

ORIGINAL ARTICLE

Gaze behaviour when monitoring pain faces: An eye-tracking study

J.A. Priebe, M. Messingschlager, S. Lautenbacher

Department of Physiological Psychology, University of Bamberg, Germany

Correspondence

Janosch A. Priebe

E-mail: janosch.priebe@uni-bamberg.de

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Conflicts of interest

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Abstract

Background: The vigilance-(attentional) avoidance hypothesis (VAH) developed for explaining phobic reactions describes an early attentional bias towards a feared stimulus followed by attentional avoidance of this stimulus. Such a pattern of attentional shifts might also be found when processing of pain-related stimuli is required. The purpose of the present study was to test the VAH for pain-associated stimuli, i.e., faces displaying pain, using the method of eye-tracking in a pain-free sample.

Methods: Forty-eight healthy participants observed pictures of faces displaying pain and other emotions (anger, joy), presented concurrently with neutral faces, while their gaze behaviours were recorded continuously.

Results: Analysis of the time course of fixation durations revealed a distinct pattern for pain faces. Participants gazed at pain faces longer than at neutral faces at the beginning (up to 1000 ms) but reduced preference for pain faces increasingly thereafter (up to 2000 ms); this decline in vigilance did not occur for anger and joy faces. Strong fear of pain (Fear of Pain Questionnaire) tended to increase attentional preference for negative faces (pain, anger), a finding, which however did not reach significance.

Conclusions: We assume that initial vigilance for pain-associated stimuli might reflect an adaptive reaction to detect a potentially harmful stimulus. Subsequently, the pain-associated stimulus might be less attended for the purpose of mood regulation when all clear is given in this situation.

1. Introduction

There is substantial evidence that biases for painful and pain-associated stimuli occur in patients suffering from chronic pain while they do less in pain-free individuals (Schoth et al., 2012; Crombez et al., 2013). Both increased vigilance (hypervigilance) (Mathews and MacLeod, 2005; Schoth et al., 2012) and enhanced attentional avoidance (Lautenbacher et al., 2009, 2011; Sharpe et al., 2014) are discussed as risk factors for the intensification of acute and development of chronic pain. To integrate such findings, the vigilance-(attentional) avoidance hypothesis (VAH) has recently been implemented in pain research. The VAH, stemming from anxiety research, describes an

early attentional bias towards a feared stimulus rapidly followed by avoidance (Mogg et al., 2000, 2004).

Recent dot-probe data from our lab demonstrate a VA pattern for pain faces in pain-fearful individuals (Baum et al., 2013b). While a flexible VA pattern for pain-associated stimuli might be adaptive, a pronounced VA might lead to worse pain outcomes as pain-relevant stimuli are detected very quickly but avoided shortly after, thus preventing successful coping.

As the dot-probe task does not allow for tracking attention continuously over time, the eye-tracking method that traces visual attention by constantly recording the gaze behaviour has been introduced (Yang et al., 2012, 2013; Vervoort et al., 2013; Lioffi et al., 2014).

What's already known about this topic?

- Enhanced attentional biases towards pain-related stimuli have been assumed to be involved in the development and maintenance of chronic pain. While the existence of attentional biases in chronic pain patients is meanwhile well established, the exact nature of the biases has remained unclear.

What does this study add?

- We investigated the time course of attention towards pain-related stimuli (pain faces compared with other emotional faces) in pain-free individuals by the use of eye-tracking to determine whether and when vigilance engagement or its opposite, attentional avoidance (disengagement) prevails.

Chinese authors, combining the eye-tracking method with a dot-probe task, found a VA pattern (initial engagement with subsequent disengagement in the fixation sequence) for sensory pain words in pain-fearful individuals (Yang et al., 2012) and for health catastrophe words in chronic pain patients (Yang et al., 2013). However, the use of – compared with pain-related pictures – less ecologically valid and interculturally restricted word stimuli might constitute a limitation of the studies.

There are two recent eye-tracking studies using pictorial stimuli, i.e., faces displaying pain and other emotions (Vervoort et al., 2013; Lioffi et al., 2014). Vervoort et al. (2013) report an initial bias (vigilance) towards pain faces followed by decreasing attentional engagement (avoidance) which was mediated by the level of pain catastrophizing and self-reported pain intensity. Additionally, Lioffi et al. (2014) report evidence for an initial attentional bias towards pain faces in chronic headache patients even when other emotional faces (joy, anger, neutral) are presented concurrently.

