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Emotion processing of facial affect expression in patients with somatic symptom disorder with predominant pain–An EEG-study

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ABSTRACT

Despite their high prevalence, somatoform pain disorders are often not recognized early enough, not diagnosed reliably enough and not treated appropriately. Patients often experience a high level of suffering and the feeling of not being understood. For the medical care system, the symptoms represent a diagnostic and therapeutic challenge. Having the aim to get a better understanding of the disease, this study investigated the patients' emotion processing. In addition, the influence of surgical masks on facial affect processing was investigated, which has become more important since the onset of the Covid-19. The study involved an electroencephalogram (EEG) experimental paradigm extracting visual event-related potentials (vERP) evoked by emotional faces with and without surgical masks. Overall, the results of the face-related vERP indicate that the healthy control participants process the different emotional faces in a differentiated way. This can be seen from the fact that in this group the amplitudes of the vERP differ according to the different affects. In contrast, the patient group does not show any affect-specific potential differences in the vERP components. Besides, in healthy control participants, masks appear to limit the brain's ability to process emotions by hiding important facial information. Patients do not show any differences in the way they process images with and without masks, which suggests that patients generally process this content more rudimentary.

1. Introduction

According to the fifth edition of the Diagnostic and statistical manual of mental disorders (DSM-5) the "Somatic symptom disorder" (300.82, F45.1) specifies a subcategory for individuals with somatic symptoms that predominantly incorporate pain (American Psychiatric Association, 2013). Characteristics are excruciating pain symptoms (lasting >6 months) with excessive thoughts, feelings and behavior and severe distress related to the pain. The pain is persistent independent on whether or not related somatic lesions are continuously present. The pain usually occurs flexibly in several places and is not deliberately feigned. Moreover, pain symptoms are associated with emotional conflicts or psychosocial stresses (Roenneberg et al., 2018). Several studies have shown that emotions are significantly associated with pain in patients with somatoform pain disorders (Price, 2002; Dimsdale and Dantzer, 2007; Wiech and Tracey, 2009). For example, it has been demonstrated that certain emotions and their processing can influence pain (Wiech and Tracey, 2009; Berna et al., 2010). Negative emotions, for example, increase pain sensitivity and brain activity triggered by pain in patients with chronic pain disorders compared to controls (Burns, 2006). A sad state of mind can lead to a greater subjective perception of pain intensity (Lehoux and Abbott, 2011).

The limited recognition of emotional aspects and differentiation of social interaction is summarized by the term "alexithymia". As a vulnerability factor that promotes the occurrence of psychological or psychosomatic complaints, it occurs more frequently in patients with somatoform pain disorder. During somatosensory amplification, affect-accompanying physiological reactions become persistent symptoms. Then symptoms mutate into affect equivalents. This contributes significantly to the development and maintenance of the disease (Burba et al., 2006; Franz et al., 2007; Peng et al., 2019; Preece et al., 2023).

There are different ways to measure the influence of emotions in pain patients. Some studies use visual event-related potentials (vERP) to investigate the processing of emotional visual stimuli in patients with

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mental disorders such as major depressive disorder or attachment anxiety (Peng et al., 2019; Ye et al., 2019; Irak et al., 2020; Kuang et al., 2021; Valt et al., 2021). The presentation of faces is typically followed by electrical activity of certain neuronal networks in the brain, which can be recorded by an electroencephalogram (= EEG). In general, faces occupy a special place in everyday social interactions (Kanwisher and Yovel, 2006). Various cortical networks, such as the fusiform face area, are involved in processing these stimuli (Bokde et al., 2005). The increased activity of these networks after visual face stimuli can be derived by using EEG techniques and temporally coupled vERP can be extracted.

The time-synchronized, averaged measurement distances after visual stimuli result in different components of the potential curve. The first vERP component to be considered is P1. It shows a positive amplitude from 100 ms to 120 ms after the visual stimulus (Itier and Taylor, 2002; Taylor, 2002; Sass et al., 2017). It is one of the early-occurring components of the vERP and it is associated with early perception and rapid processing of visual stimuli. In the literature, there are different views on whether P1 is sensitive to specific emotions (Batty and Taylor, 2003; Santesso et al., 2008; Sass et al., 2017). Some studies suggest an effect of different stimulus response at different brightness contrasts (Itier and Taylor, 2002). A study investigating the effect of faces with and without masks on emotion processing in a healthy experimental group showed no relevant differences in terms of P1 peak height (Prete et al., 2022). Regarding face processing, N170 is one of the most studied component of vERP (Hinojosa et al., 2015). It describes an averaged, temporally synchronized measurement section from 140 to 200 ms after stimulus onset. It shows a characteristic potential curve (N170). In particular, the presentation of faces leads to higher amplitudes compared to the presentation of objects, animals or hands (Bötzel et al., 1995; Bentin, 1996; Blau et al., 2007; Maffei et al., 2021; Valt et al., 2021). The sensitivity of N170 to specific facial expressions suggests that there is not necessarily only isolated face perception, as initially claimed by Bruce & Young (Bruce and Young, 1986). Rather, several studies indicated that the amplitude and latency of N170 might be influenced by specific emotional facial expressions (Blau et al., 2007; Leppänen et al., 2007; Irak et al., 2020; Maffei et al., 2021). Not only the perception of faces, but also the analysis of certain structural characteristics of a face takes place in this period. Particularly high amplitudes of N170 were shown in experiments with presentation of isolated eyes (Bentin, 1996; Eimer et al., 2011). A study examining the amplitude of N170 after the presentation of faces covered with masks also found particularly high N170 amplitudes (Prete et al., 2022). One can assume that structural features in faces are analyzed in this phase (Han et al., 2021). Between 180 and 250 ms after stimulus-onset there is again a positive amplitude, which is another component of vERP. It is called P2 and it is modulated by the specific attention given to a stimulus. A study examining fibromyalgia patients found that patients showed greater P2 amplitudes during pain-associated facial expressions. It suggests that patients with somatoform disorder also may be more attentive to pain and therefore show a higher rash during anhedonic facial expressions (Fischer-Jbali et al., 2022). Another study investigated the influence of masked faces on P2 amplitude in a healthy population. It could be demonstrated that smaller P2 amplitudes resulted after the presentation of faces with masks than after faces without masks (Prete, D'Anselmo and Tommasi, 2022). Therefore, one could assume that the processing of emotions in healthy people depends significantly on how much of the face is covered. There may be differences in the P2 amplitude of patients with somatoform pain disorder compared to healthy people, which was not investigated in the study just mentioned. Based on the knowledge of previous studies, we considered it relevant to examine whether emotion processing is impaired in patients with somatoform pain disorder. In addition, influencing factors are to be identified. It is expected that patients with somatoform pain disorder show a reduced ability to recognize defined emotional expressions compared to healthy control participants at the same age. We expect an associated deviating brain activity. We aimed also to identify similarities and differences in processes of emotion perception and processing between the two groups (Ça and Poyraz, 2016). vERP, which are temporally related to the presentation of facial affect expression, will be examined. We hypothesized that patients with somatoform pain disorder show deviant response patterns in the vERP components of the EEG (P1, N170, P2) in response to facial affect compared to healthy control participants (Peng et al., 2019; Ye et al., 2019; Schindler and Bublatzky, 2020). Moreover, in the group of patients with somatoform pain disorder, higher questionnaire scores are expected for alexithymia, depression, anxiety, somatization and post-traumatic stress disorder, which correlate with the psychophysiological parameters (EEG). In addition, the possible influence of pictures of emotional faces with masks will be investigated. Some studies have already shown that the perception and processing of emotions is significantly impaired when viewing faces with masks (Carbon, 2020; Grundmann et al., 2021; Noyes et al., 2021; Amadeo et al., 2022; Prete et al., 2022). The influence of faces with masks on emotion processing in patients with somatoform pain disorder compared to healthy control participants has not yet been investigated. It is therefore hypothesized that faces with masks will be processed more subliminally, potentially leading to greater difficulty in emotion recognition due to reduced visual cues. Previous studies have explored the deficits in processing emotional information in somatoform disorder patients. However, the impact of faces with masks on their emotional processing remains underexplored. It can therefore be assumed that a mask/no mask paradigm can react more sensitively to subtle differences in emotional processing. Masks obscure parts of the face that are crucial for emotion recognition (e.g. the mouth), which may amplify existing deficits in somatoform patients. Furthermore, masked faces might engage more subliminal processing pathways, providing insights into how somatoform patients process incomplete emotional information. Given the increased use of masks in daily life (e.g., due to health protocols), understanding how somatoform patients process masked faces has practical implications for their social interactions and therapeutic interventions.

