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Psychophysiological reactivity of currently dental phobic-, remitted dental phobic- and never-dental phobic individuals during exposure to dental-related and other affect-inducing materials

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ABSTRACT

Psychophysiological responses indicating the preparation of defensive behaviour, such as heart rate (HR)-increase and startle-response (SR) potentiation, have often been reported amongst individuals suffering from phobic disorders when exposed to phobia-related information. Although exposure is widely considered the 'gold standard' for treatment of Specific Phobia, it is unclear to what extent psychophysiological defensive response patterns change following treatment, and whether any changes are maintained. We assessed the acoustic SR- and HR-response to neutral, positive, negative and phobia-related pictures and sounds in 41 individuals currently suffering from dental phobia, 22 formerly dental phobic individuals who had remitted following an exposure-based treatment eight months prior to assessment, and 29 control individuals with no history of dental phobia. We observed SR-potentiation to dental-related stimuli in controls combined with HR–deceleration. In contrast, amongst phobic individuals SR-potentiation was accompanied by HR-acceleration to dental pictures. Successfully treated individuals showed inhibited startle reactivity in combination with HR-deceleration to dental related materials of both modalities. Our findings suggest inappropriate fight-flight preparation amongst individuals with dental phobia, reflecting overactivation of the defensive system. However, successful treatment results in inhibited physiological defence preparation, with remitted individuals displaying a response pattern that differed from that of phobic individuals and controls.

As defined by DSM-5 (American Psychiatric Association, 2013), a Specific Phobia (SP) is characterized by marked psychological and bodily fear symptoms when the phobic individual is exposed to the feared stimulus, sometimes culminating in overt flight responses. These fear symptoms are thought to be a product of hyper-responsiveness of the defensive system, observable on a neurophysiological level. While the fear symptoms of specific phobias are no longer evident after successful treatment, it is not clear whether the same is true of the putatively underlying psychophysiological responses. The current paper investigates this question via the example of dental phobia.

On a neurophysiological level, hyper-responsiveness of the defensive system is thought to be the key psychopathological process underlying SPs. This defence system shows characteristic patterns of responding, varying according to the perceived threat and the strength of the accompanying arousal of the defensive system (see Lang, Bradley, & Cuthbert, 1997; Lang, Davis & Öhmann, 2000). Functionally, these patterns of responding can be divided into two classes: defensive immobility and defensive action. Triggered by mildly arousing aversive stimulation, the individuals' orienting and stimulus processing is facilitated, physiologically accompanied by a decrease in heart rate (HR) (e.g. Graham & Clifton, 1966; Turpin, 1985) and an inhibition of defensive reflexes such as the startle response (SR) (e.g. Graham, Putnam, & Leavitt, 1975). As arousal increases, defensive reflexes become facilitated and the individual becomes defensively primed. When triggered by a large increase in sympathetic activation, evoked by

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highly arousing aversive stimuli, HR switches from deceleration to acceleration. This marks a change from defensive immobility to action, in the form of flight-fight preparation and behavioural mobilization (for a more detailed description see Lang et al., 1997).

In line with this account, and the hypothesised role of the defensive system in specific phobias, SR-potentiation on exposure to feared stimuli has been consistently observed across a wide range of phobic disorders, i.e. animal SPs including snake and spider phobia (De Jong, Merckelbach, & Arntz, 1991; Globisch, Hamm, Esteves, & Öhman, 1999; Hamm & Weike, 2005; Hamm, Cuthbert, Globisch, & Vaitl, 1997), injection phobia (Hamm et al., 1997), and Social Phobia (Larsen, Norton, Walker, & Stein, 2002; McTeague et al., 2009). Furthermore, many studies have demonstrated that phobic individuals display heart rate (HR)-acceleration (Globisch et al., 1999; Hamm et al., 1997; Sartory, Eves, & Foa, 1987) during phobia-relevant picture viewing, indicating inappropriate defensive mobilization evoked by exposure to phobia-related cues.