The reported studies indicate the importance of the investigation of VA for pain-associated stimuli. Yet, the most self-evident way of testing a VA pattern, namely the investigation of gaze behaviour in different time epochs of presentation, has not been conducted.

The present study aims to investigate the temporal pattern of attention allocation when healthy individuals monitor faces displaying pain by means of eye-tracking. For that purpose, we analysed gaze behaviour in different presentation epochs (500 ms each). Our hypotheses derived from Baum et al.

(2013b) were to find a pain-related VA pattern (1) in general; and (2) in a more distinct fashion in individuals with strong fear of pain. To test for the specificity of attentional processing of pain faces, joy and anger faces were additionally presented.

2. Materials and methods

2.1 Subjects

Forty-eight students (24 female) with an average age of 21.8 years ($SD = 2.6$) participated for course credits or payment. Only participants without psychiatric, neurological or somatic disorders (self-report) were accepted for the study. None of the participants suffered from acute or chronic pain (self-report). All subjects reported normal or corrected-to-normal vision. The study protocol was approved by the ethics committee of the Otto-Friedrich University of Bamberg.

2.2 Apparatus and stimulus material

Pictures of male and female human faces extracted from the 'Montréal Pain and Affective Face Clips' (Simon et al., 2006) served as visual stimuli. We used pictures of facial expressions displaying joy (positive-emotional), anger (negative-emotional) and pain (pain-related), as well as pictures of neutral expressions. In order to minimize emotional effects caused by colour, we transformed the coloured extracted pictures into monochrome pictures. The suitability and validity of this set of pictures was confirmed in two studies in our lab, one recognition study¹ (Baum et al., 2013a) and one dot-probe study already described in the introduction (Baum et al., 2013b). Furthermore, pictures extracted from the same set (Simon et al., 2006) were also used in two eye-tracking studies referred to in the introduction (Vervoort et al., 2013; Lioffi et al., 2014).

For our study, we created 64 pairs of pictures (horizontally aligned). Forty-eight of those pairs (16 for each emotion) consisted of one picture depicting a neutral facial expression and one picture depicting an emotional or painful expression (joy, anger or pain). In these neutral-joy, neutral-anger and neutral-pain pairs, the screen position (left-right) of the neutral picture was randomized in order to eliminate position effects. As control condition, 16 further pairs consisted of two neutral faces.

All pictures were 7.8 cm wide and 6.1 cm high. The distance between the two pictures forming a pair was 4.8 cm. Stimuli were presented vertically centred against a black background on a 19-in. monitor with a resolution of 1280 × 1024 pixels. Stimulus presentation and registration of ocular movements were accomplished by an Interactive-

¹In the recognition study, pain-free participants were able to classify pain faces with good sensitivity and specificity, proving sufficient quality of the picture material used.

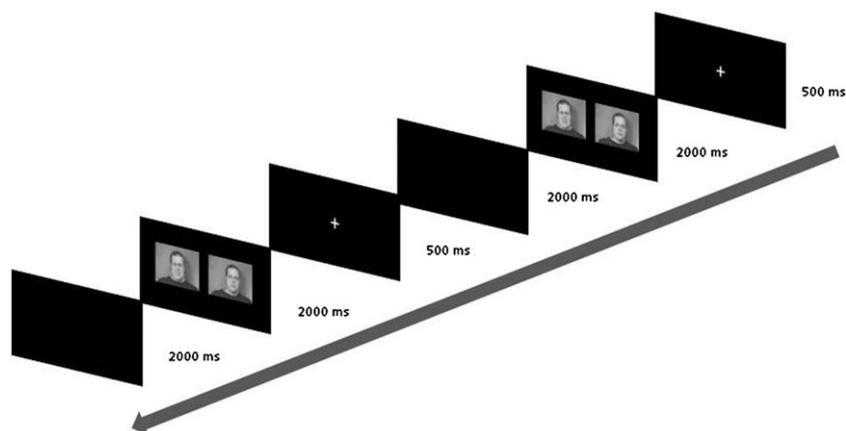


Figure 1 Free viewing task: Participants gazed at a fixation cross for 500 ms. After this, the picture pair was presented for 2000 ms followed by a blank for 2000 ms. Then, the next trial started.