2. Materials and methods

2.1. Sample size and effect size

To determine the number of participants, a power analysis was performed using the program G*Power 3.1.9.7 (Faul et al., 2007). In the $2 \times 3 \times 2$ analysis of variance (ANOVA), the group affiliation represents the between-subject factor (two levels: patients vs. controls) and the emotion (three levels: sadness, anger, joy) and the mask (two levels: with / without) represent the within-subject factors. In order to detect an effect with a mean assumed effect size ($f = 0.25$) (Cohen, 1988) with a test power of 80 % and an α error probability of $p = 0.05$, a total sample size of at least $n = 34$ is required with an assumed correlation of $r = 0.50$ between the within-subject factors. In order to compensate for possible data losses due to for example technical errors or participant withdrawals, the sample size must be increased. Based on a similar study with a different question, which included a sample of $n = 39$, the sample size was increased to $n = 40$ ($n = 20$ per group) in the study conducted here (Irak et al., 2020).

2.2. Participants

Twenty patients (16 women, 4 men) with somatoform pain disorder fulfilling the diagnostic criteria of the International Classification of Diseases (ICD-10) and a mean age of 50 (± 11) years were recruited from the LVR Hospital in Düsseldorf (Department for Psychosomatic Medicine and Psychotherapy of the HHU). Patients being on the waiting list for inpatient admission were invited by mail. Inclusion criteria for patients included the diagnosis of somatoform pain disorder according to ICD-10 criteria and an age over 18 and below 65 years. The group of twenty healthy control participants was matched by age (± five years)

and sex. It was recruited via notices with the most important information about the study on campus and via social media. Participants in the control group were not allowed to have any psychiatric diagnosis.

Exclusion criteria for all participants are presented in the following:

- alcohol/ substance abuse
- current use (defined as a period within the last 4 weeks) of psychotropic drugs during the time of study participation
- the intake of antidepressants (SSRI, SSNRI, SNRI, TCA, NaSSA or SARI type) with no stable dose for at least 14 days
- the presence of a severe, acute somatic illness requiring urgent treatment
- an uncorrected visual loss

Exclusion criteria for the healthy control participants:

- a current mental disorder or one of the following mental disorders: affective disorder, psychotic disorder in the past
- any neurological or degenerative disease, past brain surgery, and the presence of epilepsy or organic disease

All the criterions were checked before and the participants were asked to sign the declaration of consent. A positive vote by the Ethics Committee of the Medical Faculty of the Heinrich-Heine University Düsseldorf has been available since 15/03/2021. The number is 2020 - 1136.

2.3. Psychometric evaluation

The participants received a personal link to complete the questionnaires via a German website called “Umfrage-online” before the survey appointment. The Toronto Alexithymia Scale (=TAS-20) (Greenberg, 1997) has been used to assess alexithymia. Bagby et al. had determined a Cronbach’s α of 0.81 for the sum value of the original version of the TAS-20 (Bagby, Parker and Taylor, 1994). The term was first introduced by Sifneos (Sifneos, 1972). Alexithymia literally means "no words for feelings" (Franz et al., 2001). In addition, we used the PHQ-D that aims to facilitate the diagnosis of the most common mental disorders. It can be used for initial diagnosis as well as for the assessment of mental disorders during their course. For the assessment of somatization symptoms, depressive symptoms and anxiety symptoms, it is subdivided into the subscales PHQ-15, PHQ-9 and GAD-7 (Löwe et al., 2002; Gräfe et al., 2004; Spitzer et al., 2006). The depression scale has an internal consistency according to Cronbach $\alpha = 0.88$, whereas the somatization scale has an internal consistency according to Cronbach $\alpha = 0.79$. For the anxiety scale, the calculation of an internal consistency is not meaningful, since the evaluation is categorical (Gräfe et al., 2004). Furthermore, the screening instrument PTSS-10 was used to assess PTSD. It asks about trauma-associated symptoms within the last seven days (Wirtz, Overkamp and Schellong, 2004). The internal consistency is $\alpha = 0.85$ according to Cronbach (Schüffel et al., 1989).

