 DOI: 10.1111/sjop.12735

Clinical Psychology and Mental Disorder

Attentional bias towards interpersonal aggression in depression – an eye movement study

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Rantanen, M., Hautala, J., Loberg, O., Nuorva, J., Hietanen, J. K., Nummenmaa, L. & Astikainen, P. (2021). Attentional bias towards interpersonal aggression in depression – an eye movement study. *Scandinavian Journal of Psychology*.

Depressed individuals exhibit an attentional bias towards mood-congruent stimuli, yet evidence for biased processing of threat-related information in human interaction remains scarce. Here, we tested whether an attentional bias towards interpersonally aggressive pictures over interpersonally neutral pictures could be observed to a greater extent in depressed participants than in control participants. Eye movements were recorded while the participants freely viewed visually matched interpersonally aggressive and neutral pictures, which were presented in pairs. Across the groups, participants spent more time looking at neutral pictures than at aggressive pictures, probably reflecting avoidance behavior. When the participants could anticipate the stimulus valence, depressed participants – but not controls – showed an early attentional bias towards interpersonally aggressive pictures, as indexed by their longer first fixation durations on aggressive pictures than on neutral pictures. Our results thus preliminarily suggest both an early attentional bias towards interpersonal aggression, which is present, in depressed participants, also when aggression contents are anticipated, and a later attentional avoidance of aggression. The early depression-related bias in information processing may have maladaptive effects on the way depressed individuals perceive and function in social interaction and can, therefore, maintain depressed mood.

Key words: Avoidance behavior, cognitive hypersensitivity, eye tracking, social risk hypothesis, unipolar depression.

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INTRODUCTION

Cognitive models of depression emphasise the role of negative information processing bias in the development and maintenance of depression (Beck, 1987; Teasdale, 1988). According to this view, depressive symptoms are maintained through attention and memory functions biased towards negative information. Empirical studies using manual reaction time paradigms, often based on the dot-probe task and the emotional Stroop task (for meta-analyses, see: Epp, Dobson, Dozois & Frewen, 2012; Peckham, McHugh & Otto, 2010) have, indeed, shown depression-related attentional bias especially towards sad faces (e.g., Gotlib, Kasch Traill Joormann, Arnow & Johnson, 2004; Gotlib, Krasnoperova, Yue & Joormann, 2004; Joormann & Gotlib, 2007).

Recently, the eye tracking method has begun to accompany the reaction time paradigm in measuring attentional biases (for a meta-analysis, see Armstrong & Olatunji, 2012). With its continuous measurement of the spatial and temporal parameters of visual attention, eye tracking permits a detailed investigation of different stages of attentional biases, including the facilitated orienting of attention, attentional avoidance, increased maintenance and difficulty in attentional disengagement. Eye tracking studies comparing dysphoric (elevated amount of depressive symptoms) or clinically depressed participants with healthy controls have shown that depressiveness increases the maintenance of gaze on dysphoric stimuli (Caseras, Garner, Bradley & Mogg, 2007; Duque & Vazquez, 2015; Eizenman, Yu, Grupp *et al*., 2003; Kellough, Beevers, Ellis & Wells, 2008; Leyman *et al*., 2011).

A depression-related attentional bias towards threat, in contrast, has not been a common finding in either reaction time or eye tracking studies (for meta-analyses, see Armstrong & Olatunji, 2012; Peckham *et al*., 2010). Most threat-related eye tracking studies have failed to find biases in either the orientation or the maintenance of gaze towards threatening information in depression. Stimulus materials used in these studies have comprised angry faces (Leyman, De Raedt, Vaeyens & Philippaerts, 2011; Mogg, Millar & Bradley, 2000), threatening words (Ellis, Beever & Wells, 2011) and a heterogeneous group of emotional pictures with threat content (e.g., a side view of a hand holding a gun or a person walking along a cliff, Eizenman *et al*., 2003; Kellough *et al*., 2008; Sears, Newman, Ference & Thomas, 2010; Sears, Thomas, LeHuquet & Johnson 2011).

In their meta-analysis of biased attention to negative information in depression, Peckham *et al*., (2010) did not find evidence for attentional biases to stimuli implying physical threat (e.g., words like “death” or “illness”), but they did find a trend towards an attentional bias for stimuli expressing social threat, such as pictures of angry faces (e.g., Leyman *et al*., 2007) or words like “stupid” or “pathetic” (e.g., Mathews, Ridgeway & Williamson, 1996). Indeed, evolutionary systems theories of depression suggest that depressed

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individuals have increased cognitive sensitivity to interpersonal threat (Badcock, Davey, Whittle, Allen & Friston, 2017). According to the social risk hypothesis, depressed mood evolves to temporarily minimise the risk of social exclusion by adopting hypersensitivity for cues of social risk and changing aspects of social behavior to avoid uncertain outcomes (e.g., conflict or competition) (Allen & Badcock, 2003). When these adaptive changes fail to alleviate social stress, the heightened and prolonged arousal of continuous ineffectual efforts can lead to dysfunctional forms of depression (Badcock *et al*., 2017). Surprisingly, however, stimulus materials comprising pictures of interpersonal conflicts have not been consistently used in previous eye tracking studies to investigate attentional biases in depression.