Mind system being composed of a desktop PC with Intel Processor, 19-in. LED screen and the monocular eye-tracking-system EyegazeEdge™ (LC Technologies, Inc., VA, USA). In order to measure the eye's orientation, this system used the corneal reflection of an infrared light source (corneal reflex method). Eye movements were recorded with a sampling rate of 60 Hz and an accuracy of 0.4°. Gaze direction was accepted as fixation if participants' gaze did not deviate more than 0.7° from the centre of the actual fixation for at least 100 ms. For stimulus presentation and registration of ocular movements, the system was driven by the software NYAN 2^{XT} (version 2.3.3, Interactive Minds GmbH, Dresden, Germany).

An advantage of this system is that participants do not have to wear helmets or contacts that might limit their (gazing) behaviour. A kind of a camera, which was placed below the screen, recorded the position of one eye.

2.3 Fear of pain self-report

As in our dot-probe study (Baum et al., 2013b), we used the combined sum score of the German version of the Fear of Pain Questionnaire (FPQ III) (McNeil and Rainwater, 1998) in order to measure participants' pain-related fear. The FPQ III was developed as a comprehensive measure of fear of pain and validated in a pain-free population as well as in chronic back pain patients. Participants are instructed to rate the degree of fear they would likely experience if confronted with a variety of potentially painful situations, like 'breaking an arm', 'receiving an injection in the mouth' or 'paper cut on the finger'. The FPQ III contains 30 items that are rated on a 5-point scale. For developing a German version, the FPQ III was submitted to a forward-backward procedure of translation, which means that the German translation was in turn the starting point for a translation by an English native speaker (with German as his second language) back to English. Translation to German was improved until the original English version and the final English version were sufficiently similar. The German FPQ III demonstrated good internal consistency (Cronbach's $\alpha = 0.90$), which was in

accordance with Cronbach's $\alpha = 0.92$ reported for the English version (Baum et al., 2013b).

2.4 Procedure

After giving their informed consent, participants were seated 70 cm in front of the screen of the computer controlling the eye tracker. An orthogonal prolongation of the nasion should target the centre of the screen. Next, the participants run through an automatic calibration procedure for relating eye gaze and screen positions. For that purpose, participants were instructed to follow a dot with their eyes, which occurred on different screen positions. After this, the main experiment was started.

At the beginning of each trial, a fixation cross was presented in the centre of the screen for 500 ms. After the fixation cross had disappeared, one of the 64 picture pairs appeared for 2000 ms. Next, the screen turned black for 2000 ms before the next trial began with the fixation cross. Fig. 1 illustrates the procedure of the trials.

Participants were instructed to keep their eyes on the fixation cross at the beginning of each trial. Participants were furthermore told to gaze at the screen during the presentation of the two facial stimuli as they like to do. In order to increase the personal relevance of the stimuli, participants were asked to observe the pictures attentively because they might be asked about the valence and arousal of the pictures afterwards. In fact, we did not ask them because we thought such summary ratings over many trials not to be useful.

All participants performed 64 trials, in which the 64 picture pairs were presented in the same random order for all subjects. After the eye-tracking procedure, the participants were asked to complete the FPQ III; this order was chosen to avoid any bias induction in the eye-tracking protocol due to reading the pain- and emotion-related items of the FPQ III beforehand. The whole experiment lasted about 20 min.

2.5 Primary data analysis and parameters

The first parameter we were interested in was the probability of the first fixations, which either fell into the area of interest

(AOI) with the emotional or pain faces or in the AOI with the concurrently displayed neutral faces. The AOIs were squares of 7.8 cm × 6.1 cm framing the facial pictures. Second, we determined the time course over the 2000 ms of presentation of how the fixation durations were distributed between the AOIs associated with the emotional or pain faces on the one hand and the neutral faces on the other hand. For that purpose, the whole presentation time was subdivided into four time epochs: 0–500 ms, 500–1000 ms, 1000–1500 ms and 1500–2000 ms. We assumed that in the first two epochs (0–1000 ms) fixation duration reflects attentional engagement (vigilance), while in the third and fourth epochs (1000–2000 ms) attentional disengagement (avoidance) prevails. Besides the absolute fixation time of each picture in each epoch, a fixation bias score was computed, which was defined as fixation time for emotional or pain faces minus fixation time for the neutral face for each pair of pictures.