If overexcitement of the defensive system is a component of the pathology in SP, it should no longer be evident after successful treatment. However, the limited research that addresses this issue presents a mixed picture. Brief exposure-based cognitive behavioural treatment (CBT) is the 'gold standard' in the treatment of SPs (Wolitzky-Taylor, Horowitz, Powers, & Telch, 2008). In relation to HR-change after CBT, a recent review and meta-analysis (Gonçalvez et al., 2015), which focussed on Anxiety Disorders including SPs, identified 18 studies assessing HR-change during symptom provocation in SPs after treatment. In 13 of these studies, a synchronic decrease of subjective fear and HR-response was reported. However, five studies reported desynchronized subjective and physiological fear responses or no treatment effects at all. Although there was a strong tendency towards CBT reducing HR, the meta-analysis did not yield a statistically significant result. In relation to SR-change due to treatment, findings are even sparser and long-term effects are completely unknown. Two studies (De Jong, Arntz, & Merckelbach, 1993; Kashdan, Adams, Read, & Hawk, 2012) reported that a one-session in vivo exposure treatment resulted in SR-decrease either during a behavioural approach task or picture viewing in spider phobic individuals immediately post-treatment. In summary, it is not yet clear whether physiological defence-responses change in line with the decreases of subjective fear seen following successful exposure-based CBT-treatments (Wolitzky-Taylor et al., 2008) and if so, whether changes remain stable in the long run. The phenomenology of change-patterns due to successful therapeutic treatment has not previously been investigated.

We aimed to test possible changes in physiological reactivity following CBT treatment in the context of dental phobia. When viewing dental-related pictures, individuals with dental phobia have been shown to display a phobia-typical pattern of fight-flight preparation, indicated by HR-acceleration and, compared to a neutral condition, a potentiated SR (Sartory, Heinen, Wannemüller, Lohrmann, & Jöhren, 2009; Wannemüller, Sartory, Elsesser, Lohrmann, & Jöhren, 2015). They have also been shown to exhibit enhanced SRs in anticipation of cues signalling the threat of painful shocks (Bradley, Silakowski, & Lang, 2008). However, Sartory et al. (2009) and Wannemüller, Sartory, Elsesser et al. (2015) found that startle potentiation appeared modality-dependent, evident during exposure to dental-related pictures but not to sounds. Viewed from an evolutionary perspective, this is a surprising result and it prompted the authors to consider whether sound exposure might put phobic individuals into a state of 'tonic immobility' (see Kozlowska, Walker, McLean, & Carrive, 2015), or whether SR-attenuation might comprise part of a functional 'holding-still' response during dental surgery. This unexpected result suggests that studies investigating responses to dental-related stimuli amongst individuals with dental phobia should use stimuli of both modalities, in case this pattern of modality-specific responding is in fact a stable feature of dental phobia.

The CBT treatment in the current study was a coping- and exposure-based brief CBT introduced by Wannemüller et al. (2011, Wannemüller, Sartory, Jöhren, & Margraf, 2015). As with other SPs, for dental phobia brief exposure-based cognitive behavioural treatment (CBT) is the treatment of choice (Gordon, Heimberg, Tellez, & Ismail, 2013). The treatment by Wannemüller et al. (2011)and, Wannemüller, Sartory, Jöhren et al. (2015) appears to be very effective in reducing subjective and behavioural dental fear symptoms (Wannemüller et al., 2016) and to be more effective compared to other treatment formats (Wannemüller et al., 2011). Thus it provides a suitable mode of treatment for investigating the psychophysiological responding of individuals successfully treated with CBT in dental phobia.

We investigated subjective and physiological responses to visual and acoustic dental-related, neutral, negative and positive control materials in a group of dental phobic individuals (PHOB), remitted phobic individuals (R-PHOB) eight months after completion of exposure-based CBT, and never dental phobic controls (CON).