We aimed to find evidence on attentional bias towards interpersonal aggression by investigating the gaze behavior of depressed and non-depressed participants. Aggressive interpersonal behavior can be considered as an extreme form of social dysfunction. Here, pictures depicting two persons in aggressive and neutral interaction were presented in pairs, and the participants were instructed to freely view them. We investigated both early (probability of first looking at the aggressive picture and first fixation duration) and later foveal processing of threat by applying several different variables. If a negative bias to dysphoric stimuli (e.g., Beck, 2008) extends to scenes with negative interpersonal interaction, fixation durations and later processing of the pictures can be expected to be prolonged for aggressive as opposed to neutral pictures in depressed participants. No such attentional bias to aggressive pictures is expected in control participants (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & van IJzendoorn, 2007). In contrast, healthy control participants are expected to show a protective bias in their gaze behavior (Ellis *et al*., 2011; Kellough *et al*., 2008; Leyman *et al*., 2011; Sears *et al*., 2010, 2011) – that is, to attend more to the less distressing (i.e., neutral) stimulus option available.

METHODS

Participants

The required sample size for the present study was computed with *a priori* power analysis as implemented in G*Power (Version 3.1.9.2; Faul, Erdfelder, Lang & Buchner, 2007). Repeated measures analysis of variance (ANOVA) for within-between interaction effect (2 × 2 × 2) was selected. Because there are no previous eye tracking studies investigating the effects of interpersonal threat, the sample size in the present study was estimated based on a conventional medium effect size ($\eta^2_p = 0.06$; Cohen, 1988) according to the specification as in G*Power, and the correlation among repeated measures was 0.5. The calculation showed a requirement of 12 participants in each group with a statistical power ($1 - \beta$) of 0.80 and a significance level α of 0.05. The sample size calculation does not take into account covariance analyses.

The sample comprised 16 non-medicated participants with unipolar depression (depression group) and 16 age-matched healthy control participants (control group). The age of the participants varied from 18 to 63 years ($M = 45.1$ years, $SD = 12.9$), and the participants included 24 females and eight males (Table 1). There were no differences in age, $t(30) = 0.03$ and $p = 0.979$, or in gender distribution, $p = 0.685$ (Fisher's exact test), between the depressed and control participants.

The depressed participants were recruited among those who volunteered for an intervention study investigating the effectiveness of a short acceptance and commitment therapy for depression (Kyllönen, Muotka, Puolakanaho, Astikainen, Keinonen & Lappalainen, 2018). All recruited participants took part in the eye tracking study before their intervention, except two participants who were not suitable for the intervention study but participated only in the eye tracking study. The depressed participants were recruited via newspaper and e-mail advertisements and control participants via e-mail advertisements. Written informed consent was obtained from the participants before their participation. The experiment was undertaken in accordance with the Declaration of Helsinki. The ethical committee of the University of Jyväskylä approved the research protocol.

For the eye tracking study, inclusion criteria for all participants included being over 18 years old, self-reported normal or corrected-to-normal vision and right-handedness. Additional inclusion criteria for the depressed participants included current depressive symptoms (scores of 14 or above in Beck Depression Inventory-II, BDI-II, Beck, Steer & Brown, 1996) and diagnosis of unipolar depression. Only participants without depression medication were included. In addition, for both depressed and control participants, the anamnesis of any neurological condition such as brain injury, epilepsy, migraine or sleep apnoea was an exclusion criterion. Participants diagnosed with other psychiatric disorder than depression in the depression group and any current or past psychiatric disorder in the control group were excluded. In addition, the exclusion criterion for the control participants included having a score above 10 scores in BDI-II.

To confirm the inclusion and exclusion criteria, questionnaires were administered and a structured psychiatric interview was conducted by a physician independent to the study asking about the participants' current and previous diagnoses, symptoms and medications (see Supplementary material for the form used in the interview). The interview was conducted

Table 1. *Age and questionnaire scores in the depression and in the control group*

Group						
	Depressed (n = 16, 11 female)			Control (n = 16, 13 female)		
Variable	Min, Max	Mean	SD	Min, Max	Mean	SD
Age (y)	18, 63	45.10	13.10	20, 62	45.20	13.00
BDI-II	14, 31	23.31	5.44	0, 8	3.00	2.90
DASS	19, 90	42.50	20.49	0, 31	8.44	8.30
DASS subscales						
DASS-Depression	6, 40	19.81	9.50	0, 6	2.13	2.09
DASS-Anxiety	0, 23	6.56	7.80	0, 9	2.00	2.48
DASS-Stress	5, 31	16.13	7.67	0, 16	4.31	4.51

Notes: BDI-II = Beck Depression Inventory II; DASS = Depression, Anxiety, Stress Scale; Min = Minimum; Max = Maximum; SD = Standard deviation.

only for the depression group, but questions on the same topics were asked in a questionnaire for the control group. In the interview, depression was assessed based on the International Classification of Diseases and Related Health Problems 10th Revision (ICD-10) criteria and the information available from the participants. Comorbidity was assessed by asking the participants about their other current or previous psychiatric diagnoses. Self-report questionnaire data were collected in both groups using the BDI-II (Beck *et al*., 1996) and Depression Anxiety Stress Scale (DASS, Lovibond & Lovibond, 1995), including subscales: DASS-depression (DASS-D), DASS-anxiety (DASS-A) and DASS-stress (DASS-S) (Table 1). The participant groups differed in BDI-II $t(30) = 13.19$, $p < 0.001$ and the subscales of DASS; DASS-D: $t(30) = 7.27$, $p < 0.001$; DASS-A: $t(30) = 2.23$, $p = 0.039$; DASS-S: $t(30) = 5.31$, $p < 0.001$.

