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Electrophysiological evidence of early processing deficits in alexithymia

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ABSTRACT

Alexithymia describes difficulties to identify and describe one's emotions. Previous research focused on difficulties associated with the later processing stages of appraisal in alexithymia. We tested whether early processing deficits are apparent in alexithymic persons and whether these abnormalities contribute to later processing difficulties. 20 participants were selected and identified as either having high (HDA) or low (LDA) degrees of alexithymia. IAPS pictures were presented while EEG was recorded. For HDA subjects processing of emotional pictures was accompanied by reduced P1 amplitudes most pronounced for pleasant and neutral pictures. In response to unpleasant pictures the P3 amplitudes were reduced. These amplitude modulations were predicted only by one alexithymia facet. P1 amplitudes systematically covaried with P3 amplitudes supporting the assumption that deficits in early emotional processing contribute to later processing deficits.

1. Introduction

Alexithymia, a syndrome that involves a marked inability to identify, describe, regulate, and express one's emotions (Sifneos, 1976; Taylor and Doody, 1985), was originally described by Sifneos in patients with psychosomatic disorders and has been related to a broad range of physical and psychiatric disorders (e.g., alcoholism, drug addiction, and post traumatic stress disorders; see Taylor et al., 1999). At the present time, both within clinical and nonclinical populations, alexithymia is considered a continuous personality trait, with people differing in their ability to identify and describe their feelings (Jessimer and Markham, 1997). The construct of alexithymia is most widely assessed by the Toronto Alexithymia Scale (Bagby et al., 1994), a well-validated self-report questionnaire (Bagby et al., 1994; Mattila et al., 2007; Parker et al., 2003), whereby three main facets, namely *D*ifficulties in *I*dentifying *F*eelings (DIF), *D*ifficulties in *D*escribing *F*eelings (DDF) and *E*xternally *O*riented *T*hinking or a preoccupation with the details of external events (EOT), can be differentiated. There is growing empirical evidence that these facets probably refer to different aspects of emotional processing (Coffey et al., 2003; Luminet et al., 2006; de Timary et al., 2008; Gohm and Clore, 2000) with high intercorrelations between the DIF and DDF subscales and low intercorrelations of the DIF and DDF subscales with the EOT subscale (Gohm and Clore, 2000; de Timary et al., 2008; Parker et al., 2003). In addition, these facets might be differentially linked to observed abnormalities in the processing of stress and negative emotions (de Timary et al., 2008).

Several authors hypothesized that hampered regulation of emotion in alexithymia might be based on deficits in the perception and further processing of emotional stimuli (Aleman, 2005; Lane et al., 2000) which was empirically supported by imaging data (Berthoz et al., 2002; Kano et al., 2003; Lane et al., 1997; Mantani et al., 2005; Moriguchi et al., 2006a,b). Berthoz et al. (2002) emphasized that deficits in emotion processing in alexithymia are characterized by abnormalities during the appraisal of emotional stimulus content whereas perceptual aspects of stimulus processing remain unaffected. While imaging approaches (e.g., fMRI, PET) allow for identifying brain areas involved in emotional processing with high spatial accuracy, they lack the fine temporal resolution to investigate the time course of emotional stimulus processing.

Some studies provide evidence that alexithymia is associated with impaired processing of emotional stimuli, supporting the view that mainly aspects of stimulus appraisal are affected in alexithymia. Franz et al. (2004) provided evidence that alexithymia might be characterized by a processing deficit to emotional aversive stimuli. Using a modified odd-ball paradigm with three different stimulus categories (aversive probes and affective neutral pictures serving as nontargets and instructed targets) they demonstrated that subjects with alexithymia displayed increased positive deflections (especially of the P2 component) of the visual event-related potential after probe presentation as compared to subjects without alexithymia. The authors concluded that subjects with alexithymia do not express difficulties in perceptual aspects of emotional stimuli but may need more effort and cognitive resources to process emotional information. Results from Aftanas and co-workers

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(Aftanas et al., 2003; Aftanas and Varlamov, 2004, 2007) confirm the importance of appraisal processes for emotional processing in alexithymia. The authors showed that alexithymics revealed enhanced event-related theta synchronization over right anterior cortical regions in response to negative stimuli or to negative and positive film clips.

Furthermore, very few studies indicate that also early perceptual-related processes are altered in alexithymia. Schaefer et al. (2007) demonstrated that high alexithymic participants exhibited higher P1–N1 amplitudes when confronted with acoustic stimuli of increasing intensity. The authors argued that alexithymia may be associated with a general stimulus augmentation to prevent individuals from ignoring stimuli that might be dangerous. Further evidence for perceptual differences in alexithymia stems from research on anhedonia, a personality trait associated with a decrease in the ability to feel pleasure. Anhedonia is conceptualized as linked to alexithymia, an assumption which was partly supported empirically (e.g., Deborde et al., 2006; Loas et al., 1997, 1998). Franken et al. (2006) used a visual oddball paradigm and found that both early, middle and late ERP components of subjects with low levels of hedonic tone were attenuated compared with ERPs of subjects with high levels of hedonic tone. The authors suggested that decreased hedonic tone is associated with reductions in both automatic and effortful cognitive processing of relevant stimuli. In accordance to this finding Rey et al. (2010) reported that anhedonics experience less positive feelings when confronted with positive pictures differing in luminance which might be associated with the perceptual encoding and emotional processing in anhedonia.

In summary, previous research suggests emotion processing abnormalities in alexithymia that might be investigated by means of event-related potentials (ERP). There is converging empirical evidence that late potentials such as the P3 associated with higher order aspects of cognitive information processing are reduced in alexithymia (Hajcak and Olvet, 2008). As the P3 is positively related to experienced intensity of feelings (Hamm et al., 2003; Polich and Kok, 1995; Pollatos et al., 2007) this hypothesis is in accordance to numerous empirical studies showing reduced self-reported arousal in alexithymia, e.g. demonstrating reduced arousal in participants with high degrees of alexithymia (Pollatos et al., 2008b; Roedema and Simons, 1999), less pronounced arousal increases after exposure to negative film clips (Stone and Nielson, 2001) or a trend towards lower self-rated intensity during emotional imagery (Mantani et al., 2005). Importantly, there is also some evidence that early components of the ERP like the P1 and N2 could be affected in alexithymia (Franken et al., 2006; Schaefer et al., 2007). This is relevant because early deficits in perceptual encoding could account for later processing abnormalities.