2.4. Stimuli

In the experiment, 156 static images with a presentation duration of 2000 ms were presented in a randomized sequence. They were taken from the study "Adults’ facial reaction to affective facial expressions of children and adults" (Müller et al., 2019). Here, based on the Karolinska Directed Emotional Faces Set (Lundqvist, Flykt and Öhman, 1998) 5 affective portraits were further processed using Abrosoft Fantamorph Deluxe. Video clips were created that presented facial affects showing a progression starting from neutral to maximum affective expression ("apex"). The static images shown in the study represent the apex. Additionally, faces of men and women (equally divided) with the emotions joy, anger and sadness were shown with and without a mask. The images were separated by intertrial intervals (600 to 2000 ms), which include a white screen with a black fixation cross in the center. This is intended on the one hand to direct the participants’ concentration to the center of the screen, and on the other hand to reduce potentially distracting eye movements (Sutton et al., 1965). The set of 156 stimuli takes a total presentation time of about 8 min (see Fig. 1).

2.5. Procedure

During the measurement participants sat comfortably on a chair in a room without windows at a distance of one meter to the computer screen (Philipps, Modell No BDM3270QP). Before viewing the emotions, the participants read instructions presented on the screen which told them to focus on each facial expression. Patients were asked to empathize with the emotional situation. Additionally, they were asked to move as little as possible, maintaining the gaze at the fixation in the center of the screen.

2.6. EEG data collection

The EEG was recorded using a 32 electrodes net placed according to the 10–20 system. During recording as well as offline, FCz was used as a reference electrode. Due to the position of the reference electrode at vertex height in the centre, artefacts caused by facial expressions and movements can be reduced. At the beginning of our study there was a written instruction relating to the following experiment. Not only the expected mimic responses with following artefacts had to be minimized but also hemisphere effects had to be prevented. The skin impedance was measured before the recording and kept below 10 kΩ. A digital signal processor of the type V-Amp 1® from the manufacturer “Brain Products GmBH” was used for digital recording, processing, amplification and transmission of the signals via a USB connection to the recording PC. There, the electrical signals were recorded by “BrainVision Recorder® software” (‘BrainVision Recorder’, 2020). An 8-bit connection enabled the transmission of the image information associated with the stimulus material presented from the presentation PC to the recording PC. The image information was recoded according to the information (anger, joy, sadness, male, female, with mask, without mask). Together with the raw EEG data, the image information was then transferred to the recording PC via USB.

2.7. EEG data analysis

The EEG data was filtered by using the version 2.3 of the software "Brain Vision Analyzer" (‘BrainVision Analyzer’, 2019) as a derivative of the electrical activity (in μV) over the corresponding brain areas and cleaned of artefacts. This was followed by a parameterization, which comprises the processing steps to be carried out on the raw EEG signal in “BrainVision Analyzer” for further statistical evaluation.

2.8. Statistical analysis

The questionnaires’ data and EEG data were pseudonymized, stored electronically and statistically analyzed using SPSS version 27 (IBM Corp., 2020). The significance level was set at $p < 0.05$ (2-sided). The data were checked for normal distribution using the Kolmogorov-Smirnov test (Duller, 2008, p. 108). Pearson correlation coefficients were used to calculate correlations between normally distributed and interval-scaled data. In the case of unclear scale level and/ or lack of variance homogeneity, correlations were carried out using Spearman correlations. All descriptive data are presented as means ± standard deviation (M ±SD). Group comparisons of interval scaled data were performed as ANOVA and t-tests. For variables with repeated measures, appropriate tests and correction procedures were used as needed. For both groups, a peak analysis of the ERP components was carried out with regard to differences in brain activity in relation to the different pictures. Analyses of variance were used to investigate the

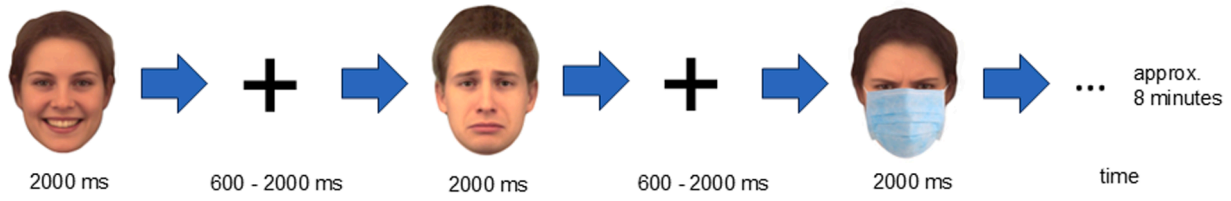

Fig. 1. EEG paradigm (156 emotional face stimuli (anger/joy/sadness) with/without mask (2000 ms) separated by an intertrial interval (fixation cross) (600 – 2000 ms).

main effects of the factors "emotion" (anger, joy, sadness), "mask" (with, without) and "group" (patients, healthy control participants), as well as the interaction between these factors. The psychophysiological data was compared with regard to the different experimental conditions (anger, joy, sadness) in both groups.

3. Results

3.1. Psychometric results

TAS-20

Among the patients, 15 out of 20 had a sum score of ≥ 61 points and five out 20 were placed below the cut-off (Greenberg et al., 1997), indicating a clinically meaningful level of alexithymia in 3 out of 4 pain patients. The healthy control participants were all below the empirically based "cut-off value of ≥ 61 points" (Taylor et al., 1997). The two groups differed significantly from each other in this questionnaire, t (38) = 7.56, $p < 0.001$ (see Table 1). Averaged sum values (M) and standard deviations (SD) of the two groups are shown in Table 2.

PHQ-D

The PHQ-D questionnaire consists of three subscales: PHQ-9, PHQ-15 and GAD-7. The sum score PHQ-9 captures the subscale for depression and is calculated from the sum of the following items: 14,15,16,17,18,19,20,21 and 22. The patients had significantly more depressive symptoms than the healthy control participants, t (27.29) = 8.76, $p < 0.001$ (see Tables 1 and 2). The cut-off value for a mild depression is ≥10 (Kroenke et al., 2001). The sum score PHQ-15 is a subscale for somatoform complaints (items 1–13 with somatic symptoms and items 16 and 17 of the depression module). The cut-off value for a somatization is ≥10 (Kroenke et al., 2002). Table 1 describes the results of the sample. Patients showed a significantly higher symptom intensity than healthy control participants, t (32.84) = 7.17, $p < 0.001$ (see Tables 1, 2 and Fig. 2). Items 23–29 result in the anxiety disorder subscale (GAD-7), which is discussed below. The cut-off chosen based on a previous meta-analysis is ≥8 (Plummer et al., 2016). The patient group showed significantly more anxiety symptoms than the healthy control participants (see Tables 1, 2 and Fig. 2).