Of the 16 depressed participants, 14 participated in a structured psychiatric interview. Two participants in the depression group who did not participate in the psychiatric interview reported elevated BDI-II scores (18 and 28) and an existing depression diagnosis, and they were therefore included in the study.

In the depression group, based on the psychiatric interview, five participants met the criteria of mild depression (F32.0) and one participant was diagnosed with mild dysthymic disorder (F34.1). Three participants were diagnosed with recurrent depressive disorder along with mild current episode (F33.0). Two participants met the criteria of moderate depression (F32.1), and three were diagnosed with recurrent depressive disorder along with moderate current episode (F33.1).

Apparatus

A Dell Precision T5500 workstation with Asus VG-236 (1980 × 1040, 120 Hz) monitor controlled the stimulus presentation. The monitor was positioned 60 cm away from the eyes of the participant. Eye movements were recorded with Eyelink 1000 table-mount eye tracking system employing 1000 Hz sample rating while tracking the right eye of the participant.

Stimulus materials

The stimuli comprised 60 digitised color pictures (400 pixels wide, 300 pixels high) of visually matched interpersonally aggressive (30) and neutral (30) pictures, each showing two persons in interaction (Nummenmaa, Hirvonen, Parkkola & Hietanen, 2008). Aggressive scenes depicted interpersonal attack scenes such as strangling, punching and threatening with a weapon, whereas neutral scenes depicted daily non-emotional activities such as having a conversation or giving instructions. The pictures were paired into aggressive vs. neutral visual scenes (30 pairs) in such a way that the physical environment, actors and overall composition were the same in both pictures (Fig. 1). Nummenmaa *et al*., (2008) had equated the scenes in terms of luminosity, average contrast density, global energy and complexity, and they had measured the pixel area covered by faces and the frequency of the actors looking towards the camera; no differences were found between the aggressive and neutral scenes. In the Nummenmaa *et al*. (2008) study, the participants rated the stimuli. The aggressive pictures resulted in an increased experience of fear, anger and disgust and a decreased experience of pleasure compared with the neutral pictures ($ts > 3.7$, $ps < 0.01$). For more detailed information on ratings, see Nummenmaa *et al*. (2008).

Procedure

Participants were individually tested in a quiet room and seated in a chair in front of a table. They rested their head on a chin and forehead rest and were instructed to stay still during the experiment. A five-point calibration-validation routine was performed and accepted if the mean deviation between the calibration and validation was less than 0.3°.

Stimulus presentation is illustrated in Fig. 1. When the participants fixated their gaze to the fixation point for drift correction, the experimenter manually initiated each trial. This procedure allowed observation of a possible calibration error and need for renewing the calibration. After a randomised duration of 1–3 s, two pictures (aggressive and neutral) appeared at the same time at opposite positions to the fixation point in random order. The distance from the fixation point to the inner edge of each picture was always 1.75°. The pictures were presented for 5 s, followed by the drift correction point and next trial. Altogether 30 trials were presented in a random order. The participants were asked to freely view the pictures just as they would be viewing photographs on a computer screen at home.

Dependent measures and statistical analyses

The area-of-interests comprised the locations occupied by the pictures. The saccade detection threshold of the eye's angular velocity of 30°/s was used. The following eye tracking variables were extracted for analysis: probability of first-pass viewing, first fixation duration, first-pass dwell time, total dwell time, first-pass fixation count, total fixation count and run count. The probability of first-pass viewing is the number of trials in which a participant first looked at the aggressive picture divided by the total number of trials (30). Threat information can possibly be extracted from the peripheral vision when participants look at the fixation cross at a

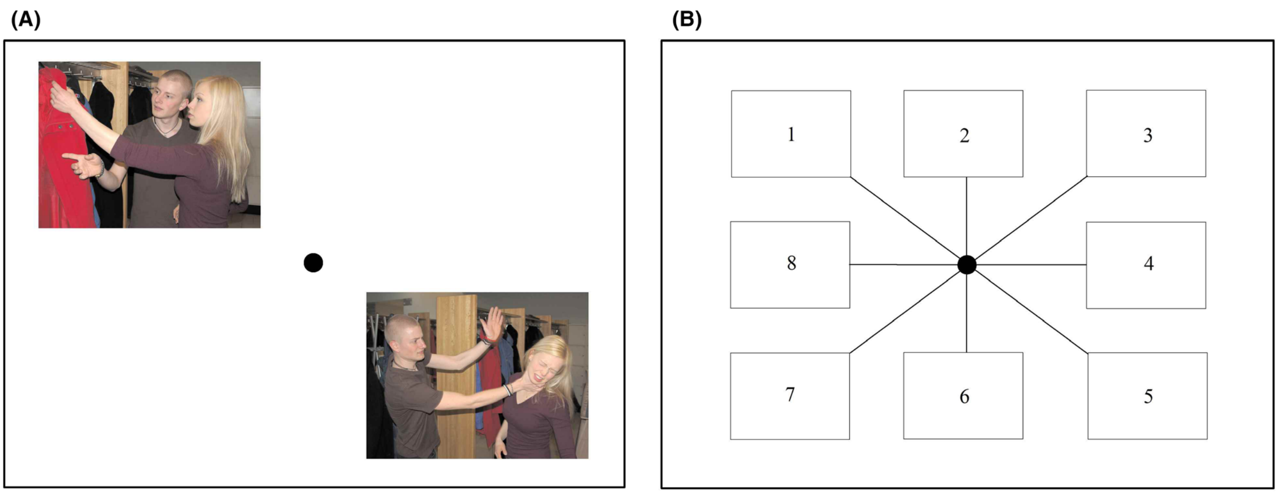

Fig. 1. Illustration of the stimulus presentation. (A) An example of a trial. (B) Pictures in a trial were always positioned opposite to each other. In (A), pictures are presented in positions 1 and 5, and the other options for the positions were 2 and 6, 3 and 7, and 4 and 8. Numbers are only for descriptive purposes, not shown during the stimulus presentation. Note also that distances and locations of the stimuli presented in the illustration do not accurately match with the actual stimulus presentation.