In the present study we focused on participants within a non-clinical range of alexithymia to obtain a sample contrasting high vs. low scores in alexithymia in order to have a representative selection of individuals without psychiatric or neurological problems and without reported drug intake or currently received medication. The present study aimed to investigate the time course of brain dynamics accompanying emotion inducing stimulation in response to affective pictures (Cuthbert et al., 2000; Keil et al., 2002; Pollatos et al., 2005; Schupp et al., 2000; Waldstein et al., 2000) in alexithymia by the use of event-related potentials technique. We hypothesized that a reduced P3 in alexithymia is accompanied by a modulation of the P1 component reflecting perceptual difficulties in processing of emotional information. With respect to the N2 it is known that N2 amplitudes are more pronounced when stimuli are difficult to encode (Nittono et al., 2007). This could be a consequence of processing abnormalities on a prior perceptual level as assumed in alexithymia. We therefore hypothesized this component to be increased in alexithymia reflecting a consecutive higher cognitive demand to encode emotional information. Taking previous work on the different facets of alexithymia into account (e.g. de Timary et al., 2008; Luminet et al., 2006; Pollatos et al., 2008a,b; Vermeulen et al., 2006), we hypothesized that the emotional aspects of alexithymia as reflected in the DDF and DIF subscales would interact with the processing of emotional stimuli while the cognitive aspects as reflected in the EOT scale would not interfere with emotion processing.

2. Methods

Fifty subjects were screened for alexithymia using the Toronto Alexithymia Scale (TAS; Taylor and Doody, 1985). The TAS-20 is the most psychometrically valid and commonly used self-report measurement of alexithymia (Bagby et al., 1994; Mantani et al., 2005) consisting of 20 items rated on a 5-point scale with total scores ranging from 20 to 100. All selected subjects were confirmed right-handed by means of the Handedness Questionnaire (Oldfield, 1971). None of the participants had a history of neurological or psychiatric disorders, reported about drug intake (except of alcohol within a normal consumption range) or currently received any medication (except of contraceptives).

Based on the total TAS sum score the first and the last quartile of the participants were chosen and categorized as having either high (HDA) or low (LDA) degrees of alexithymia. Two experimental groups were formed in a manner that each group consisted of 10 (5 male) age- and gender-matched participants. The participants in the HDA and LDA groups were aged 28.3 ± 4.3 years and 28.4 ± 5.4 years, respectively (mean $\pm$ SD). In the HDA group the mean total TAS score was 55.3 (SD 5.8), in the LDA group 26.6 (SD 1.4). This procedure is comparable to previous studies using, e.g. the 33rd percentile and the 66th percentile or the first vs. last quartile as cutoffs for categorizing participants in having either high or low degrees of alexithymia (Franz et al., 2004; Moriguchi et al., 2006a), e.g. yielding into mean sum scores of 34 in the LDA vs. 59 in the HDA group (Franz et al., 2004). Concerning the German version of the TAS no standardized threshold exists for identifying clinically relevant degrees of alexithymia. Using the English version, the common international cutoff refers to a sum score of >61 to assess clinically relevant degrees of alexithymia, e.g. in psychosomatic patients (Franz et al., 2004). Referring to the healthy population, the obtained groups of HDA vs. LDA represent both ends of alexithymia as extreme groups in a non-clinical population thus justifying the chosen categorization. In accordance to the chosen selection method, both groups differed significantly in the total TAS score ($F(1,18) = 231.3$, $p < .001$, $\eta^2 = .93$; $\varepsilon = 1.00$) as well as in the TAS subscores "difficulties in identifying feelings (DIF)" (TAS 1: *HDA* 17.4 vs. *LDA* 8.3, $F(1,18) = 39.7$, $p < .001$, $\eta^2 = .69$; $\varepsilon = 1.00$) and "difficulties in describing feelings (DDF)" (TAS 2: *HDA* 18.4 vs. *LDA* 6.1, $F(1,18) = 86.2$, $p < .001$, $\eta^2 = .82$, $\varepsilon = 1.00$). For the subscore "externally oriented thinking or a preoccupation with the details of external events (EOT)" only a trend towards group differences was observed (TAS 3: *HDA* 19.5 vs. *LDA* 12.2, $F(1,18) = 3.26$, $p = .09$). In order to further elucidate the effects of the three facets of alexithymia, regression analyses were conducted when the overall group effect alexithymia was significant.

All participants had normal or corrected to normal visual acuity and gave their written informed consent. Experiments were conducted in accordance with the Declaration of Helsinki with the approval of the local ethics committee.

2.1. Stimulus material

420 pictures (140 pleasant, 140 neutral, 140 unpleasant) from the IAPS served as emotional stimuli. The IAPS is a standardized and well-characterized collection of visual images designed to evoke either neutral, positive, or negative emotional states (Lang et al., 1999). Pictures in the IAPS vary with respect to two primary dimensions: affective valence, ranging from unpleasant to pleasant (1–9); and arousal, ranging from calm to excited (1–9). The valence and arousal level of each picture have been quantified in the IAPS. Negative pictures included such images as frightening animals and mutilated human bodies, while neutral pictures depicted daily necessities such as tableware and books.

The task was administered on a personal-computer-controlled 22-in. color display (refreshment rate, 100 Hz), using Presentation software (Neurobehavioral Systems, Inc.) to control the presentation and timing of all stimuli. Each picture was displayed in color and occupied the entirety of the 22-in. monitor (aspect ratio 4:3). At a viewing distance of approximately 100 cm, each picture occupied a visual angle of nearly 17° in the vertical plane, and 27° in the horizontal plane.

According to the normative ratings of the IAPS, the three emotion contents differed significantly regarding pleasantness ($mean_{pos}$ 7.4, $mean_{neu}$ 5.2 and $mean_{neg}$ 3.0, respectively; $F(2,417) = 285.1$; $p < .001$), while pleasant and unpleasant pictures yielded higher arousal scores than neutral ones ($mean_{pos}$ 6.1, $mean_{neg}$ 6.5, $mean_{neu}$ 3.1; $F(2,417) = 182.4$; $p < .001$; post hoc LSD tests, $p < .001$), but did not differ significantly regarding their normative arousal ratings (post hoc LSD tests, p = n.s.).