We expected currently phobic individuals to perceive dental-related materials as highly threatening, indicated by ratings of high arousal and unpleasantness. On a physiological level, we expected them to display a pattern of immediate fight-flight preparation responses reflecting a state of circa-strike, with HR-increase and, compared to neutral materials, a potentiated SR during exposure to dental-related materials. Since dental surgery is generally considered to be unpleasant and unwelcome, we expected non-phobic controls to rate dental materials equally arousing and (un)pleasant as negative materials. However, we expected controls to display a pattern of oriented attention with a potentiated SR to both negative and dental related stimuli, compared to neutral materials, accompanied by HR-decrease, as seen for orienting responses (e.g., Graham & Clifton, 1966; Turpin, 1985). We used positive and negative control materials of both modalities and expected all groups equally to show unimpaired activation of the appetitive and defensive system, indicated by HR-orienting to those stimuli. We also expected all groups to show startle inhibition to positive and potentiating to negative materials, as these are the normal response patterns evoked by such stimuli (Lang et al., 1997). However, our main aim was to investigate whether the physiological response pattern to dental-related stimuli of phobic individuals in complete remission would still reflect a high activation of the defensive system as expected for the PHOB-group, or if the response-pattern of R-PHOBs would resemble that of individuals never affected by dental phobia.

1. Method

The study was approved by the local ethics committee of the Ruhr-University Bochum.

1.1. Participants

Participants (N = 92; 60.9% female) included three groups. The first group comprised individuals diagnosed with current dental phobia (PHOB, n = 41). The second group included never dental phobic controls (CON, n = 29). The third group consisted of 22 individuals who had previously been diagnosed with dental phobia, but had successfully been treated with a CBT program and were remitted (R-PHOB), thus no longer fulfilling the criteria for dental phobia at the time of the psychophysiological assessment. The PHOB-condition consisted of phobic individuals who were either untreated (n = 34) or had completed the same CBT program as participants in the R-PHOB group but still fulfilled criteria for dental phobia (n = 7). The untreated and unsuccessfully treated phobic individuals within the PHOB group did not differ in any dental fear or clinical state measure (see the subgroup comparisons of Table 1), suggesting that they could be pooled into one homogeneous group of individuals, i.e. people currently meeting diagnostic criteria for dental phobia.[1] Untreated phobic participants completed the experimental assessment after their first diagnostic session, approximately one week before they were due to start a course of CBT. The physiological responses of participants in the R-PHOB group (and unsuccessfully treated phobic individuals within the PHOB group) were assessed 8 months post-treatment when returning for a follow-up appointment. The mean post-treatment FU-interval was 8.04 (SD = 2.52) months.

At the time of physiological assessment at least one comorbid disorder (besides dental phobia) was diagnosed in 8 (36.36%) individuals of the R-PHOB-group and 13 (31.71%) of the PHOB-group. Altogether 27 (13 within the R-PHOB/14 within the PHOB-condition) current disorders besides dental phobia were diagnosed in both clinical groups: 17 Anxiety Disorders (11/6), 3 Post-traumatic Disorders (0/3); 2 Substance Abuse Disorders (excluding nicotine-abuse) (0/2); 4 current Minor Depressive Episodes (1/3); and 1 Somatoform Disorder (1/0).

Participants in the two clinical groups were recruited from the 'Treatment Centre for Dental Fear', a cooperation between the Ruhr-University Bochum and a local dental clinic specialising in the treatment of dental fearful patients. The Centre consists of a psychological unit attached to the clinic, with treatment provided by postgraduate clinical psychologists specialized in treatment of dental fear. Control participants were recruited via posters at the campus of the Ruhr-University and at the Dental Clinic. The Dental Anxiety Scale (DAS, Corah, 1969) was used to screen them. If an individual had a DAS score <13, and reported no subjective dental fear or avoidance of dental surgeries, they were invited to participate in the study as a non-phobic control.