beginning of the trial. In this case, the probability of first-pass viewing would reflect a threat-related bias. The first fixation duration on a picture reflects the early, primarily stimulus-driven (exogenous) attentional response, which holds gaze in foveated stimuli (Krejtz, Holas, Rusanowska & Nezlek, 2018). First-pass dwell time is the summed duration of all fixations and saccades during the first look at a picture. This measure and the first-pass fixation count indicate for how long and with how many separate perceptual events, respectively, the picture was initially inspected before looking away. The total dwell time and total fixation count include the summed duration of all fixations and saccades, and number of all fixations, respectively, including both initial viewing and later look-backs on the picture. Run count indicates the total number of visits in the pictures during a trial.

To investigate the eye movement parameters in a reliable way and to provide evidence on a possible attentional bias, we applied viewing order as a factor in the statistical analysis. This is important in two-picture free viewing tasks for at least two possible reasons. First, for any scene comprising several objects looked at for a limited time, eye movement parameters may differ as a function of viewing order, and repetitions of emotional pictures have been shown to affect eye movement behavior (Calvo & Nummenmaa, 2007; Nummenmaa, Hyönä & Calvo, 2006). Second, the processing of threat may be intertwined with viewing order because participants learn during the experiment that the picture pairs are always composed of same emotional valences (aggressive vs. neutral). Thus, the viewing order probably induces priming effects – for example, after first looking at a neutral picture, one knows that the other picture will be a threatening one and this knowledge may modify the viewing behavior.

For all the variables except the probability of first-pass viewing, the data were analysed using repeated measures ANOVA with a between-subject factor of group (depressed vs. control) and with within-subject factors of valence (aggressive vs. neutral) and viewing order (first-aggressive-then-neutral vs. first-neutral-then-aggressive). For the probability of first-pass viewing, the data were analysed with only the between-subject factor of group and within-subject factor of valence. The results were also computed with DASS-A as a covariate (repeated measures analysis of covariance, ANCOVA) because anxiety is associated with increased vigilance for threat (Armstrong & Olatunji, 2012). We report the possible changes DASS-A as covariant caused to the original analyses and the possible interaction effects of the variables with DASS-A. Significant effects found in 2 × 2 × 2 ANOVA were further analysed with 2 × 2 ANOVA and/or paired-samples t-tests. Partial eta squared (η^2_p) measures were used for effect size descriptions in ANOVA and Cohen's *d* in *t*-tests.

RESULTS

For all the analyses presented below, *F*-values, *p*-values and effect size estimates (η^2_p) for the repeated measures ANOVAs (group × valence × viewing order) are presented in Table 2. In addition, the *p*-values of significant main and interaction effects in ANOVA are reported in the text as well as the *F*-values, *p*-values and effect size estimates (η^2_p) for the further repeated measures ANOVA breaking down the interaction effects.

Probability of first-pass viewing

The main and interaction effects of valence and group were non-significant.

First fixation duration

A main effect of valence ($p = 0.008$) was observed. The first fixation durations were longer for aggressive pictures ($M = 199.63$ ms, $SD = 36.18$) than for neutral pictures ($M = 186.15$ ms, $SD = 32.40$). The main effect of valence, however, was moderated by a valence × order × group interaction ($p = 0.041$). No other main or interaction effects were present. Both effects remained significant when DASS-A scores were applied to the ANCOVA model, and there were no significant interaction effects with DASS-A scores (all $p \geq 0.096$).

Next, in order to further investigate the 3-way interaction, a repeated measures 2 × 2 ANOVA with a within-subject factor valence and a between-subject factor group was applied separately to the data from the first and second viewing order (Fig. 2). For the first viewing order, there was a main effect of valence, $F(1, 30) = 5.11$, $p = 0.031$, $\eta^2_p = 0.145$). The first fixation duration was longer for the aggressive ($M = 195.06$ ms, $SD = 43.29$) than the neutral ($M = 182.44$ ms, $SD = 39.19$) pictures when each picture was viewed first in order. Neither a main effect of group ($p = 0.870$) nor an interaction between valence and group ($p = 0.902$) was found.

For the second viewing order, there was also a main effect of valence, $F(1, 30) = 7.92$, $p = 0.009$, $\eta^2_p = 0.209$. The first fixation duration was significantly longer for the aggressive ($M = 204.20$ ms, $SD = 34.14$) than neutral ($M = 189.85$ ms, $SD = 31.85$) pictures when each picture was viewed second in order. Importantly, however, there was also a trend towards a significant interaction effect between valence and group ($p = 0.070$). Because of the trending interaction, we further analysed the effect of valence separately for the depression group and control group. Follow-up t-tests demonstrated that, in the depression group, the first fixation duration was significantly longer for aggressive pictures ($M = 211.91$ ms, $SD = 24.65$) than for neutral pictures ($M = 188.00$ ms, $SD = 27.02$) when they were viewed second in order: $t(15) = 3.91$, $p = 0.001$, $d = 0.925$. In the control group, instead, the first fixation duration between the stimulus types did not differ when looked at second in order (aggressive: $M = 196.48$ ms, $SD = 40.91$; neutral: $M = 191.71$ ms, $SD = 36.86$), $t(15) = 0.59$, $p = 0.567$, $d = 0.123$).