Pleasantness and arousal were assessed after each experimental block using the Self-Assessment Manikin, SAM (Bradley and Lang, 1994). The SAM is a non-verbal pictorial self report scale that directly measures the valence and arousal associated with a person's affective reaction to a wide variety of stimuli. Participants were asked to rate how pleasant vs. unpleasant and how aroused vs. calm they felt while watching the emotional pictures with scores ranging from 1 (very unpleasant or low arousing) to 9 (very pleasant or high arousing).

2.2. Procedure

The main experiment used a block design with three picture presentation blocks consisting of 140 pictures of one emotion content (unpleasant, neutral, pleasant) randomized across subjects. This block-wise procedure was chosen to maximize the induced emotion effect. A single trial always began with a fixation cross for 500–1000 ms followed by an IAPS slide visible for 3 s. Participants were instructed to avoid exploratory eye-movements and eye-blinks and to attentively watch the pictures. A varying time interval of 1.5–3 s was applied before the next trial started. At the end of each block participants were asked to provide valence and arousal ratings on a 9-point scale using the Self Assessment Manikin (SAM) (Bradley and Lang, 1994).

2.3. Analysis of the self-reported feelings

Mean valence and arousal ratings were calculated separately for the three emotion contents (pleasant, unpleasant and neutral) and submitted to repeated measures analyses ANOVAs with three levels of Emotion Content (pleasant, neutral, unpleasant) and two levels of Alexithymia (high/low degrees of alexithymia).

2.4. EEG recording

EEG was recorded from 128 leads according to the 5%-system (Oostenveld and Praamstra, 2001) with a DC amplifier (bandpass: 0.01–100 Hz; SYNAMPS, Neuroscan, Charlotte, NC, USA) and digitised at a sampling rate of 1000 Hz. Electrode positions were determined with an electrode cap (Falk Minow Services, Munich, Germany). The reference electrode was positioned at Cz; the ground electrode was placed on the left cheek. The EEG was re-referenced offline to average mastoid reference. Horizontal and vertical eye movements were recorded with electrodes placed at the outer canthus of each eye (EOG_H) and above and below the left eye (EOG_V). Nonpolarizable Ag–AgCl electrodes were used and electrode resistance was maintained below 8 KΩ.

2.5. EEG data reduction and analysis

The EEG record was examined for EOG, muscle activity, and other sources of electrophysiological artifacts. Blinks were corrected using the Gratton and Coles algorithm implemented in the analysis software (Vision Analyser, Brain Products, Munich, Germany). Trials contaminated by artifacts were eliminated prior to averaging, accounting for approximately 4% of the trials (neutral condition: 4%, positive condition: 4%, negative condition: 5%). The EEG was filtered (bandpass 0.01–30 Hz) and averaged offline. EEG data were epoched with onset of the picture presentation for 1000 ms relative to a 200 ms pre-stimulus baseline.

Visually evoked potentials were averaged for 12 regions, formed by crossing hemisphere (right/left) with horizontal plane (anterior, middle, posterior), and vertical plane (inferior, superior; compare Keil et al., 2002; Pollatos et al., 2007). Peak amplitudes and latencies were assessed in the time window of the P1 (80–160 ms) and the N2 (200–330 ms), as well as mean voltages in the time window of the P3 (260–450 ms).

As the visual evoked P1 is characterized by a bilateral posterior topography, P1 (peak amplitudes and latencies) was analysed using mixed design ANOVAs with two levels of *hemisphere* (right/left), two levels of *region* (postero-inferior, postero-superior), and three levels of *emotion content* (pleasant, unpleasant and neutral) as repeated measures and two levels of *alexithymia* (high/low degree of alexithymia) as between subject factor. N2 (peak amplitudes, peak latencies) und P3 (mean area) were analysed using mixed design ANOVAs with two levels of *hemisphere* (right/left), six levels of *region* (antero-inferior, antero-superior, middle-inferior, middle-superior, postero-inferior, postero-superior), and three levels of *emotion content* (pleasant, unpleasant and neutral) as repeated measures and two levels of *alexithymia* (high/low degree of alexithymia) as between subject factor. In order to increase readability, significant main effects are always reported first. In case of significant higher order interaction effects, these main effects must be qualified by the later reported interaction effects.

In Section 3, uncorrected *F*-values are reported together with the Greenhouse-Geiser epsilon values and corrected probability levels. Post hoc analyses were computed using post hoc Bonferroni-adjusted analyses implemented in SPSS. In case of interaction effects not attributable to SPSS implemented post hoc tests, we conducted post hoc ANOVAs for separated either by group, region or emotion content.

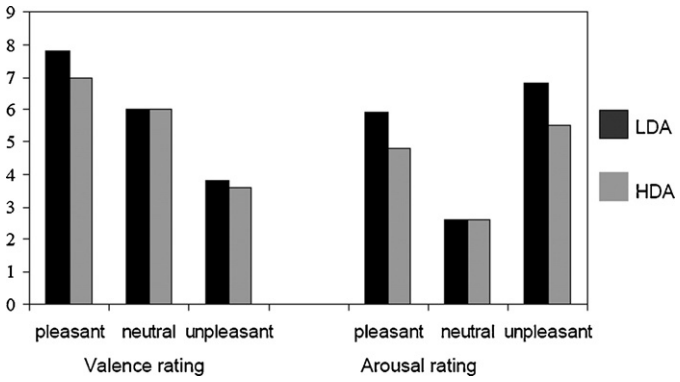

Fig. 1. Mean valence and arousal scores for HDA ($N = 10$) and LDA ($N = 10$) participants.

3. Results

3.1. Experienced feelings during emotional picture presentation

Fig. 1 shows the valence and arousal ratings for all three experimental conditions contrasting participants with high (HDA) and low (LDA) degrees of alexithymia.