1.2. Diagnostics and psychological treatment

A post-graduate clinical psychologist confirmed DSM-IV diagnosis of a Specific (Dental) Phobia in the PHOB and R-PHOB-groups and determined comorbid disorders using the German Mini-DIPS (Margraf, 1994). The Mini-DIPS is a semi-structured diagnostic interview short-form of the German DIPS (Schneider, Margraf, Barlow, DiNardo, & Becker, 2006). The DIPS has been demonstrated to be a reliable diagnostic instrument, with good test-retest reliability (rtt = 0.64–0.89) and an inter-rater reliability of kappa r = 0.80–1.00 (Schneider et al., 2006). High accordance between the Mini-DIPS and DIPS has been reported, with kappa-coefficients ranging between 0.76 and 0.89 and excellent interrater-reliabilities with kappa-coefficients between 0.90 and 1.0 (Margraf, 1994).

Amongst participants who had received CBT, the presence or absence of dental phobia was assessed by a clinical psychologist via administration the Specific Phobia section of the Mini-DIPS at a follow-up assessment directly prior to the experimental session.

Psychological treatment consisted of a five session CBT-protocol, aimed at teaching and applying cognitive (helpful thoughts) and bodily (applied relaxation; diaphragmatic breathing) coping-strategies in various exposure exercises, i.e., video-exposure, dental-noise exposure and in vivo exposure. In a pilot study, the program led to substantial reductions in subjective and behavioural fear responses, corresponding to large effect sizes (Wannemüller, Sartory, Jöhren et al., 2015). A three-session version of the treatment was shown to be superior to two forms of dental-hypnosis (Wannemüller et al., 2011). For additional information, see Sartory and Wannemüller (2010). At post-treatment and follow-up assessment participants who had received treatment were ask to rate the global treatment success (GSR) on a 7-point Likert scale ranging from 1 (very much worse) to 7 (very much better) with 4 indicating no change.

1.3. Questionnaires

Dental Anxiety Scale (DAS, Corah, 1969; German version translated by the authors). This self-report questionnaire consists of four items measuring subjective dental fear in four dental-related situations. Scores range from 4 to 20. The DAS additionally served as a screening instrument in the CON-group. In our sample we found good internal consistency (Cronbach's $\alpha = 0.80$).

Dental Cognitions Questionnaire (DCQ, De Jongh, Muris, Schoenmakers, & Ter Horst, 1995; German version translated by the authors). This self-report questionnaire consists of 38 prototypical negative cognitions (beliefs and self-statements) related to dental treatment. Fourteen items focus on negative beliefs pertaining to dentistry in general (e.g. "Dentists don't care …") and to the patients themselves (e.g. "I can't stand pain"), and the remaining 24 items contain negative self-statements (e.g. "Everything is going wrong"). Patients are asked to indicate if these negative cognitions occur to them during dental treatment. The number of 'yes' answers (DCQ: range = 0–38) are summed (DCQ frequency-score). Individuals with dental phobia have been found to report a significantly higher number of negative cognitions than non-phobic controls (De Jongh et al., 1995). Data from a previous study (Sartory, Heinen, Pundt, & Jöhren, 2006) demonstrated excellent internal consistency (Cronbach's $\alpha = 0.90$).

Hierarchischer Angstfragebogen (engl. transl. **'Hierarchical Fear Questionnaire'**, HAF, Jöhren, 1999). The German HAF consists of 11 items measuring subjective dental fear. Patients rate how much anxiety they would experience in 11 hierarchically-ordered phobic situations on a scale from 1 (not at all) to 5 (extremely). The authors reported a cut-off score for dental phobia of 38 and noted that 100% of individuals who exceeded this score were subsequently diagnosed with dental phobia using a semi-structured interview. An internal consistency of Cronbach's $\alpha = 0.80$ has been reported by the authors. We found an internal consistency of Cronbach's $\alpha = 0.92$ in the present sample.