First-pass dwell time

The main effects of group ($p = 0.011$), valence ($p = 0.039$) and viewing order ($p < 0.0001$) were found. In addition, the interaction effect between valence and order was significant ($p = 0.001$). The depressed participants viewed both neutral and aggressive pictures for significantly longer durations ($M = 1604.98$ ms, $SD = 75.76$) than the control participants ($M = 1313.05$ ms, $SD = 75.76$) during the first pass. Neutral pictures ($M = 1570.38$ ms, $SD = 388.72$) had significantly longer first-pass dwell times than aggressive pictures ($M = 1347.65$ ms, $SD = 485.93$). The pictures viewed second in order ($M = 1770.81$ ms, $SD = 363.87$) had a significantly longer first-pass dwell time than those viewed first in order ($M = 1147.22$ ms, $SD = 424.44$). The significant effects remained when DASS-A scores were applied as a covariate in the ANCOVA, except the main effect of valence, which was not significant ($p = 0.206$). There were no significant interaction effects with DASS-A scores in ANCOVA (all $p \geq 0.195$).

Follow-up t-tests investigating the valence × order interaction showed that when neutral pictures were looked at second in order ($M = 1992.82$ ms, $SD = 551.29$), they had a significantly longer first-pass dwell time ($M = 1548.81$ ms, $SD = 580.17$) than

Table 2. *Results of the 3-way repeated measures of ANOVA. F- and p-values and partial eta squared (η^2_p) for effect size estimates*

Variable	Group	Valence	Valence × group	Order	Order × group	Valence × order	Valence × order × group
Probability of first-pass viewing	$F(1, 30) < 0.001$ $p = 1.0$ $\eta^2_p < 0.001$	$F(1, 30) = 3.47$ $p = 0.072$ $\eta^2_p = 0.102$	$F(1, 30) = 0.386$ $p = 0.539$ $\eta^2_p = 0.013$				
First fixation duration	$F(1, 30) = 0.025$ $p = 0.875$ $\eta^2_p = 0.001$	**$F(1, 30) = 7.97$** **$p = 0.008^{**}$** **$\eta^2_p = 0.210$**	$F(1, 30) = 8.65$ $p = 0.360$ $\eta^2_p = 0.028$	$F(1, 30) = 3.26$ $p = 0.081$ $\eta^2_p = 0.098$	$F(1, 30) = 0.786$ $p = 0.382$ $\eta^2_p = 0.026$	$F(1, 30) = 0.129$ $p = 0.722$ $\eta^2_p = 0.004$	**$F(1, 30) = 4.56$** **$p = 0.041^{*}$** **$\eta^2_p = 0.132$**
First-pass dwell time	**$F(1, 30) = 7.43$** **$p = 0.011^{*}$** **$\eta^2_p = 0.198$**	**$F(1, 30) = 4.67$** **$p = 0.039^{*}$, $^{\#}$** **$\eta^2_p = 0.135$**	$F(1, 30) = 0.169$ $p = 0.684$ $\eta^2_p = 0.006$	**$F(1, 30) = 66.40$** **$p < 0.0001^{***}$** **$\eta^2_p = 0.689$**	$F(1, 30) = 0.052$ $p = 0.820$ $\eta^2_p = 0.002$	**$F(1, 30) = 13.39$** **$p = 0.001^{**}$** **$\eta^2_p = 0.309$**	$F(1, 30) = 0.123$ $p = 0.728$ $\eta^2_p = 0.004$
First-pass fixation count	$F(1, 30) = 1.90$ $p = 0.178$ $\eta^2_p = 0.060$	**$F(1, 30) = 4.77$** **$p = 0.037^{*}$, $^{\#}$** **$\eta^2_p = 0.137$**	$F(1, 30) = 0.061$ $p = 0.807$ $\eta^2_p = 0.002$	**$F(1, 30) = 63.10$** **$p < 0.0001^{***}$** **$\eta^2_p = 0.678$**	$F(1, 30) = 0.560$ $p = 0.460$ $\eta^2_p = 0.018$	**$F(1, 30) = 13.58$** **$p = 0.001^{**}$** **$\eta^2_p = 0.312$**	$F(1, 30) = 0.008$ $p = 0.927$ $\eta^2 p < 0.0001$
Run count	**$F(1, 30) = 4.30$** **$p = 0.047^{*}$, $^{\#}$** **$\eta^2_p = 0.125$**	**$F(1, 30) = 8.49$** **$p = 0.007^{**}$, $^{\#}$** **$\eta^2_p = .221$**	$F(1, 30) = 0.189$ $p = 0.667$ $\eta^2_p = 0.006$	**$F(1, 30) = 289.18$** **$p < 0.0001^{***}$** **$\eta^2_p = 0.906$**	$F(1, 30) = 0.019$ $p = 0.891$ $\eta^2_p = 0.001$	$F(1, 30) = 0.969$ $p = 0.333$ $\eta^2_p = 0.031$	$F(1, 30) = 1.92$ $p = 0.176$ $\eta^2_p = 0.060$
Total dwell time	$F(1, 30) = 3.90$ $p = 0.058$ $\eta^2_p = 0.115$	**$F(1, 30) = 8.70$** **$p = 0.006^{**}$, $^{\#}$** **$\eta^2_p = 0.225$**	$F(1, 30) = 0.106$ $p = 0.747$ $\eta^2_p = 0.004$	$F(1, 30) = 0.768$ $p = 0.388$ $\eta^2_p = 0.025$	$F(1, 30) = 0.141$ $p = 0.710$ $\eta^2_p = 0.005$	$F(1, 30) = 1.19$ $p = 0.283$ $\eta^2_p = 0.038$	$F(1, 30) = 1.02$ $p = 0.320$ $\eta^2_p = 0.033$
Total fixation count	$F(1, 30) = 0.925$ $p = 0.344$ $\eta^2_p = 0.030$	**$F(1, 30) = 9.96$** **$p = 0.004^{**}$, $^{\#}$** **$\eta^2_p = 0.249$**	$F(1, 30) = 0.069$ $p = 0.795$ $\eta^2_p = 0.002$	**$F(1, 30) = 18.36$** **$p < 0.0001^{***}$** **$\eta^2_p = 0.380$**	$F(1, 30) = 0.061$ $p = 0.806$ $\eta^2_p = 0.002$	$F(1, 30) = 0.947$ $p = 0.338$ $\eta^2_p = 0.031$	$F(1, 30) = 0.124$ $p = 0.727$ $\eta^2_p = 0.004$