2.6 Statistical analysis

In order to analyse the impact of the emotional picture content on the direction of the first fixation, one-sample *t*-tests were computed, testing the fixation probabilities for each emotional stimulus class (pain, anger, joy) against chance level (50%), which would mark the attentional preference of emotional content as being only on the level of random decisions. Thereby, only those trials were considered in which fixations in fact occurred.

Two analyses were run in order to examine the time course of fixations in the AOIs associated with the emotional or pain faces on the one hand and the neutral faces on the other hand over time. First, in order to show whether there were general attentional preferences for happy, angry or pain faces relative to the concurrently presented neutral faces, the fixation times of each emotional class were analysed. For that purpose, three repeated measurement analyses of variance (ANOVAs) with the factors ‘epoch’ (0–500 ms vs. 500–1000 ms vs. 1000–1500 ms vs. 1500–2000 ms) and ‘stimulus class’ (neutral vs. emotional) were run separately for happy, angry and pain faces. Second, the fixation bias scores were subjected to a repeated measurement ANOVA

with the factors ‘epoch’ (0–500 ms vs. 500–1000 ms vs. 1000–1500 ms vs. 1500–2000 ms) and ‘stimulus class’ (positive-emotional vs. negative-emotional vs. pain). By this analysis, we intended to compare directly the course of fixation durations over time between the three emotional picture classes. In order to investigate the impact of pain-related fear, the FPQ scores were entered as covariates into the analysis of the bias scores (analysis of covariance, ANCOVA).

Significance level was set at $\alpha = 5\%$. If sphericity could not be assumed, a Greenhouse & Geisser correcting was accomplished (adjustment of dfs). For post hoc testing of AN(C)OVA effects, we used Bonferroni-corrected *t*-tests for dependent samples.

3. Results

The results are reported in two sections: (1) location of the first fixation; and (2) time course of the absolute fixation durations and bias scores including the impact of pain-related fear.

3.1 Location of the first fixation

Regarding the location of the first fixation, either at an emotional target or at a neutral control picture, analysis did not reveal significant deviations from chance level for angry and happy faces [anger: $M = 49.9\%$; $t(47) = 0.05$; $p = 0.960$; joy: $M = 50.7\%$; $t(47) = 0.514$; $p = 0.610$]. Pain faces, however, attracted the first fixation less often than neutral faces [$M = 46.3\%$; $t(47) = 2.30$; $p = 0.026$].

3.2 Time course of the fixations (absolute durations and bias scores)

The report of the analysis of the time course of the fixations consists of two parts. The findings regarding the absolute fixation durations were given first, those

Table 1 Means (SD) of the fixation durations for the emotional picture categories (pain, anger, joy) and the corresponding neutral pictures [neutral (pain), neutral (anger), neutral (joy)] as well as of the fixation bias scores (FB) for each of the picture categories [pain (FB), anger (FB), joy (FB)].

	Epoch 1	Epoch 2	Epoch 3	Epoch 4
Pain (ms)	120.10 (4.84)	240.10 (8.69)	216.91 (10.92)	211.90 (10.09)
Neutral (Pain) (ms)	100.51 (4.39)	155.46 (7.26)	187.14 (9.92)	190.77 (10.18)
Pain (FB) (ms)	19.59 (6.61)	84.64 (13.70)	28.97 (19.00)	21.13 (18.67)
Anger (ms)	116.53 (5.56)	223.52 (6.88)	221.13 (8.30)	226.75 (9.54)
Neutral (Anger) (ms)	106.11 (4.28)	170.82 (6.45)	179.89 (8.73)	171.76 (8.88)
Anger (FB) (ms)	10.42 (7.45)	52.70 (11.02)	41.24 (14.88)	55.00 (16.37)
Joy (ms)	119.54 (4.08)	247.97 (7.65)	246.63 (8.46)	249.07 (8.98)
Neutral (Joy) (ms)	104.00 (3.93)	149.19 (6.81)	152.46 (8.62)	149.89 (8.46)
Joy (FB) (ms)	15.54 (5.73)	98.68 (12.37)	94.18 (15.39)	99.18 (15.28)