PTSS-10

Table 1
t-tests of psychometric questionnaires TAS-20 (Toronto Alexithymia Scale), PHQ-9 (Patient Health Questionnaire, subscale for depression), PHQ-15 (Patient Health Questionnaire, subscale for somatoform complaints), GAD-7 (Generalized Anxiety Disorder Scale-7), PTSS-10 (Posttraumatic Symptom Scale), t = *t*-tests, df = degrees of freedom, p = *p*-value.

test	t	df	p	Average difference	95 % confidence interval	
					lower value	upper value
TAS-20	7.56	38.00	0.00	22.45	16.44	28.46
PHQ-15	7.17	32.84	0.00	12.45	8.92	15.98
PHQ-9	8.76	27.29	0.00	11.85	9.08	14.62
GAD-7	6.96	29.75	0.00	8.10	5.72	10.48
PTSS-10	7.65	38.00	0.00	23.45	17.25	29.65

Table 2
averaged sum values (M) and standard deviations (SD) in both groups in TAS-20 (Toronto Alexithymia Scale), PHQ-9 (Patient Health Questionnaire, subscale for depression), PHQ-15 (Patient Health Questionnaire, subscale for somatoform complaints), GAD-7 (Generalized Anxiety Disorder Scale-7), PTSS-10 (Post-traumatic Symptom Scale).

	patients	healthy control participants
TAS-20	61.85 ± 10.56	39.40 ± 8.04
PHQ-15	16.70 ± 6.49	4.25 ± 4.27
PHQ-9	14.95 ± 5.45	3.10 ± 2.61
GAD-7	10.85 ± 4.55	2.75 ± 2.53
PTSS-10	32.00 ± 12.18	8.55 ± 6.27

The questionnaire for PTSD showed that all patients had scores above the cut-off value (Wirtz et al., 2004). PTSD is suspected from a total score of 12 points. This means that all patients had post-traumatic stress symptoms. There was a significant difference with regard to PTSD in the patients compared to the healthy control participants, t (38) = 7.65, $p < 0.001$ (see Tables 1, 2 and Fig. 2).

3.2. ERP-results

Studies investigating the perception of emotional facial expressions showed that the processing of structural and emotional facial features can be investigated in different vERP components (Hinojosa et al., 2015; Han et al., 2021; Song et al., 2022). They are derived in specific electrodes and have an indirect topographical reference to the neuronal networks such as fusiform face area (Holmes et al., 2009; Hinojosa et al., 2015).

3.3. P1 amplitude and latency

For the analysis of P1, that is peaking around 100 ms, the occipital electrodes O1 (left) and O2 (right) were considered for the analysis (Liu et al., 2022). The mixed ANOVA (2 × 3 × 2) with the between-participants factor "group" (patients versus healthy control participants) and the within-participants factors "emotion" (joy, sadness, anger) and "mask" (with and without) revealed neither significant main effects nor significant interactions for P1 amplitude nor for P1 latency ($p > 0.05$ for all comparisons).

3.4. N170 amplitude and latency

According to the most common studies for the N170 peak analysis and grand average calculation in both groups the electrodes P7 (left) and P8 (right) were chosen. Additionally, the time slot between 160 and 280 ms after facial affect presentation was selected (Hinojosa et al., 2015). A mixed ANOVA (2 × 3 × 2) concerning N170 amplitude with the between-participant factor of "group" (patients versus healthy control participants) and the within-participant factors "emotion" (joy, sadness, anger) and "mask" (with and without) revealed a main effect of "mask" F (32.99,1) = 38; $p < 0.001$, η_p^2=0.47. The mean height of N170 peak was significantly higher after facial affect presentation with masks in comparison to facial affect presentation without masks in both groups

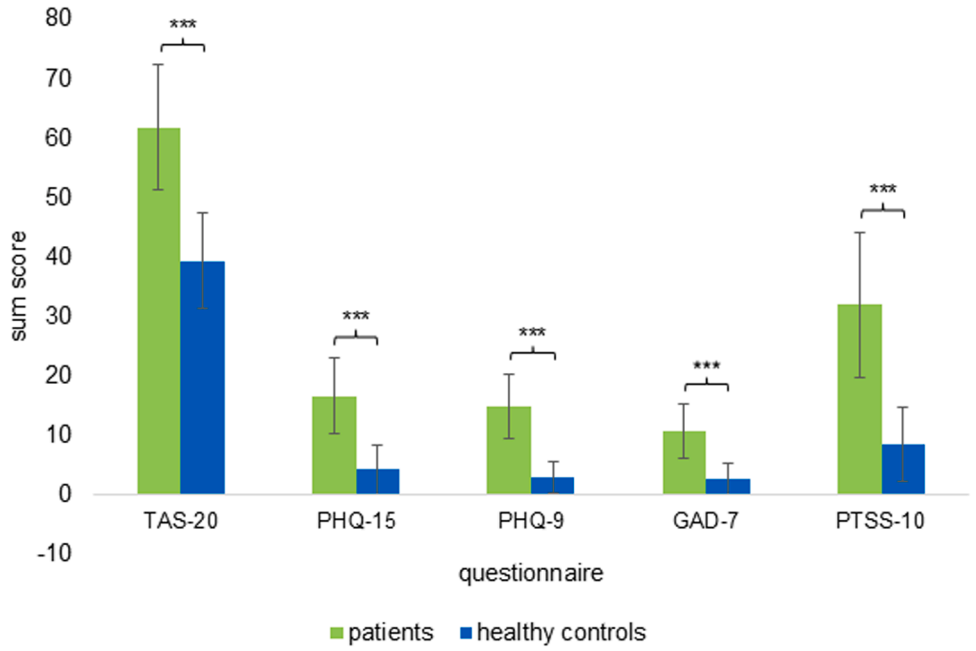

Fig. 2. averaged sum scores of both groups in TAS-20 (Toronto Alexithymia Scale), PHQ-9 (Patient Health Questionnaire, subscale for depression), PHQ-15 (Patient Health Questionnaire, subscale for somatoform complaints), GAD-7 (Generalized Anxiety Disorder Scale-7), PTSS-10 (Posttraumatic Symptom Scale); patients are represented in green, healthy controls in blue. Error bars represent standard deviation (±SD), and the asterisk indicates a significant difference (*** $p < 0.001$).