Notes: [1]Significant effects in bold.
$^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$.
[#]Non-significant when DASS-anxiety as a covariate.

aggressive pictures looked at second in order: $t(31) = 2.90$, $p = 0.007$, $d = 0.785$. There was no difference in the first-pass dwell time between neutral ($M = 1147.95$ ms, $SD = 446.36$) and aggressive ($M = 1146.48$ ms, $SD = 479.70$) pictures viewed first in order: $t(31) = 0.02$, $p = 0.982$, $d = 0.003$.

First-pass fixation count

The main effects of valence ($p = 0.037$) and viewing order ($p < 0.0001$) as well as an interaction effect of valence and viewing order ($p = 0.001$) were found. No main effect of group or interaction effects involving group were observed. The main effect of valence indicated that the first-pass fixation count was larger for neutral pictures ($M = 5.56$, $SD = 0.97$) than for aggressive pictures ($M = 4.99$, $SD = 1.53$). The main effect of viewing order was demonstrated by the larger number of fixations for pictures viewed second ($M = 6.07$, $SD = 1.10$) than that for those viewed first ($M = 4.48$, $SD = 1.29$) in order. The main effect of order and interaction effect of valence × order remained when DASS-A scores were applied to the ANOVA model, but the main effect of valence was not significant ($p = 0.137$). There were no significant interaction effects with DASS-A scores in ANCOVA (all $ps \geq 0.334$).

The paired t-test investigating the valence × viewing order interaction showed that when the pictures were looked at second in order, neutral pictures ($M = 6.62$, $SD = 1.20$) had a larger number of fixations than aggressive pictures ($M = 5.51$, $SD = 1.77$): $t(31) = 3.02$, $p = 0.005$, $d = 0.734$. Again, the first-pass fixation count for aggressive ($M = 4.47$, $SD = 1.48$) and neutral ($M = 4.49$, $SD = 1.30$) pictures did not differ when they were viewed first in order: $t(31) = 0.11$, $p = 0.911$, $d = 0.014$.

Run count

For the run count, the main effects of group ($p = 0.047$), valence ($p = 0.007$) and viewing order ($p < 0.0001$) were found. The participants in the control group visited the pictures more often during trials ($M = 1.71$, $SD = 0.07$) than did the participants in the depression group ($M = 1.51$, $SD = 0.07$). During the experiment, the neutral pictures were viewed more often ($M = 1.66$, $SD = 0.30$) than the aggressive ones ($M = 1.56$, $SD = 0.30$). The pictures viewed first in order were also visited more often ($M = 1.84$, $SD = 0.31$) than those viewed second ($M = 1.38$, $SD = 0.28$). There were no interaction effects. However, when DASS-A scores were applied as a covariate, the main effects of group ($p = 0.057$) and valence ($p = 0.071$) were non-significant. There were no interaction effects with DASS-A scores in ANCOVA (all $p \geq 0.372$).

Total dwell time

The main effect of valence was observed ($p = 0.006$), indicating longer dwell times on neutral pictures ($M = 2322.29$ ms, $SD = 529.76$) than on aggressive ones ($M = 1801.00$ ms, $SD = 509.42$). No other main or interaction effects were found. When DASS-A scores were applied to the ANOVA model, the main effect of valence was non-significant ($p = 0.085$). There were no significant interaction effects with DASS-A scores in ANCOVA (all $p \geq 0.108$).

Total fixation count

For the total fixation count, the main effects of valence ($p = 0.004$) and viewing order ($p < 0.0001$) were found. The