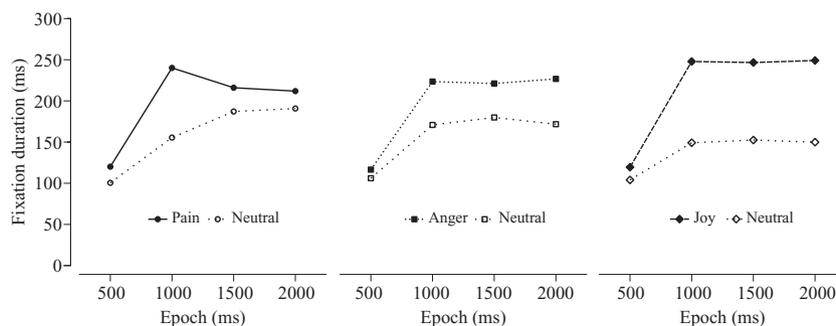


Figure 2 Means of the absolute fixation durations for the three emotional stimulus classes (pain, anger and joy faces) compared with neutral faces over four epochs of 500 ms during stimulus presentation.

regarding the fixation bias scores were given second; means with SD are presented in Table 1.

3.2.1 Analysis of absolute fixation durations

Three ANOVAs with the factors 'epoch' (0–500 ms vs. 500–1000 ms vs. 1000–1500 ms vs. 1500–2000 ms) and 'stimulus class' (neutral vs. emotional) were run separately for the picture pairs pain – neutral, happy – neutral, angry – neutral. Fig. 2 illustrates the results of this analysis.

All three ANOVAs comparing the fixation durations of the emotional pictures with the concurrently presented neutral pictures revealed similar results: In each case, the main effect of 'stimulus class' [pain: $F(1, 47) = 12.99$, $p = 0.001$, $\eta = 0.216$; joy: $F(1, 47) = 97.52$, $p < 0.001$, $\eta = 0.675$; anger: $F(1, 47) = 25.50$, $p < 0.001$, $\eta = 0.352$], the main effect of 'epoch' [pain: $F(3, 141) = 619.79$, $p < 0.001$, $\eta = 0.930$; joy: $F(3, 141) = 570.08$, $p < 0.001$, $\eta = 0.924$; anger: $F(3, 141) = 846.29$, $p < 0.001$, $\eta = 0.95$], and the interaction of 'stimulus class' and 'epoch' [pain: $F(3, 141) = 5.96$, $p = 0.001$, $\eta = 0.113$; joy: $F(3, 141) = 12.17$, $p < 0.001$, $\eta = 0.206$; anger: $F(3, 141) = 3.06$, $p = 0.032$, $\eta = 0.235$] were highly significant.

Fig. 2 clearly shows in any case that the emotional and pain faces produced longer fixation durations than neutral faces (significant main effect for 'stimulus class'), and that the fixation durations varied with time (significant main effect for 'epoch'). In order to understand the significant interactions of 'stimulus class' and 'epoch' in each of the three ANOVAs, paired sample t -tests, comparing the fixation durations of the emotional or pain faces and the concurrently displayed neutral faces, were computed.

For the pain-associated stimuli, the t -tests revealed a significant (Bonferroni-corrected $\alpha' = 0.013$) difference between the fixation durations of the pain face and the neutral face in the first epoch [$t(47) = 2.97$; $p = 0.005$] and a significant difference between these durations in the second epoch [$t(47) = 6.18$; $p < 0.001$]. In epochs 3 and 4, however, the difference

between fixation durations of the pain faces and the neutral faces did not reach significance [$t(47) = 1.52$; $p = 0.13$ and $t(47) = 1.13$; $p = 0.264$].

The analyses for the two other emotional categories revealed that the absolute fixation times of the happy face and the angry face differed significantly (Bonferroni-corrected $\alpha' = 0.013$) from the fixation times of the corresponding neutral faces in epochs 2–4 ($ps < 0.013$). In epoch 1, however, the fixation time was only longer for the happy faces compared with the concurrently displayed neutral faces [$t(47) = 2.71$; $p = 0.009$] while the difference between the angry face and the neutral face was not significant ($p > 0.1$).

In sum, the post hoc analyses of the absolute fixation durations suggest a different time course for gazes at the pain faces than at the two other types of emotional faces. A direct comparison of the three emotional categories became possible by the analyses of the fixation bias scores, which is reported next.

