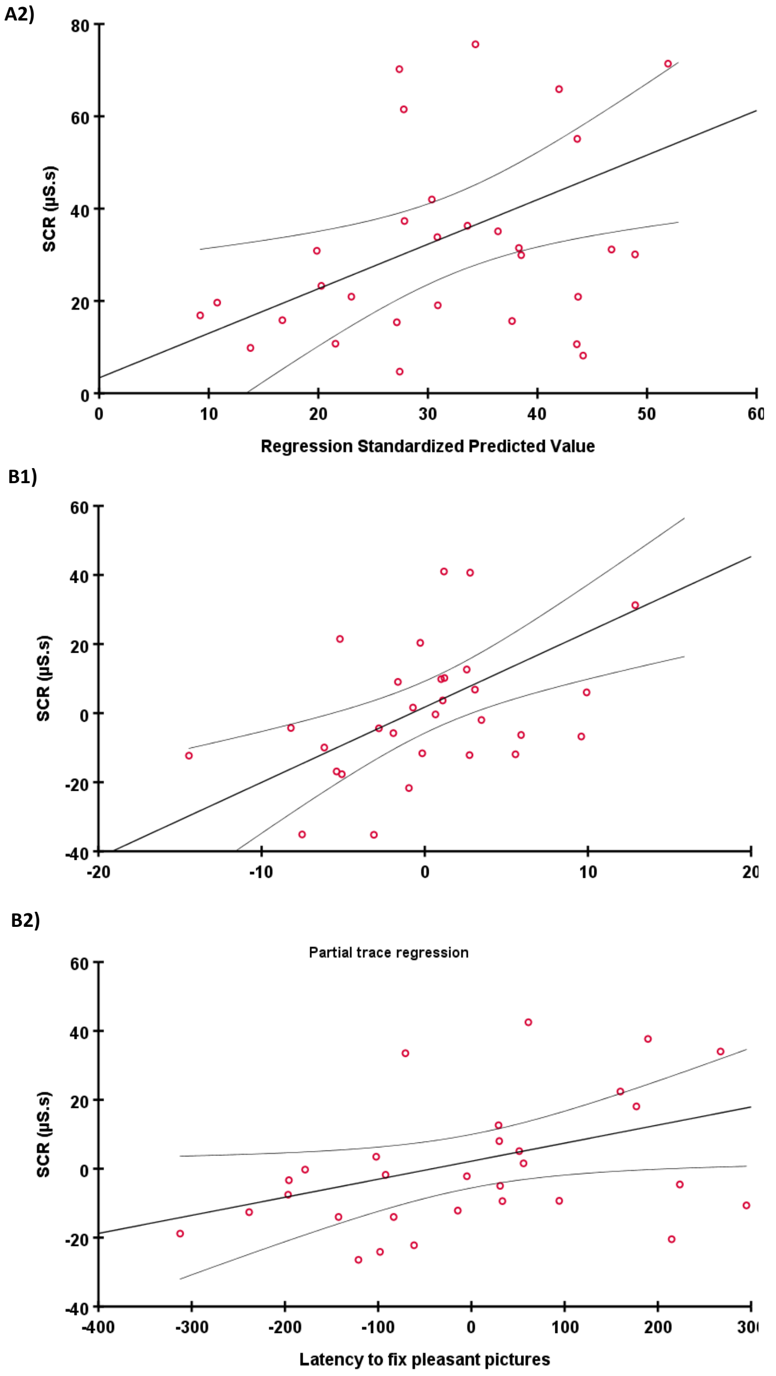

Figure 2. A. Multiple linear regression model to predict SCRs. VIF: maximal variance inflation factor, index allowing to verify the premise of multicollinearity (A1) and representation of the model (A2) B. Partial trace regression with intervals of confidence for BDI scores (B1) and for latency of fixation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

Appendices

Appendix 1: Images selection

	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

Table S1. Physical properties from the pairs of images selected. Mean value and standard deviation of differences between the two images composing each pair concerning valence, activation and physical properties for women and men and for unpleasant-neutral (U-N), neutral-neutral (N-N) and pleasant-neutral (P-N) conditions. R = red, B = blue, G = green, p = p value of multivariate analyses for each sex, W/M = comparisons between women and men.

Appendix 2: Subjective assessment of images

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

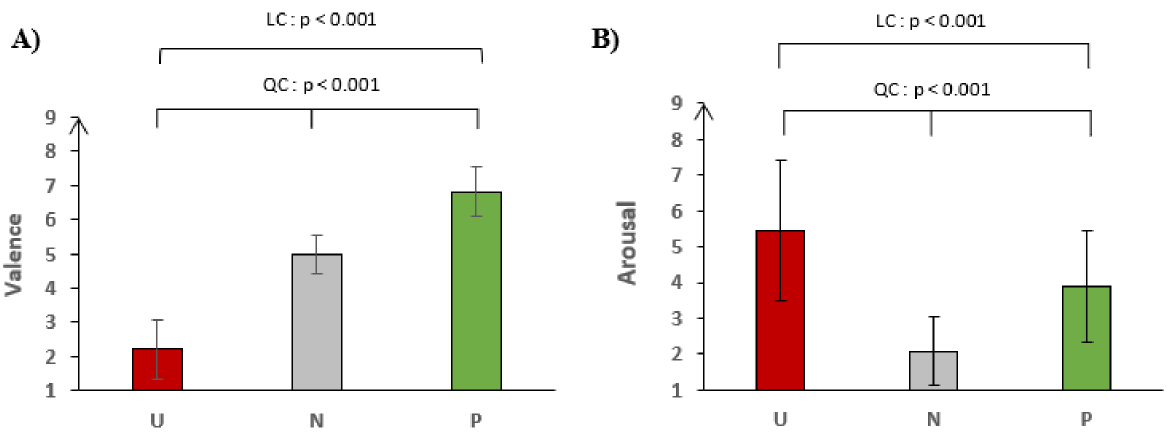

Figure S1. Subjective assessment of valence (A) and arousal (B). U: Unpleasant; N: Neutral; P: Pleasant; LC: Linear contrast; QC: Quadratic contrast.