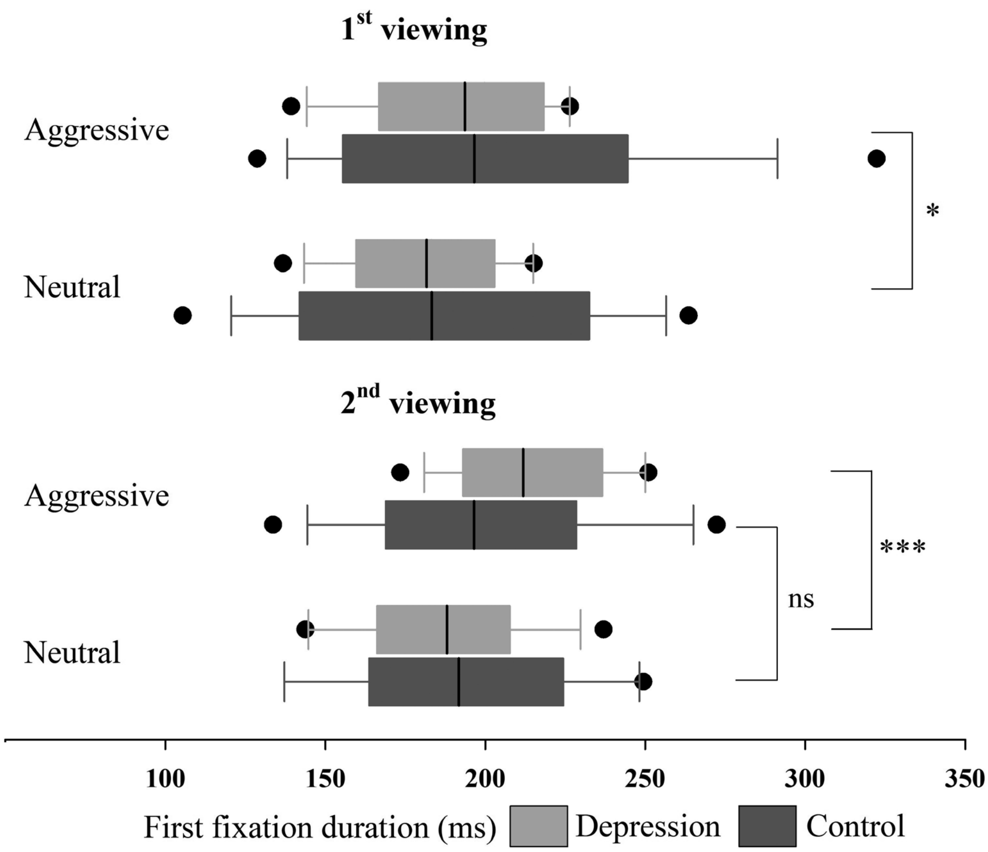

Fig. 2. Means and standard deviations of the first fixation duration in the depression and control group for aggressive and neutral pictures shown separately for the first and the second viewing order (outliers that lie outside the 10th and 90th percentiles are marked with black dots). * $p = 0.031$ (the main effect of valence in the follow-up group x valence ANOVA); ***$p = 0.001$ (the follow-up paired t-test); ns = non-significant.

fixation count was larger for neutral ($M = 8.28$, $SD = 1.35$) than for aggressive pictures ($M = 6.78$, $SD = 1.76$). The fixation count for the pictures that were viewed first ($M = 7.92$, $SD = 0.93$) was higher than that for the pictures viewed second in order ($M = 7.14$, $SD = 1.03$). Main effect of group and interaction effects were non-significant. When DASS-A scores were applied as a covariate, the main effect of valence was significant at the trend level ($p = 0.050$). There were no interaction effects in ANCOVA with DASS-A scores (all $p \geq 0.158$).

DISCUSSION

The present study examined depressed and non-depressed participants' gaze behavior when they freely watched visually matched picture pairs of interpersonally aggressive and neutral human interactions. In line with evolutionary systems theories of depression, which suggest increased cognitive sensitivity to interpersonal threat (Allen & Badcock, 2003), we assumed that pictures of aggressive human interaction could differentiate depression and control groups' attentional processing of these pictures.

Anticipated aggressive pictures enhanced attentional engagement in the depression group

Both groups showed longer first fixation duration to aggressive than neutral pictures when the pictures were viewed for the first time. This finding is in contrast with a meta-analysis showing no threat bias in control participants (Bar-Haim *et al*., 2007), but it is similar to previous studies using the visual search task and demonstrating that threatening faces are detected faster than other faces (e.g., Calvo, Avero & Lundquist, 2006; Öhman, Lundqvist & Esteves, 2001). In addition, a review investigating attention orienting to emotional stimuli found some indication of greater exogenous attention to emotional than to neutral distractors in the majority (93%) of studies (Carretié, 2014). The present results provide evidence that aggressive pictures containing threatening faces and being highly emotional in comparison to neutral pictures can bias attention also when participants are freely viewing the pictures.

Interestingly, the group difference was found in the first fixation duration for the pictures that were viewed second. The depression group showed a bias towards interpersonally aggressive pictures as compared to neutral pictures, whereas no such bias was observed in the control group. The enhanced attentional engagement observed in the depression group with the aggressive pictures viewed after the neutral pictures may reflect their increased emotional reaction to the anticipated aggressive pictures. This is because during the task, the participants must have learned that the stimuli were always composed of neutral vs. aggressive picture pairs, especially because the stimuli were presented for a relatively long time (5 s).

Anticipation can play a significant role in perception: expectations based on prior experience and contextual knowledge influence the processing of subsequent stimuli (e.g., Bar, 2004;

Hietanen & Astikainen, 2013; Sussman, Szekely, Hajcak & Mohanty, 2016). In anxious individuals, these anticipatory, top-down factors have been associated with threat-related perceptual sensitivity (Sussman *et al.*, 2016). Although speculative, our findings of depression-related early attentional engagement with aggressive pictures might reflect similar anticipatory effects, wherein difficulties in cognitive control and maladaptive emotion regulation strategies (e.g., rumination, LeMoult & Gotlib, 2018) build up depressed participants' emotional reaction when the aggressive pictures are expected.