3.2.2 Analysis of fixation bias scores

The two-way ANCOVA with the factors 'epoch' and 'stimulus class' and the covariate 'FPQ-score' run over the fixation bias scores revealed a significant main effect of 'stimulus class' [$F(1.6; 71.8) = 7.33$; $p = 0.003$; $\eta^2 = 0.137$] and a significant interaction of 'epoch' and 'stimulus class' [$F(4.2, 193.4) = 2.81$; $p = 0.024$; $\eta^2 = 0.058$]. In addition, there was a significant interaction of the factor 'stimulus class' and the covariate 'FPQ-score' [$F(1.6; 71.8) = 3.67$; $p = 0.041$; $\eta^2 = 0.074$]. Fig. 3 illustrates the results of this analysis (except for the covariate effects, which will be illustrated later by correlation analyses).

The significant main effect of 'stimulus class' was caused by an increased fixation bias for happy faces relative to angry faces [$t(47) = 4.348$; $p < 0.001$], and an increased fixation bias for happy faces relative to pain faces [$t(47) = 3.783$; $p < 0.001$]. The difference between the angry faces and the pain faces was not significant ($t < 1$).

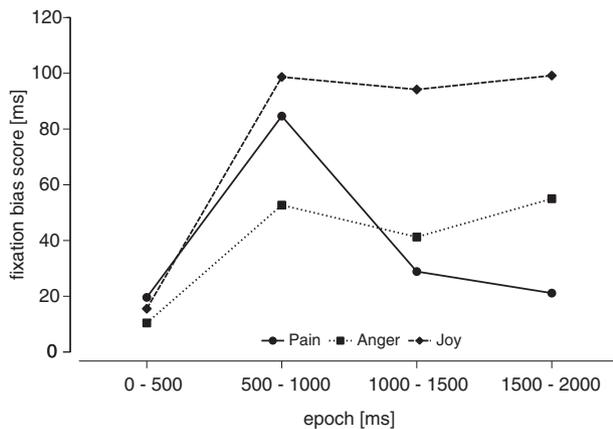


Figure 3 Means of the fixation bias scores for the three emotional stimulus classes (pain, anger and joy faces) over four epochs of 500 ms during stimulus presentation.

The significant interaction of both factors indicates that the effect of ‘stimulus class’ was dependent on the effect of ‘epoch’. An inspection of Fig. 3 reveals that all three emotional stimulus classes were similarly slightly preferred relative to the neutral stimuli in the first 500 ms of their presentation. Accordingly, no significant differences between the three stimulus classes occurred (all $ps > 0.05$). In the following epoch 2, fixation bias scores of all emotional stimuli increased significantly relative to epoch 1 [pain: $t(47) = 4.925$, $p < 0.001$; anger: $t(47) = 4.019$, $p < 0.001$; joy: $t(47) = 6.895$, $p < 0.001$]. Thereby, the increase of fixation bias scores from epoch 1 to epoch 2 was apparently bigger for happy and pain faces than for angry faces, leading to a significant difference between happy and angry faces [$t(47) = -3.800$; $p < 0.001$] and a marginally significant (Bonferroni-corrected $\alpha' = 0.017$) difference between pain and angry faces [$t(47) = -2.261$; $p = 0.028$].

Fig. 3 further reveals that the fixation bias scores in epochs 3 and 4 remained at the level of epoch 2 for happy and angry faces, while fixation bias scores of pain faces dropped in epochs 3 and 4. t -tests confirmed this impression. The fixation bias scores for pain faces decreased significantly from epoch 2 to both epoch 3 and epoch 4 [$t(47) = 2.912$, $p = 0.005$; $t(47) = 2.983$, $p = 0.005$], respectively, while the fixation bias scores for happy and angry faces remained stable (all $ps > 0.05$). In addition, in epochs 3 and 4, the fixation bias scores for pain faces were significantly smaller than the fixation bias scores for happy faces [epoch 3: $t(47) = -3.526$, $p = 0.001$; epoch 4: $t(47) = 3.008$, $p = 0.004$]. In contrast, the fixation bias scores for pain faces and angry faces did not differ in epoch 3

[$t(47) = -0.802$; $p = 0.426$] and in epoch 4 [$t(47) = 1.851$; $p = 0.070$]. In sum, the post hoc analyses of fixation bias scores clearly suggested that pain faces captured attention in epoch 1 and especially in epoch 2 as the other two emotional stimulus classes did but were increasingly less observed in epochs 3 and 4 relative to the other two emotional stimulus classes.