With respect to *arousal ratings*, a significant main effect of *emotion content* ($F(2,36) = 16.3$; $p < .001$; $\eta^2 = .48$; $\varepsilon = 1.0$) was assessed. Pleasant and unpleasant pictures were rated as more arousing than neutral ones ($ps < .01$). The between-subject factor *alexithymia* ($F(1,18) = 3.53$; $p = .076$) marginally failed to reach significance indicating a trend towards lower arousal scores in participants with high degrees of alexithymia with highest descriptive differences for the pleasant and unpleasant condition. No significant interaction *alexithymia* × *emotion content* ($F(1,18) = 1.26$; $p = .30$) was observed. Based on the observed trend for a significant group factor *alexithymia* we conducted three separate regression analyses with arousal scores in each emotion content as dependent variable and the alexithymia subscales as independent variables. Only self-rated arousal during unpleasant picture presentation was significantly explained by one alexithymia facet, namely the subscale "EOT" (*E*xternally *O*riented *T*hinking; $T = -2.74$, $\beta = -.54$, $p < .05$; $F(1,18) = 7.52$, $p < .05$, $R = .54$, $R^2 = .30$).

With respect to *valence ratings*, the statistical analysis revealed a highly significant effect for *emotion content* ($F(2,36) = 49.60$; $p < .001$; $\eta^2 = .73$; $\varepsilon = 1.00$). Post hoc Bonferroni-adjusted analyses revealed that valence ratings for pleasant pictures (mean 7.4) were significantly higher as compared to neutral (mean 6.0; $p < .001$) and unpleasant slides (mean 3.7; $p < .001$). In addition, valence ratings for neutral slides were significantly higher as compared to unpleasant slides ($p < .001$). Neither the between-subject factor *alexithymia* ($F(1,18) = 0.98$; $p = .34$) nor the interaction between *emotion content* and *alexithymia* ($F(2,36) = 0.56$; $p = .57$) were significant.

3.2. Visual evoked potentials (VEPs) to emotional pictures

As can be seen in Fig. 2, the course of the visual evoked potentials differed between participants with high and low degrees of alexithymia in the P1, N2 and P3 latency ranges.

Fig. 2 visualizes the obtained group differences at midline electrode locations depicting frontal, central, parietal and occipital electrodes for neutral, positive and negative picture content within the P1 as well as the P3 time range. Additionally, CSD maps are plotted for each condition and each group. In accordance to the latency ranges reported in earlier studies using emotional pictures as stimuli (Cuthbert et al., 2000; Keil et al., 2002; Pollatos et al.,

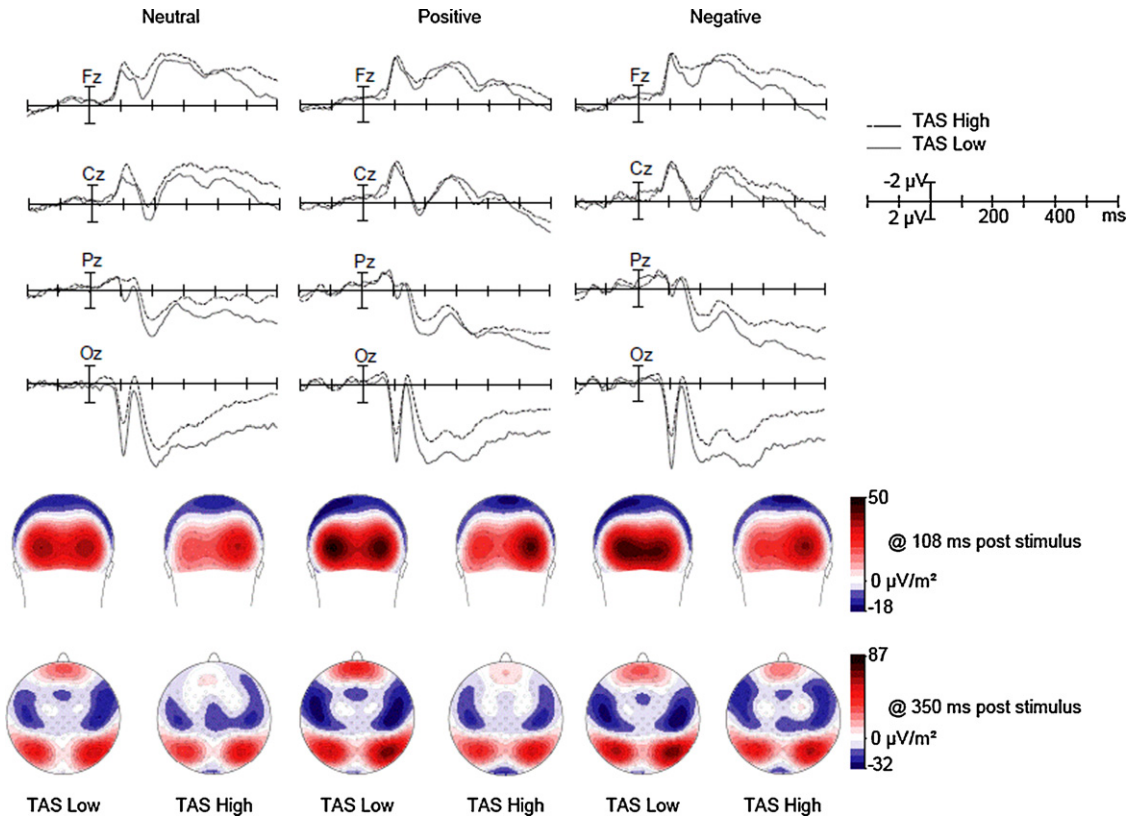

Fig. 2. Course of the VEPs for HDA ($N = 10$) and LDA ($N = 10$) participants in the P1, N2 and P3 latency ranges.

2005, 2007), the P1 (range 80–160 ms, peak and latency), the N2 (range 200–330 ms, peak and latency), and the P3 (mean amplitude 260–450 ms) were examined in more detail. Fig. 3 summarizes the electrode clusters underlying the statistical analyses. Results are presented with focus on the group factor alexithymia in Table 1.