(without: $M = -4.35$ μV ±4.27 μV, with: $M = -7.53$ μV ±5.73 μV). This effect is shown for both groups in Fig. 3(A1).

The mixed ANOVA with a between-participant factor of "group" (patients versus healthy control participants) and the within-participant factors "emotion" (joy, sadness, anger) and "mask" (with and without) concerning N170 latency revealed a main effect on "emotion" that approached significance, $F(75.54,1.99) = 3.16$, $p = 0.05$, $\eta_p^2 = 0.76$. The pairwise post-hoc comparisons showed that the significant interactions in the latency of N170 were influenced by differences between sadness and anger in healthy control participants (see Table 3).

3.5. P2 amplitude and latency

For the evaluation of the P2 peaks, the amplitudes of the central electrodes (C3, C4 and Cz) were averaged (Gole et al., 2012; Tanovic et al., 2018). As summarized in Table 4, a mixed ANOVA (2 × 3 × 2) with a between factor of "group" (patients vs. healthy control participants), and within factors of "emotion" (joy, sadness, anger) and mask

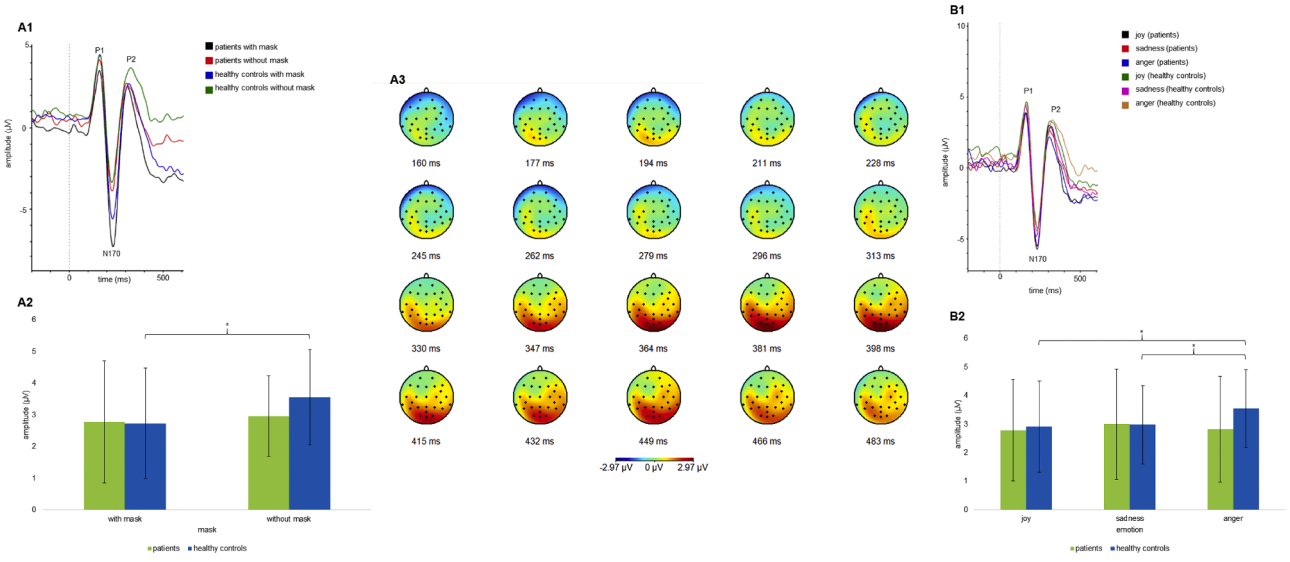

Fig. 3. (A1) The grand average of ERP waveforms for faces with a mask in patients (black), without a mask in patients (red), with a mask in healthy controls (blue) and without a mask in healthy controls (green) at P7 (for better visualization) in the time window from 200 ms before to 500 ms after facial affect presentation. (A2 Interaction between mask and group for P2 amplitude in μV at C3, C4 and Cz patients are represented in green, healthy controls in blue. Error bars represent standard deviation (±SD), and the asterisk indicates a significant difference (*$p < 0.05$)
(B1) The grand average of ERP waveforms for patients after the presentation of joyful faces (black), sad faces (red) and angry faces (blue) in comparison to the grand average of ERP waveforms for healthy controls after the presentation of joyful faces (green), sad faces (pink) and angry faces (brown) at P7 (for better visualization) in the time window from 200 ms before to 500 ms. (B2) Interaction between emotion and group for P2 amplitude in uV at C3, C4 and Cz, patients are represented in green, healthy controls in blue. Error bars represent standard deviation (±SD), and the asterisk indicates a significant difference (*$p < 0.05$).

Table 3
Pairwise post-hoc comparisons concerning the main factor "emotion" in N170.

emotion	emotion	mean value difference	p[b]	95 % confidence interval for difference[b]	
				lower value	upper value
joy	sadness	1.44	0.43	−2.23	5.12
	anger	−3.04	0.12	−6.89	0.80
sadness	joy	−1.44	0.43	−5.12	2.23
	anger	−4.49*	0.02	−8.09	−0.89
anger	joy	3.04	0.12	−0.80	6.89
	sadness	4.49*	0.02	0.89	8.09

*Mean difference is significant at 0.05 level. b. Adjustment for multiple comparisons: Least significant difference (corresponds to no correction) $p = p$-value.

Table 4
Mixed ANOVA (2 × 3 × 2) with a between factor of "group" (patients vs. healthy control participants), and within factors of "emotion" (joy, sadness, anger) and mask (with, without) in P2.

	Df	Mean of squares	F[a]	p	partial eta-square	decentered parameterization[b]
emotion	1.95	2.33	2.48	0.09	0.06	4.82
emotion * group	1.95	3.27	3.48	0.04	0.08	6.77
mask	1.00	15.03	13.02	0.00	0.26	13.02
mask * group	1.00	6.18	5.35	0.03	0.12	5.35
emotion * mask	1.85	1.75	1.73	0.19	0.04	3.20
emotion * mask * group	1.85	1.56	1.54	0.22	0.04	2.84
group	1.00	4.50	0.31	0.58	0.01	0.31

a) using alpha = 0.05; b) Greenhouse-Geisser correction for degrees of freedom was applied.
Df = Degrees of freedom, $F = F$-test, $p = p$-value.