For the purpose of detailing the interaction of the factor ‘stimulus class’ and the covariate ‘FPQ-score’, bivariate correlations between the FPQ score and the overall fixation bias scores (aggregated over the four epochs) were computed for each stimulus class. However, none of the three resulting correlations reached significance ($r_{\text{pain}} = 0.240$, $p = 0.100$; $r_{\text{anger}} = 0.233$; $p = 0.111$; $r_{\text{joy}} = -0.065$; $p = 0.661$); one might see a slight tendency that high FPQ scores were associated with prolonged fixation durations of stimuli with a negative-emotional valence (pain, anger) relative to neutral stimuli.

4. Discussion

The objective of the present study was the investigation of the time course of gaze behaviour while observing pain faces compared with other emotional faces (anger, joy). The results were the following. (1) The initial attentional orientation measured via the first fixations did not reveal an early capture by emotional faces. In case of pain faces, rather the opposite seemed to be true. (2) However, participants gazed at emotional faces including pain faces on average longer than at neutral ones. (3) Furthermore, the time course of attention allocation differed between the emotional categories. Between 500 and 1000 ms (epoch 2), a strong attentional preference for happy and pain faces developed, whereas the fixation bias scores for angry faces increased but not to the level of the happy and pain faces. (4) While the bias scores for angry and happy faces remained stable in epochs 3 and 4, the bias score for pain faces decreased significantly from 1000 to 2000 ms.

4.1 Pain-specific time course of gaze behaviour

Our results indicate a distinct and – compared with the other emotional stimuli – unique time course of gaze behaviour elicited by pain faces. After an initially slight attentional preference in epoch 1 (0–500 ms) compared with neutral faces, a clear preference for pain faces developed in epoch 2 (500–1000 ms). However, we observed in turn a decline of preference for the pain faces in the later epochs 3 and 4 (1000–

2000 ms). This decline in fixation durations was pain specific as the bias scores for anger and joy faces remained stable over the later phases of the presentation time.

Clearly, we did not find the hypothesized VA pattern because no absolute attentional avoidance of pain faces compared with neutral ones occurred. Even in the later epochs, attention was still captured by pain faces more than by neutral faces (bias score >0). However, the initial preference declined substantially in epochs 3 and 4 and showed clear tendency to disappear. We can only speculate whether absolute attentional avoidance may have occurred in epochs later than 2000 ms. Accordingly, our data do not finally falsify a VA pattern as the pain-specific decline in fixation durations in later epochs drives the gaze pattern in the expected direction.

4.2 Time course of gaze behaviour due to other emotions

There is clear evidence from the present study that also the joy and anger faces affected attention in specific manners. The sustained attentional preference for facial expressions of joy is in line with some studies, which found lasting attentional biases for positive-affective stimuli in healthy participants (Mogg et al., 1991; Calvo and Lang, 2004; Isaacowitz et al., 2006; Nummenmaa et al., 2006; Wieser et al., 2009), although evidence is mixed (Bradley et al., 1998, 2000; Mogg et al., 2000; Keogh et al., 2001a,b; Khatibi et al., 2009; Vervoort et al., 2013).

Angry faces attracted fixations to the least amount among our emotional picture categories. This is in line with studies, which found no general effects for anger faces but vigilance or attentional avoidance only in participants with high fear of negative evaluation (Wieser et al., 2009) or social phobia (Chen et al., 2002).

The clear difference between gaze behaviours elicited by pain and angry faces is one of the most striking findings of our study. The fixation bias score for angry faces remained at a low but stable level from 500 to 2000 ms (epochs 2–4), while the fixation bias score for pain faces substantially increased in epoch 2 and decreased thereafter until epoch 4. Pain-related stimuli have a negative-emotional valence, just as anger-related stimuli have. Hence, the differences cannot solely be explained by the emotional valence of the two stimulus classes. Pain signals might be more imperative and demand for more immediate action than anger signals.