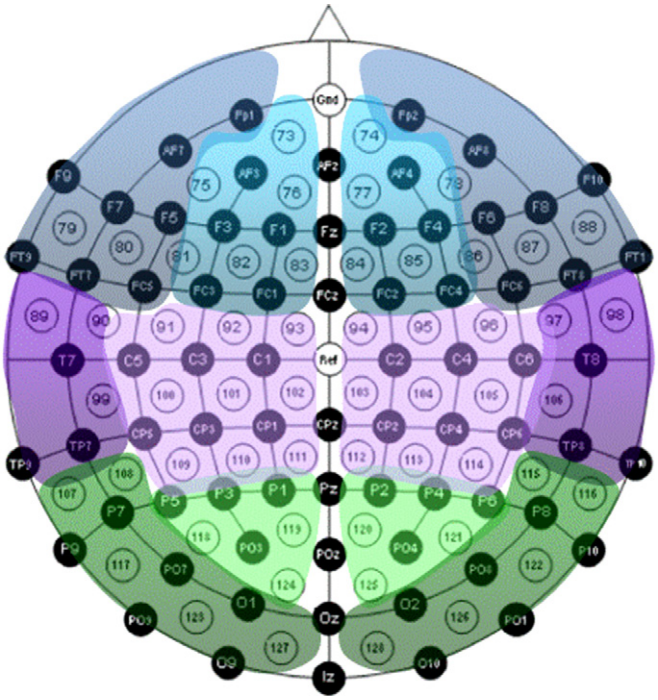

Fig. 3. Forming of 12 electrode pools (anteroinferior, anterosuperior, middle-inferior, middle-superior, posteroinferior, posterosuperior).

3.3. P1

For peak amplitudes of the P1 component, a main effect *alexithymia* (see Table 1) revealed significantly reduced amplitudes for participants with high degrees of alexithymia (mean 0.87 µV) as compared to participants with low degrees of alexithymia (mean 2.53; compare Fig. 4). A significant main effect *emotion content* (see Table 1) was observed indicating highest P1 amplitude for neutral and pleasant pictures as compared to unpleasant pictures (mean amplitudes 2.00 µV, 1.95 µV, and 1.09 µV; see Table 1). Additionally, the main effect Hemisphere revealed higher activation of the right posterior electrodes (mean 2.05 µV) as compared to left positions (mean 1.35 µV), whereby a significant interaction *hemisphere* × *alexithymia* (see Table 1) occurred: Post hoc ANOVAs for each hemisphere showed that only participants with high degrees of alexithymia showed higher amplitudes at right electrode locations as compared to left positions (mean 1.49 µV and 0.26 µV, respectively) while no such differences were observed for participants with low degrees of alexithymia (mean 2.62 µV vs. 2.44 µV; compare Table 1).

An identical analysis for P1 latencies revealed no significant effects.

Regression between P1 and alexithymia facets. In order to examine the relationships between the observed P1 peak amplitude differences and alexithymia subscales, we conducted four stepwise regression analyses for each emotion content with P1 amplitudes at posterior electrode clusters (posterior–superior, posterior–inferior, left and right) as criterion and DDF, DIF and EOT as predictors in order to have a more detailed look at possible specific effects and the structural composition of alexithymia. Main results are summarized in Table 2.

In the regression analyses with P1 as criterion, only the predictor DDF accounted for significant proportions of variance of the criterion for all emotion contents. The DDF scores signifi-

Table 1
Main statistical results. Mixed design ANOVAs with two levels of *hemisphere* (right/left), two levels of *region* (postero-inferior, postero-superior), and three levels of *emotion content* (pleasant, unpleasant and neutral) as repeated measures and two levels of *alexithymia* (high/low degree of alexithymia) as between subject factor. Post hoc tests specified when conducted.

	Main effects	Interaction effects with respect to group	Post hoc tests
P1	*Emotion content* $F(2,36) = 5.17$, $p < .05$; $\eta^2 = .22$, $\varepsilon = .69$		P1 neutral/pleasant > unpleasant (Post hoc Bonferroni-adjusted analyses, *ps* < .05).
	Hemisphere $F(1,18) = 8.15$, $p < .05$; $\eta^2 = .31$, $\varepsilon = .77$; right > left *Alexithymia* $F(1,18) = 8.84$, $p < .01$; $\eta^2 = .33$, $\varepsilon = .80$. HDA>LDA		
		Hemisphere × *alexithymia* $F(1,18) = 4.50$, $p < .05$; $\eta^2 = .20$, $\varepsilon = .52$	HDA: right > left $F(1,9) = 3.86$, $p < .05$; $\eta^2 = .12$, $\varepsilon = .58$. LDA: right = left $F(1,9) = 0.57$, p = n.s. (Post hoc ANOVAs for each group).
N2	*Emotion content* $F(2,36) = 3.65$, $p < .05$; $\eta^2 = .17$, $\varepsilon = .63$.		N2 pleasant/unpleasant > neutral (post hoc Bonferroni-adjusted analyses, *ps* < .05).
	Region $F(5,90) = 105.12$, $p < .001$; $\eta^2 = .85$, $\varepsilon = 1.00$.		Frontal > central > posterior (Post hoc Bonferroni-adjusted analyses, *ps* < .05).
		Alexithymia × *emotion content* $F(2,36) = 3.66$, $p < .05$; $\eta^2 = .17$, $\varepsilon = .61$.	HDA > LDA neutral/unpleasant: (Post hoc ANOVAs for each emotional content) Neutral: $F(1,18) = 4.51$, $p < .05$; $\eta^2 = .20$, $\varepsilon = .52$. Unpleasant: $F(1,18) = 4.76$, $p < .05$; $\eta^2 = .21$, $\varepsilon = .54$. Pleasant: $F(1,18) = 0.04$, p = n.s.
P3	*Emotion content* $F(2,36) = 41.08$, $p < .001$; $\eta^2 = .70$, $\varepsilon = 1.00$.		P3 pleasant/unpleasant > neutral (Post hoc Bonferroni-adjusted analyses, *ps* < .05).
	Region $F(5,90) = 67.55$, $p < .001$; $\eta^2 = .79$, $\varepsilon = 1.00$.		Postero-inferior/postero-superior > medial-inferior/medial-superior > anterior–superior > anterior–inferior (Post hoc Bonferroni-adjusted analyses, all comparisons *ps* < .05).
	Alexithymia × emotion content $F(2,36) = 4.81$, $p < .05$; $\eta^2 = .21$, $\varepsilon = .70$.		HDA > LDA: P3 unpleasant $F(1,18) = 4.10$, $p < .05$; $\eta^2 = .27$, $\varepsilon = .79$. HDA = LDA: Neutral: $F(1,18) = 0.34$, p = n.s. Pleasant: $F(1,18) = 0.55$, p = n.s. (Post hoc ANOVAs for each emotional content).
	Alexithymia × emotion content × region ($F(10,180) = 4.07$, $p < .05$; $\eta^2 = .19$, $\varepsilon = .71$)		HDA > LDA: Unpleasant Postero-superior (8.2 μV vs. 4.6 μV; $p < .01$) Postero-inferior regions (8.7 μV vs. 4.4 μV; $p < .05$) (Post hoc ANOVAs for unpleasant content and each region).
	Emotion content × *region* $F(10,180) = 7.07$, $p < .01$; $\eta^2 = .28$, $\varepsilon = .92$.		P3 pleasant/unpleasant pictures > neutral over posterior and medial-superior regions (Post hoc Bonferroni-adjusted analyses, all comparisons *ps* < .05).