(with, without) revealed a main effect of "mask" F (38,1) = 13.02; $p < 0.001$; $\eta_p^2 < 0.001$ on the P2 peak. In both groups, there were flatter P2 peaks after facial affect presentation with masks than without masks (see Fig. 3(A1)).

Furthermore, the mixed ANOVA (2 × 3 × 2) showed that P2 amplitudes were significantly modulated by the interaction between "mask" and "group", F (38,1) = 5.35; $p = 0.03$; ηp2=0.12 (see Table 4). While P2 amplitudes differed significantly between masked and unmasked faces for controls (masked: 2.73 μV ±1.27 μV; unmasked: M = 3.55 μV ±1.51 μV, $p = 0.03$), they did not differ significantly within the patient group (masked: M = 2.78 μV ±1.92 μV; unmasked: 2.96 μV ±1.74 μV, $p > 0.05$) (Fig. 3(A1) and (A2)).

(A2) Interaction between mask and group for P2 amplitude in μV at C3,C4 and Cz, patients are represented in green, healthy controls in blue. Error bars represent standard deviation (±SD), and the asterisk indicates a significant difference (* $p < 0.05$).
(A3) Temporal evolution of the topographic maps over the entire scalp in images without masks for the interval from 160 - 500 ms, showing the difference between patients and healthy controls.
(B1) The grand average of ERP waveforms for patients after the presentation of joyful faces (black), sad faces (red) and angry faces (blue) in comparison to the grand average of ERP waveforms for healthy controls after the presentation of joyful faces (green), sad faces (pink) and angry faces (brown) at P7 (for better visualization) in the time window from 200 ms before to 500 ms.
(B2) Interaction between emotion and group for P2 amplitude in μV at C3, C4 and Cz, patients are represented in green, healthy controls in blue. Error bars represent standard deviation (±SD), and the asterisk indicates a significant difference (* $p < 0.05$).

Fig. 3(A3) shows the topographical activity pattern over the entire scalp during the period 160 to 500 ms after images without masks. The difference between the two groups is clearly pronounced in the occipital area.

Furthermore, the mixed ANOVA showed another interaction between "emotion" and "group", F (73.90,1.95) = 3.48; $p = 0.04$, η_p^2=0.08 (see Table 4). The post hoc pairwise comparisons showed that the significant interactions could be regulated through differences between anger and sadness and also between anger and joy for healthy controls (see Table 5, Fig. 3(B2). In Fig. 3(B1) the grand average of ERP waveforms for patients and healthy control participants at P7 in the time window from 200 ms before to 500 ms after the presentation of angry, sad and joyful faces is demonstrated. It can be seen, that the P2 amplitudes after angry faces are significantly higher in the healthy control group (brown) in comparison to the patients (black) (see Fig. 3(B1)).

The mixed ANOVA (2 × 3 × 2) with the between-participant factor of "group" (patients versus healthy control participants) and the within-participant factors "emotion" (joy, sadness, anger) and "mask" (with and without) concerning P2 latency revealed the main effect on "mask". In the whole sample, there were shorter latencies after images with masks compared to images without masks (with: M = 422.12 ms ±56.57 ms, without: M = 399.87 ms ±60.65 ms).

4. Discussion

The objective of the study was to elicit emotion processing in patients with somatoform pain disorder in comparison to healthy control participants using psychometric questionnaires and vERP after the presentation of an emotional face paradigm. In addition, we aimed to investigate the effect of masks on emotional face processing in these two groups.

Psychometric data. The questionnaires TAS-20, PHQ-D and PTSS-10 were used in the study. Numerous additional symptoms in patients with somatoform pain disorder were identified. This underlines the frequent presence of psychological stress in patients with somatoform disorder (Pieh et al., 2011).

The fact that 70 % of the patients and none of the healthy control participants in the TAS-20 fulfilled the criteria for alexithymia, underlines the importance of this symptom in patients with somatoform pain disorder. Studies have already found many similarities between alexithyme patients and patients with somatoform pain disorder. Both a lower quality of life and a diffuse circumscription of pain symptomatology in people with alexithymia are also seen in patients with somatoform pain disorder (Cox et al., 1994; Garcia Nuñez et al., 2010).

Our findings replicate earlier findings about elevated levels of depression in patients with somatoform pain disorder (Wiborg et al., 2013; Kämpfer et al., 2016). In our study 90 % of the patient group showed depressive symptoms. A large proportion of the patients showed anxiety and somatization symptoms, and even all patients were above the cut-off value for post-traumatic stress disorder (seen Table 2) (Wirtz, Overkamp and Schellong, 2004). The multicenter study by Pieh et al. pointed to the presence of a high comorbidity rate in somatoform disorders, as did the previous study (Pieh et al., 2011).

The PTSS-10 was used to screen for PTSD. Traumatic events in youth are frequent in patients with somatoform pain disorder (Joksimovic and Kruse, 2017). The result in the examined patient group supports this statement, as the entire patient group was clearly above the cut-off value. In the exploratory correlation analyses, it was found that patients with a high sum value in the PTSS-10 often showed higher P2 amplitudes. This suggests that patients are more attentive to many stimuli. Their traumatic experiences in the past may lead to stronger electrophysiological reactions.

P1. No significant differences for P1 amplitude and latency between

Table 5
pairwise post-hoc comparisons concerning the interaction factor group * emotion in P2.

group	emotion	emotion	mean value difference	p[b]	95 % confidence interval for difference[b]	
					lower value	upper value
patients	joy	sadness	−0.21	1.00	−0.77	0.35
		anger	−0.03	1.00	−0.59	0.53
	sadness	joy	0.21	1.00	−0.35	0.77
		anger	0.18	1.00	−0.31	0.67
	anger	joy	0.03	1.00	−0.53	0.59
		sadness	−0.18	1.00	−0.67	0.31
healthy control participants	joy	sadness	−0.07	1.00	−0.63	0.49
		anger	−0.64*	0.02	−1.20	−0.09
	sadness	joy	0.07	1.00	−0.49	0.63
		anger	−0.57*	0.02	−1.06	−0.08
	anger	joy	0.64*	0.02	0.09	1.20
		sadness	0.57*	0.02	0.08	1.06

*Mean difference is significant at 0.05 level. b. Adjustment for multiple comparisons: Least significant difference (corresponds to no correction); $p = p$-value.

patients and healthy control participants were shown in this study. In research on emotion regulation, early vERP components, such as P1, are generally less important than later vERP components (N170, P2), since the processing of emotions in specific cortical networks takes a certain amount of time and therefore mainly influences later vERP (MacNamara et al., 2022; Żochowska et al., 2022). It may be assumed that the altered emotion processing in patients with somatoform pain disorder primarily affects later vERP components. In recent study, which examined the effect of masks in emotional faces using a very similar paradigm in healthy control participants, did not find differences in the peak height of P1 (Prete et al., 2022). This was confirmed in the present study, where the amplitude of P1 was not significantly affected after masked faces. In contrast, other studies found that certain emotional facial expressions such as anger modulate the height of P1 when compared to neutral faces (Naumann et al., 2022; Song et al., 2022). However, it is questionable whether this finding can be compared with the present study, because our paradigm did not involve neutral faces.