4.3 Fear of pain as influence on gaze behaviour

The role of fear of pain as influence factor on attentional biases for pain-related stimuli requires further discussion. While our data suggest a pain-specific bias pattern in a pain-free sample, which is not dependent on fear of pain, in some former studies biases for pain-related information were only found in healthy individuals and pain patients with strong fear of pain (Keogh et al., 2001a,b; Khatibi et al., 2009; Baum et al., 2013b).

Asmundson and Hadjistavropoulos (2007) could demonstrate that the exact operationalization of fear of pain determines the occurrence of positive or negative findings. When fear of pain was defined as a result of both general and pain-specific fearfulness, the authors found relationship with attentional biases. When a pain-specific measure alone was used – as in our study – such a relationship could not be verified. Furthermore, the missing relationship between gaze behaviour and fear of pain in our study is in line with meta-analytic findings, which have provided similar evidence for behavioural measures of attentional biases (Crombez et al., 2013).

4.4 Evidence for a VA pattern in gaze behaviour

We assumed to find a VA pattern in gaze behaviour when monitoring pain faces. We suggest that the initial vigilance can be seen as an orienting reaction, which allows a fast detection of potentially harmful stimuli. This reaction, however, also leads to an unnecessary confrontation with unpleasant stimuli if coping with pain is either not necessary or impossible. Thus, attentional avoidance of pain-related stimuli may serve as strategy for mood regulation to prevent unnecessary negative feelings (Asmundson et al., 1997; Khatibi et al., 2009). Altogether, a flexible VA pattern of pain-related attention may be adaptive. However, increased vigilance, i.e., hypervigilance, may lead to an excessive and rigid processing of painful stimuli at the expense of other stimuli which may result in a dysfunctional dominance of pain. On the other hand, a complete loss of vigilance or even attentional avoidance may in turn prevent any active confrontation with pain, which is necessary to develop and optimize coping strategies.

The question arises whether we have produced any firm evidence for a VA pattern in gaze behaviour while monitoring pain faces. The early vigilance phase could be clearly demonstrated. However, although vigilance

declined indeed markedly thereafter, it still remained at levels, which indicate attentional preference compared with neutral stimuli. Accordingly, we did at best prove a shift towards attentional avoidance but not avoidance itself. It is idle to speculate whether true avoidance would have occurred using longer presentation times. Additionally, it has to be demonstrated in future studies whether attentional avoidance can be confirmed more easily in conditions triggering strong phobic reactions to pain.

An alternative interpretation of the observed gaze pattern is that the pain faces lost their experiential salience more quickly than the angry and joy faces. At the beginning of the presentation time, salience was certainly comparable as could be shown by the comparable bias scores in the first second of presentation. In addition, an earlier study from our own lab, using evoked brain potentials and the same set of pictures, provides evidence for comparable salience of pain and happy faces (Lautenbacher et al., 2013). However, similar initial or average values of salience do not exclude different changes over time.

Another challenge of the VAH remains: The allocation of the first fixations preferentially away from the pain faces and towards the neutral faces in our study suggests initially attentional avoidance rather than vigilance. It might be that this result reflects a very rapid first engagement-disengagement cycle mainly based on automatic and superficial processing and too fast for our eye tracker, which is followed by a second slower cycle with in-depth analyses and voluntary reactions to the stimuli, which could be assessed in our study. A recent study investigating attention to happy and angry faces by means of the attentional blink effect observed both rapid engagement and disengagement from angry faces within the first second of presentation and suggests such rapid allocation of attention (Maratos, 2011).

4.5 Limitations

Even if eye-tracking has been shown to follow most of the shifts of spatial attention continuously and smoothly, it has to be kept in mind that gaze behaviour does not equal attention allocation, but is at best an informative indicator of it. Latent shifts of attention do not manifest in gaze behaviour. Furthermore, since we used a passive viewing paradigm without constant response requirements, we could not control whether the pain- and emotion-related information was indeed processed.

In summary, we found early attentional vigilance for pain faces (up to 1000 ms) followed by a decline of

attentional preference for these stimuli in the next 1000 ms of presentation. This time course of attention to pain faces was different from the time courses for positive (joy) and other negative (anger) emotional stimuli. Fear of pain was not a definite influence on these findings.

Author contributions

J.A.P.: First author of manuscript, data analysis, interpretation of data. M.M.: Acquisition of data, data analysis. S.L.: Supervision, conception and experimental design, interpretation of data, co-author.

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