Table 2
Regression analyses between 1. P1 respectively 2. N2 and alexithymia facets as well as between 3. P3, P1, arousal and alexithymia facets (DDF: difficulties in describing feelings).

	Predictors included in the model		
	Pleasant picture presentation	Unpleasant picture presentation	Neutral picture presentation
P1 as criterion	DDF only predictor At left posterior–superior electrode cluster: $T = -2.24$, $\beta = -.47$, $p < .05$; $F(1,18) = 5.00$, $p < .05$; $R^2 = .22$ At left posterior–inferior electrode cluster: $T = -3.24$, $\beta = -.61$, $p < .01$; $F(1,18) = 7.45$, $p < .05$; $R^2 = .37$	DDF only predictor At right posterior–inferior electrode cluster: $T = -2.61$, $\beta = -.52$, $p < .05$; $F(1,18) = 6.80$, $p < .05$; $R^2 = .27$ At left posterior–inferior electrode cluster: $T = -2.73$, $\beta = -.54$, $p < .01$; $F(1,18) = 7.45$, $p < .05$; $R^2 = .29$	DDF only predictor At left posterior–inferior electrode cluster: $T = -4.98$, $\beta = -.76$, $p < .001$; $F(1,18) = 24.85$, $p < .001$; $R^2 = .58$
N2 as criterion		DDF only predictor At right anterior–superior electrode cluster: $T = -2.76$, $\beta = -.55$, $p < .05$; $F(1,18) = 7.64$, $p < .05$; $R^2 = .30$	DDF only predictor At right anterior–inferior electrode cluster: $T = -2.34$, $\beta = -.48$, $p < .05$; $F(1,18) = 7.25$, $p < .05$; $R^2 = .23$
P3 as criterion		DDF, P1, arousal included predictors At left posterior–inferior electrode cluster: $F(3,16) = 8.57$, $p < .01$, $R^2 = 0.62$ DDF ($\beta = -.67$, $T = -4.02$, $p < .01$) P1 amplitude ($\beta = .44$, $T = 2.80$, $p < .05$) Arousal ($\beta = .42$, $T = 2.46$, $p < .05$)	DDF, P1 included predictors At left posterior–superior electrode cluster: $F(2,17) = 9.06$, $p < .01$, $R^2 = 0.50$ DDF ($\beta = -.64$, $T = -4.50$, $p < .01$) P1 amplitude ($\beta = .54$, $T = 3.08$, $p < .01$)

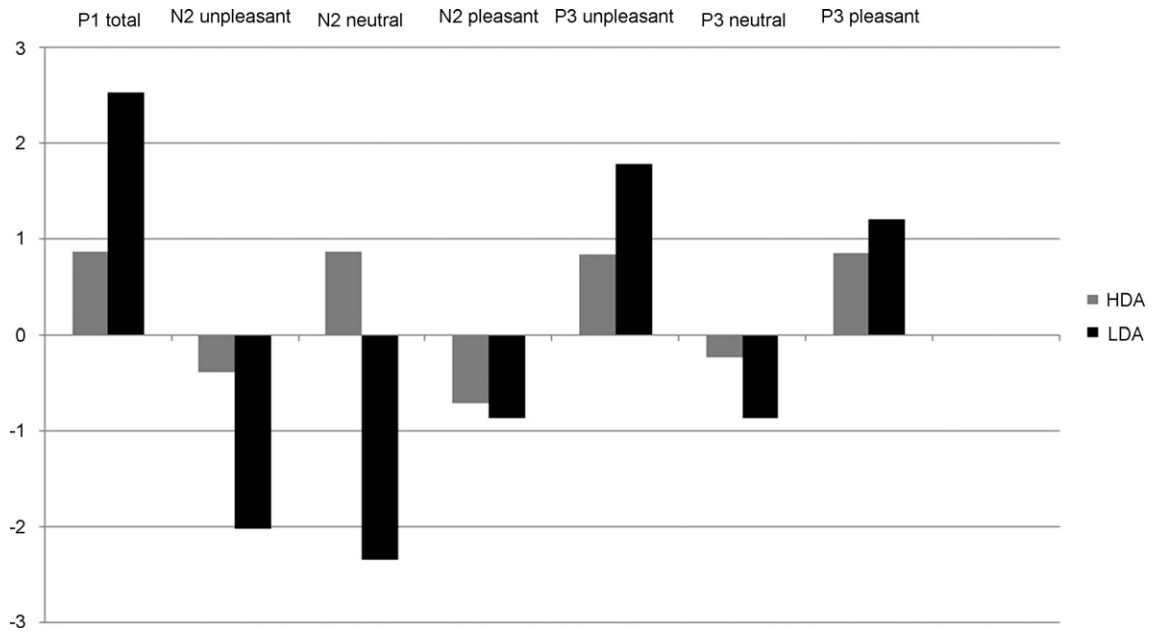

Fig. 4. Main results of the group comparisons highlighting significant effects of alexithymia on P1, N2 and P3.

cantly explained variance of P1 amplitudes during *pleasant* picture presentation (at left posterior–superior and left posterior–inferior electrode clusters), during *unpleasant* picture presentation (at right posterior–inferior and left posterior–inferior electrode clusters), and during *neutral* picture presentation (at left posterior–inferior electrode cluster; see Table 2). Negative regression coefficients between DDF and P1 amplitudes indicated that subjects with higher scores in the DDF subscale displayed a stronger attenuation of P1 amplitudes.

3.4. N2

The mixed-design ANOVA with N2 amplitudes as dependent measure revealed a significant main effect of *region* (see Table 1) with highest N2 amplitudes over frontal electrodes as compared to central and posterior ones (mean amplitudes −5.13 μV, −2.49 μV, and 4.02 μV, respectively). The main effect of *emotion content* was significant reflecting more negative going N2 amplitudes in response to pleasant (mean −1.62 μV) and unpleasant (mean −1.21 μV) pictures as compared to neutral ones (mean −.78).