In previous studies, attentional bias towards threat has been reported in the context of anxiety disorders (Armstrong & Olatunji, 2012; Peckham *et al*., 2010). However, in the depression group, our result of prolonged first fixation duration on aggressive pictures seems to not be attributable to the anxiety symptoms in this group. The significant effects remained when DASS-A scores were applied as a covariant in the ANOVA model, and there were no significant interaction effects between anxiety scores and other variables.

Related to the other early information processing measure, our hypothesis about the higher probability of all participants' initial orienting of attention towards aggressive pictures over neutral ones was not supported. Moreover, no group differences were found in the initial orienting towards aggressive pictures. This is consistent with the prevailing evidence of non-existent attentional vigilance to threatening stimuli in depression (Kellough *et al*., 2008; Mogg, McNamara, Powys, Rawlinson, Seiffer & Bradley, 2000; Sears *et al*., 2010). Furthermore, a recent meta-analysis investigating eye tracking studies showed that attentional bias to dysphoric and happy contents in depression is not evident in early information processing, but occurs in later stages (Suslow *et al*., 2020).

Avoidance of aggressive pictures in both groups

In both depression and control groups, neutral pictures were viewed more often (higher run count), viewed for longer (first-pass dwell time and total dwell time) and fixated on more often (first-pass fixation count and total fixation count) than aggressive pictures. These effects were non-significant when DASS-A scores were applied as a covariate in the analysis, suggesting that the effects may be partly driven by anxiety symptoms. However, for first-pass dwell time and first-pass fixation count, interaction effects of valence and viewing order remained when anxiety scores were controlled for. We found that the time spent viewing a picture (first-pass dwell time) and the number of fixations (first-pass fixation count) for aggressive and neutral pictures differed only in the second viewing order. That is, when neutral pictures were viewed second, they were viewed for significantly longer durations and had more fixations than aggressive pictures viewed second. No differences were found in these variables when neutral pictures were viewed first. Therefore, our findings appear to reflect avoidance behavior: participants' reluctance to leave the neutral picture when they had already visited the aggressive picture and, contrarily, the participants leaving the aggressive picture viewed second early when they already knew the first picture was neutral. It has been previously suggested that attention allocated away from threat contents in a top-down manner could reduce negative emotional consequences related to viewing of threat contents (Cisler & Coster, 2010).

Limitations of the study and future directions

The most important limitation is the small sample size. Here we wanted to recruit non-medicated depressed participants because medication can affect responses (Wells, Clerkin, Ellis & Beevers, 2014); this resulted in a smaller sample size. It needs to be mentioned also that the *t*-tests following the ANOVA results were not corrected for multiple comparisons. Note also, that the *p*-value of the follow-up ANOVA breaking down the 3-way interaction in the first fixation duration was not significant ($p = 0.070$).

Further studies investigating how the anticipation of negative pictures or events in depressed individuals affects gaze behavior and emotional reactivity, along with the underlying causes of the increased emotional reactivity, could be conducted. Also, interpersonal stimuli presenting different emotional valences (i.e., dysphoric, positive, threatening) could be applied in future studies of attentional biases in depression. These may have relevance for understanding dysfunctional information processing in depression and depression-related difficulties in psychological adjustment in everyday life (cf. Holas, Krejtz, Rusanowska, Rohnka & Nezlek, 2019) and, thus, be useful in developing attention trainings and psychotherapy treatments. Although in line with the evolutionary theories of depression (Allen & Badcock, 2003), this study cannot confirm how specific the findings are to interpersonal threat and/ or aggression. However, previous studies that have mainly used threat pictures other than those related to interpersonal threat (e.g., pictures of a single angry animal or a gun pointed towards the viewer) have not found attentional bias towards threat in depression (Armstrong & Olatunji, 2012).

SUMMARY AND CONCLUSIONS

In sum, when the aggressive pictures were viewed first both groups showed an attentional bias towards interpersonally aggressive pictures in early information processing (first fixation duration), but when the participants were able to anticipate the aggressive pictures, this bias was evident in the depressed participants only. At the entire sample level, our results also demonstrated the participants' tendency to avoid interpersonally aggressive pictures. Our findings of depression-related early attentional maintenance of anticipated aggressive pictures may reflect cognitive sensitivity to interpersonal conflicts, which can affect social cognition and maintain depressed mood.

CONFLICTS OF INTEREST

The authors confirm that there are no known conflicts of interest associated with this publication. The study was supported by the Academy of Finland (project no. 140126 to Raimo Lappalainen).

The authors thank Professor Raimo Lappalainen and Ms. Heidi Kyllönen for recruiting the participants, and Dr. Marja-Liisa Kinnunen, PhD, M.D., for conducting the clinical interviews.

AUTHORS CONTRIBUTION

Matti Rantanen: Investigation, Data curation, Formal analysis, Visualization, Writing – original draft, Writing - reviewing and editing Jarkko Hautala: Conceptualization, Data curation, Methodology, Software, Formal analysis, Writing – reviewing and editing manuscript Otto Loberg: Data curation, Formal analysis, Investigation, Methodology, Software, Writing – reviewing and editing manuscript Jaakko Nuorva: Investigation, Writing – reviewing and editing manuscript Jari K. Hietanen: Conceptualization, Methodology, Writing – reviewing and editing manuscript Lauri Nummenmaa: Conceptualization, Methodology, Writing – reviewing and editing manuscript Piia Astikainen: Funding acquisition, Project administration, Supervision, Conceptualization, Methodology, Writing – original draft, Writing – reviewing and editing manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Received 11 September 2020, accepted 3 March 2021

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Supplementary Material