N170. One of the most important components of face processing is N170 (Hinojosa et al., 2015). In line with previous evidence, the amplitude of N170 was modulated by structural factors (Blau et al., 2007; Hinojosa et al., 2015; Han et al., 2021). For example, these structural factors can be glasses or the appearance of an emotional face with a larger mouth and teeth instead of a neutral face (Cao et al., 2016; Song et al., 2022). A previous study investigating the neural response to masked faces due to COVID-19 pandemic in healthy control participants showed almost significantly higher amplitudes of N170 response to masked faces compared to unmasked faces (Prete et al., 2022). One could hypothesize that N170 is modulated by the attention generated by a face shown with special structural properties. In the present study with twice as many participants, the effect of the mask on the N170 amplitude was highly significant. It should be noted that masks significantly change the structure of faces, leading to higher amplitudes of N170 after masked faces in comparison to unmasked faces. Masks lead to more intensive processing and seem to increase attention due to their structural change. Other studies that showing similar results, emphasize that structural characteristics of faces rather than emotional expressions in faces are processed in N170 (Han et al., 2021; Żochowska et al., 2022).

In the following, the latency differences of N170 are interpreted, which varied by the pictures with changing emotions and the use of masks. After pictures without masks, the emotions sadness and joy resulted in significantly shorter latencies across the sample. From an evolutionary perspective, facial expressions are an important non-verbal resource of expressing and communicating emotional states in humans (Schindler and Bublatzky, 2020). Giel et al. propose that a blunted reaction to anhedonic emotional stimuli, such as sadness, represents an evolutionary failure of the attention system. In such cases, individuals attempt to suppress negative emotions and their processing. This behavior may contribute to the development and maintenance of chronic pain (Giel et al., 2018).

The recognition and processing of these emotions seemed to be accelerated when faces were not obscured by masks. Some studies already indicate slower recognition and processing of a facial expression by masks (Eisenbarth and Alpers, 2011; Prete, D'Anselmo and Tommasi, 2022).The recognition and processing process and thus the latency of N170 take longer when faces are not seen in their entirety (Chu, Wang and Wang, 2007). For the emotion joy, the lower part of the face seems to be particularly important (Eisenbarth and Alpers, 2011).

In contrast, faces without masks with the emotion anger led to significantly longer latencies for all participants. Anger seems to have a special significance, which increases attention in people. Many studies investigating altered emotion processing in patients with affective disorders (such as depression) found a so-called "negativity bias" (Lawrence et al., 2004; Surguladze et al., 2005; Leppänen et al., 2007). This term reflects a more intense response to anhedonic stimuli and a reduced response to hedonic stimuli. It would seem logical that in patients with somatoform pain disorder, angry facial stimuli lead to a longer and more intense perception and processing compared to healthy control participants, which should be investigated in the future with the help of larger samples.

P2. Consistent with current research, the whole sample showed higher P2 amplitudes after images without masks than after images with masks (Amadeo et al., 2022). An obvious reason for this seems to be that masks obscure a large part of the face and thus attenuate emotion processing (Carbon, 2020; Noyes et al., 2021; Amadeo et al., 2022; Naumann et al., 2022). More emotions arrive when faces are not obscured by masks. So far, this influencing effect of masks on emotion processing has not been investigated in patients with somatoform pain disorder.

Therefore, the effect of the masks on the P2 amplitudes in the experimental groups was compared in this study: It can be noted that especially in the control group the P2 amplitude was significantly higher after unmasked faces than after faces with masks.

This observation may be explained by the findings of Ferrari et al. in 2021. The authors argue that face masks that cover the lower half of the face reduce the amount of information that reaches the areas of the brain specialized in processing faces. In addition, the authors hypothesize that long-term functional and structural plasticity at both the cellular and systems level is affected in the long term due to the partial deprivation of visual inputs caused by wearing face masks (Ferrari et al., 2021).

This was not the case in the group of patients with somatoform pain disorder. Here, the images without masks did not lead to higher P2 amplitudes. Consequently, one could assume that the ability of patients with somatoform pain disorder to recognize and process emotions might be fundamentally weakened, which may be expressed by the smaller P2 amplitudes on average. Whether there is a surgical mask that covers the mouth and nose, it does not influence the P2 amplitude in the patient group. This seemingly attenuated response in patients with psychiatric

diseases has also been found in other studies, in line with the study results presented here (Güney et al., 2019). The study by Peng et al. (2019), for example, compared the vERP in patients with somatoform pain disorder and healthy control participants according to pictures that showed painful or non-painful situations. Patients did not show any differences in the vERP after the corresponding stimuli. Healthy control participants, in contrast showed significant differences in vERP after the painful vs. non-painful images (Peng et al., 2019). Overall, these results show that patients not only have difficulties in separating painful from non-painful situations compared to healthy control participants, but also in extracting the presence of masks in faces. One could assume that their ability to differentiate between different influences is reduced. Understanding how somatoform disorder patients process emotional stimuli differently can inform the development of targeted therapeutic interventions. For instance, therapies could be designed to improve emotion recognition skills, especially in contexts where visual cues are limited, such as with masked faces. The study's insights into how masks affect emotional processing can be applied to real-world scenarios, such as social interactions during health crises where mask-wearing is prevalent. This can help in developing strategies to support somatoform patients in navigating social situations more effectively and improved social functioning.