In addition, a significant *alexithymia* × *emotion content* interaction (see Table 1) was observed. Post hoc ANOVAs for each emotional content revealed that participants with high degrees of alexithymia exhibited greater N2 peak amplitudes as compared to participants with low degrees of alexithymia in response to neutral (mean −2.34 μV vs. −0.87 μV) and unpleasant pictures (mean −2.02 μV vs. −0.38 μV) but not for pleasant pictures (mean −0.86 vs. −0.71 μV).

No significant effects were observed for N2 latencies.

Regression between N2 and alexithymia facets. We conducted four stepwise regression analyses for each emotion content with N2 peak amplitudes at anterior electrode clusters (anterior–superior, anterior–inferior, left and right) as criterion and DDF, DIF and EOT as predictors.

The results indicated that only DDF scores accounted for significant proportions of variance in N2 amplitudes for unpleasant and neutral pictures. DDF scores significantly explained variance of the criterion N2 during *unpleasant* picture presentation (at right anterior–superior electrode cluster: see Table 2) and during *neutral* picture presentation (at right anterior–inferior electrode cluster). Negative regression coefficients indicated that subjects with higher scores in the DDF subscale displayed more negative going N2 amplitudes.

3.5. P3

An ANOVA with P3 amplitudes as dependent measure revealed a significant main effect of *emotion content* (see Table 1), indicating higher P3 amplitudes for pleasant and unpleasant stimuli as compared to neutral ones. In addition, a significant main effect of *region* was found: highest P3 amplitudes were observed over the postero-inferior (5.3 μV) region, followed by postero-superior (5.0 μV), middle-inferior (0.21 μV), middle-superior (−0.98 μV), anterior–superior (−2.5 μV) and anterior–inferior (−3.5 μV) region.

The interaction effect *emotion content* × *region* revealed higher P3 amplitudes for pleasant and unpleasant pictures as compared to neutral ones over posterior and middle-superior regions. Concerning the interaction *alexithymia* × *emotion content* post hoc ANOVAs for each emotional content showed that participants with low degrees of alexithymia exhibited greater P3 amplitudes in response to unpleasant pictures (mean 1.79 μV) as compared to participants with high degrees of alexithymia (mean 0.84 μV), while P3 amplitudes for pleasant and neutral pictures in both participants' groups were comparable. The interaction of *alexithymia* × *emotion content* × *region* indicated higher mean P3 amplitudes for LDA participants to unpleasant pictures in the postero-superior (8.2 μV vs. 4.6 μV) and postero-inferior regions (8.7 μV vs. 4.4 μV) as compared to HDA participants (see also Figs. 2 and 4) but no such differences in the other regions.

Regression between P3, P1, arousal and alexithymia facets. We conducted four stepwise regression analyses in each emotion condition with P3 amplitudes at posterior electrode clusters (posterior–superior, posterior–inferior, left and right) as criterion. We selected these regions as the significant main effect *region* showed highest amplitudes here and the significant interaction *alexithymia* × *emotion content* was referring to posterior electrode clusters. In addition to DDF, DIF, and EOT, both arousal as well as P1 amplitudes were included as predictors. The rationale to select

these additional predictors was twofold: First, the P3 is strongly related to experienced intensity of feelings (Hamm et al., 2003; Polich and Kok, 1995; Pollatos et al., 2007) and we observed a relationship between the EOT subscale and the perceived arousal. Secondly, we wanted to elucidate whether early visual processing as reflected in the P1 would contribute to later cognitive processing of emotional pictures.

All predictors combined explained up to 62% of the variance of P3 amplitudes during unpleasant picture presentation (at left posterior–inferior electrode cluster: see Table 2). Reporting the results for this cluster only, there were significant effects for DDF, for P1 amplitude and for arousal as predictors. Concerning the P3 during neutral picture presentation as criterion all predictors significantly explained up to 50% of the variance of the criterion (at left posterior–superior electrode cluster: see Table 2) with significant effects for DDF and for P1 amplitude. The regression coefficients indicated that lower P3 amplitudes are explained by higher DDF scores in combination with smaller P1 amplitudes and attenuated arousal.

4. Discussion

We provide new electrophysiological evidence for early processing deficits in response to emotional stimuli for alexithymic persons as mirrored in significantly reduced P1 amplitudes to emotional pictures. Using regression analyses we showed that these differences between the HDA and LDA groups were driven by affective features of alexithymia that describe core problems of emotional awareness (Coffey et al., 2003; Lane et al., 1998) as hypothesized in the concept of emotional blindsight by Lane et al. (1997). Our results throw a new light on alexithymia and its conceptualization as impairment in the capacity to consciously access emotional material (Lane et al., 1998; Luminet et al., 2006; Taylor et al., 1999) by demonstrating a hampered perception of emotionally salient stimuli at an early stage in the time course of visual processing.

The present findings suggest that an attenuation of basic emotional processes starts as early as 120 ms as reflected in reduced P1 amplitudes. Importantly, these early deficits on a perceptual level precede the observed lack in cognitive and emotional capacities for modulating emotions in alexithymic persons (Vermeulen et al., 2006; Mantani et al., 2005; Moriguchi et al., 2006b). Supporting this assumption, we found significantly reduced P3 in the HDA group for unpleasant pictures, and more importantly, regression analyses demonstrated that basic perceptual processes as reflected in the P1 component significantly contribute to P3 amplitude modulations for unpleasant and neutral pictures but not when pleasant pictures are perceived. As we obtained positive regression coefficients between P1 and P3 it can be followed that reduced P1 amplitudes associated with emotional components of alexithymia contribute to later processing deficits in the P3 time range. Concerning the regression analyses, we used stepwise methods which have certain well-known methodological shortcomings like this procedure will not necessarily produce the best model if there are redundant predictors or there is an inflated risk of capitalising on chance features of the data (Judd and McClelland, 1989). We tried to minimize these shortcomings by testing as precise hypotheses as possible, e.g. by examining only electrode clusters especially suitable for certain components. Nevertheless, concerning the facets of alexithymia we could not theoretically apply differentiated hypotheses for each component.