In fact, previous studies demonstrated that face masks may lead to confusion when interpreting other people's face expressions (Carbon, 2020; Kleiser et al., 2022). Specifically, a study by Kleiser in 2022 found that face masks resembling medical face masks significantly impair the neural processing of facial expressions, affecting emotion recognition. Importantly, while the face masks caused delays in recognizing emotions, they did not completely abolish this ability. However, the face mask did not trigger an over-activity of visual cortical areas, which indicate an enhanced effort to compensate for the reduced signal (Kleiser et al., 2022). These findings highlight the impact of face masks on our ability to perceive and interpret emotions, potentially leading to misunderstandings and inadequate reactions by perceivers. It can be assumed that this impairment leads to a significant disadvantage in non-verbal communication and consequently in social interactions (Molnar-Szakacs et al., 2021). Empathically competent people may instinctively notice this loss and become irritated. On the other hand, people with limited emotional competence (as is assumed for patients with somatoform disorders) are possibly less affected by the restricted facial expressions caused by masks, leading to reduced involuntary attention. To explore these differences between patients and healthy subjects with regard to unconscious focusing of attention, we focused on early components of event-related potentials, specifically the N170 and P2 components. The N170 is associated with face perception and identification. We hypothesized that patients and healthy subjects would exhibit distinct N170 responses when processing emotional faces with masks.

When analyzing the P2 amplitude with regard to the individual emotions shown by the faces, the groups differed significantly. While the healthy control participants showed significantly higher P2 amplitudes after angry facial expressions compared to joyful or sad facial expressions, this phenomenon did not occur in the patients. A previous study assumed that facial expression recognition in the P2 phase is taking place in two steps (Han et al., 2021). While the facial structure is recorded in the N170 phase, according to the study, emotion concepts are first extracted in the P2 phase and then individual emotion categories are distinguished. In the study, the presentation of angry facial expressions was followed by a high P2 amplitude in a healthy participant collective, which was significantly higher than after joyful facial expressions (Han et al., 2021). It can therefore be stated that the lack of this high P2 amplitude after angry faces compared to other emotions (here: sadness and joy) in patients with somatoform pain disorder is a relevant aspect that characterizes the group in the study conducted here. Thus, it may be concluded from our data that patients with somatoform pain disorder may always process angry faces as if the other person has a mask on. Patients with somatoform pain disorder could therefore be characterized by both the deficit of a differentiated recognition of the emotion concept and the extraction of individual emotion categories. A study examining a therapeutic approach to dealing with negative emotions in patients with somatoform pain disorder showed that this had a crucial impact on patient's outcome (Yoshino et al., 2019). The results presented here underline the deficit in patients' ability to extract and process negative emotions such as anger, which should be addressed therapeutically. The findings may therefore contribute to more personalized treatment plans by identifying specific areas where patients struggle. For example, if a patient has more difficulty recognizing emotions in masked faces, therapy can focus on enhancing their ability to interpret other social cues. The study adds to the broader understanding of how emotional processing deficits manifest in somatoform disorders. This can lead to more comprehensive approaches in both research and clinical practice, ultimately improving patient outcomes.

According to the "negative bias" described in the evolutionary literature, humans tend to pay more attention to negative or threatening signals in order to ensure their survival and reproductive success. Hedonic signals, on the other hand, help individuals relax and build resilience ((Vaish et al., 2008; Kuang et al., 2021). In the healthy control group, this phenomenon is indicated as high P2 amplitudes following exposure to angry faces. However, Patients deviate from this evolutionary explanation in their processing.

The perception of a masked face may represent a potentially anxiety-inducing signal that interferes with the correct and rapid recognition of others' emotions, but also a decreased P2, which is a higher-order component closely related to inter-individual psychological differences. According to this speculation, modulation of the P2 component could serve as a warning signal, considering previous evidence of P2 changes during face perception in patients with affective domain disorders, such as social anxiety (Eldar et al., 2010; van Peer et al., 2010; Yuan et al., 2014) but also in other clinical conditions such as schizophrenia (Müller et al., 2014).

In a study that electrophysiologically examined emotion processing in patients with fibromyalgia, it was found that patients with comorbid depression have a lower depth of processing of emotional content than healthy control participants (Fischer-Jbali et al., 2022). This result also supports the findings of our study. The absence of the significantly higher P2 amplitudes after angry faces compared to other emotions in patients with somatoform pain disorder could indicate a lower depth of processing. In contrast, healthy control participants seem to clearly extract angry faces from the other emotions sadness and joy.

When looking at the latency of P2 in the whole sample, it was noticeable that masks shortened the processing time. This effect was already observed in the study by Prete et al. (Prete et al., 2022). A possible explanation could be that masks suppress the emotional content of human facial expressions and suppress slow intensive processing. Instead, they lead to faster and presumably more ambiguous processing of the actual affect. Emotions are not properly recognized and attention is more on the mask than on the actual emotion. It can be stated that an intensive and accurate processing of an affect can only take place adequately if the nose and mouth are not covered by masks.

5. Conclusion and future directions

The current study compared emotion processing in patients with somatoform pain disorder with healthy control participants.

Our data show that somatoform pain disorders usually are associated with other psychological stress. Some psychiatric diseases from this group overlap in their development and course. As they often occur side by side as comorbidities, it is still difficult to differentiate on which of the psychiatric illnesses the focus should be placed.

Particularly, in the P2 phase, the amplitudes of the two groups were different. In the group of healthy participants, faces without masks led to significantly higher P2 amplitudes. In patients with somatoform pain

disorder, faces without masks were not followed by higher P2 amplitudes. This suggests that the depth of processing of emotional faces in the patient group is not only suppressed by masks but also suppressed in general. This effect demonstrates their core problem: the recognition and processing of emotions. This was particularly evident in the fact that in healthy control participants, significant differences were found in the P2 amplitudes depending on the emotions shown. This was not seen in the patient group, which shows that the different emotions may not be perceived in such a differentiated way as in the healthy control participants. The flattened recognition and processing of emotions in patients with somatoform pain disorder are thus highlighted.

In summary, the recognition and processing of facially expressed emotions is a relevant deficit in patients with somatoform pain disorder, which must be recognized early and treated specifically, as these processes obtain to the core of human emotional and social communication.

Data availability

The data that support the findings of this study are available on request from the corresponding author*. The data are not publicly available due to restrictions their containing information that could compromise the privacy of research participants.

CRediT authorship contribution statement

Eva Metzen: Writing – original draft, Visualization, Supervision, Software, Methodology, Data curation, Conceptualization. **Mahboobeh Dehghan Nayyeri:** Visualization, Methodology, Data curation, Conceptualization. **Ralf Schäfer:** Visualization, Validation, Software. **Ulrike Dinger:** Supervision. **Matthias Franz:** Visualization, Formal analysis. **Rüdiger Seitz:** Methodology, Data curation. **Jörg Rademacher:** Validation, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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