Our results substantially extend other studies investigating early stages of emotion processing in alexithymia by using masked emotional stimuli (Eichmann et al., 2008; Pollatos et al., 2008a,b; Reker et al., 2010). It could be demonstrated that alexithymia is associated with automatic hyporesponsiveness to masked negative emotional faces in the fusiform gyrus (Eichmann et al., 2008) and in several other regions including the amygdale, the insula, the superior temporal gyrus and the middle occipital and parahippocampal gyrus (Reker et al., 2010) which is in line with the obtained reduced P1 in the present study. Reker et al. (2010) suggested that the observed reduced automatic reactivity of the amygdala and visual occipito-temporal areas implicates less automated engagement in the encoding of emotional stimuli in high alexithymia. This is in line with the observation of attenuated electrodermal responses to negative stimuli in relationship to the affective dimension of alexithymia (Pollatos et al., 2008a,b). The results of the present study implicate that similar to the affected automated processing of emotional stimuli basic processes of perception and subsequently of encoding of overtly presented emotion stimuli are hampered by the affective components of alexithymia.

In accordance with this assumption we observed significantly higher N2 amplitudes for neutral and negative stimuli in the HDA group as compared to the LDA group which may specifically reflect higher cognitive demand to encode information from these emotional categories appropriately (Dennis and Chen, 2007; Gramann et al., 2007; Pollatos et al., 2008a,b). This fits investigations showing N2 amplitudes are pronounced when stimuli are difficult to encode (Nittono et al., 2007), when there is a mismatch between the expected and the actual stimulus (Gramann et al., 2007) or when failures occur in emotional face categorization (Pollatos et al., 2008a,b). In this context empirical data on anxiety disorders and PTSD are of high relevance. In a recent paper Eldar and Bar-Heim (2009) demonstrated that an attention training aiming to avoid threat information led to significantly enhanced N2 and reduced P3 amplitudes in high anxious individuals while early components as the P1 were not affected. The authors interpreted their results as modulation of top-down processes in anxious individuals. A comparable pattern was observed by Araki et al. (2005) for patients suffering from posttraumatic stress disorder (PTSD). The authors demonstrated that lower P3 amplitudes in PTSD patients were associated with higher avoidance scores as measured by self-report (Araki et al., 2005). From these results it can be concluded that the affective aspects of alexithymia interact both with early attentional orienting processes and with top-down processes of attentional control which probably reflecting attentional avoidance of emotional stimuli. This interpretation is in line with data from Aftanas and Varlamov (2004) who suggested that the obtained enhanced electrophysiological reactivity measured by EEG frequency bands during viewing of emotional film clips in alexithymic participants reflect greater avoidance motivational tendencies in these group.

While central abnormalities in the time course of emotion processing in alexithymia were associated with the emotional aspects of alexithymia, differences in perceived arousal were related to the cognitive style conceptualized in the EOT scale “externally oriented thinking”. This result fits nicely into studies highlighting that the three alexithymia facets are differentially linked to observed abnormalities in the processing of negative emotions (Coffey et al., 2003; Luminet et al., 2006; de Timary et al., 2008; Gohm and Clore, 2000). Additionally, it can be argued that the emotional as well as the cognitive components of alexithymia might have cumulative effects on later stages of emotion processing as mirrored in differential effects of the alexithymia facets on the P3 amplitude as well as on perceived arousal. In accordance to previous studies self-reported arousal was reduced in response to positive and negative pictures in alexithymia (Pollatos et al., 2008a,b; Roedema and Simons, 1999) and associated with reduced P3 amplitudes as hypothesized. As the P3 is strongly related to experienced intensity of feelings (Hamm et al., 2003; Polich and Kok, 1995; Pollatos et al., 2007) we assume that the observed P3 effect reflects the lower arousal experience in HDA subjects. Confirming this assumption self-reported pleasantness did not differ between both groups.

We categorized participants as HDA vs. LDA in accordance to other studies using healthy populations (Franz et al., 2004; Moriguchi et al., 2006a). Nevertheless, to speak of a clinically relevant degree of alexithymia international cutoffs refer to a sum score of >61 which was not reached in the HDA group. Therefore, we only investigated alexithymia as a personality trait in two extreme groups within the "normal" range without representing clinical degrees of alexithymia. As our purpose was to show whether perceptual differences of emotional stimuli exist in the time course of processing referring to this personality trait, the chosen categorization of high alexithymia is of relevance for the construct of alexithymia per se, as it demonstrates that higher degrees of this variable significantly interact with processing abnormalities in the whole time range of emotion processing. The obtained findings need to be validated with a clinical population, whereby interfering variables like depression or anxiety must be carefully counterbalanced in order not to interfere with processing deficits.

The study aimed at investigating interindividual differences in alexithymia using a well-selected but nevertheless rather small sampling size what is a potential limitation of the present work. While many previous finding, e.g. concerning the experienced intensity of feelings and their relatedness to the P3 amplitude are in accordance to the obtained results of the current work thereby adding evidence to the argument that the chosen sample is well-selected, sufficiently big and representative for the healthy population, other interesting question such as sex effects could not be addressed in this study. A cross-validation of the obtained results using a bigger sample is therefore to be addressed in the future and should allow additional insight in the processes underlying the observed processing deficits in interaction to alexithymia. Though demonstrating coherent and well-fitting results in regard to previous work on alexithymia unless further replicated this is a limitation and potential caveat for generalizing these results to the healthy population.

We conclude that the emotional aspects of alexithymia are associated with noticeable abnormalities in the time course of emotion processing. This is interpreted as a modulation on an early perceptual level as well as of top-down processes of attention control. We demonstrated a positive relationship between basic perceptual processes and later cognitive stimulus processing suggesting possible cumulative effects of processing deficits in alexithymia. Our results provide evidence that different facets of alexithymia are associated with augmented arousal as well as differences in the time course of central visual processing and that both processes might interfere with the consolidation of somatic markers required for guiding individual behaviour (compare Damasio, 1994; Damasio et al., 2000). This in turn could account for social and emotional deficits apparent in alexithymia in a cumulative manner. Further research with bigger sample sizes should address possible gender effects as well as experimental manipulations of top-down processes in order to further elucidate the nature of observed deficits in the central processing of emotional stimuli in alexithymia.

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