Revised Iowa Dental Control Index (R-IDCI, Brunsman, Logan, Patil, & Baron, 2003; German version translated by the authors). This self-report questionnaire consists of 9 items concerning the desire for control (five items: e.g. 'To what degree would you like control over what will happen to you in the dental chair?') and predicted control (four items: e.g. 'How much do you think you can control what will happen to you while in the dental chair?') during dental treatment. Item ratings range from 1 (none) to 5 (totally) and are summed. Dental phobic individuals show a pattern of a high desire for control and low feeling of control, combined with high levels of dental distress compared to non-phobic individuals (Logan, Baron, Keeley, Law, & Stein, 1991). We found internal consistencies of Cronbach's $\alpha = 0.85$ for the 'desired control' and $\alpha = 0.85$ for the 'predicted control' scale.

A German 21-item set from the **Depression Anxiety Stress Scale** of Lovibond and Lovibond (1995) was used. This self-report questionnaire measuring negative emotional status is answered on a 4-

[1] We also checked for subgroup-differences in the dependent measures, i.e. subjective ratings, HR-response and SR. There was only one statistically significant difference, indicating a more positive evaluation of POS pictures in untreated phobic compared to unsuccessfully treated phobic individuals ($F(1,39) = 6.87$, $p = 0.012$). With regards to HR and SR there were no statistically significant differences between these two subgroups.

Table 1
Means (SDs) and post-hoc group-comparisons of demographical and clinical data of remitted phobic (R-PHOB), phobic (PHOB) and never-phobic control individuals (CON) and subgroup-comparisons of untreated and unsuccessfully treated phobic individuals.

	In remission (R-PHOB) n = 22			Phobic (PHOB) n = 41					Control (CON) n = 29	Group comparisons (test statistic) and post hoc-comparisons[a]	Subgroup-comparisons (test statistics)
			total[b]	Untreated (n = 34)	unsuccessfully treated (n = 7)			total[c]	total		
Age (y.)			41.86 (8.36)	35.74 (10.14)			40.86 (7.06)	36.61 (9.80)	35.45 (10.96)	$F = 3.19^{*}$ n.s.	$F = 0.1.61$ n.s.
Sex ratio (f/m)			15/7	20/14			2/5	22/19	19/10	n.s.	n.s.
Education (y.)			11.36 (1.53)	11.90 (2.32)			10.43 (1.13)	11.62 (2.22)	16.24 (0.19)	$F = 43.15^{***}$ CON > R-PHOB, PHOB	$F = 2.61$ n.s.
	pre	post	FU	pre	pre	post	FU				
Dental fear											
DAS	18.05 (1.86)	12.27 (3.88)	10.64 (3.16)	16.71 (2.34)	18.14 (3.34)	15.43 (4.58)	17.86 (3.76)	16.92 (2.63)	8.00 (1.89)	$F = 106.47^{***}$ PHOB > R-PHOB > CON	$F = 1.09$ n.s.
HAF	47.69 (4.97)	32.54 (10.08)	27.82 (8.22)	45.03 (5.57)	45.86 (10.38)	41.07 (10.62)	43.86 (8.36)	44.67 (6.36)	–	$F = 59.48^{***}$ PHOB > R-PHOB	$F = 0.16$ n.s.
DCQ	22.57 (7.48)	13.38 (7.25)	12.59 (8.67)	21.00 (8.49)	20.29 (7.54)	15.00 (11.65)	19.71 (9.32)	20.61 (8.56)	–	$F = 9.74^{**}$ PHOB > R-PHOB	$F = 0.11$ n.s.
IDCI-R-d	21.44 (3.85)	21.33 (2.91)	20.60 (3.70)	22.39 (3.82)	20.86 (3.85)	21.49 (1.54)	22.39 (1.27)	22.38 (3.22)	–	$F = 2.93$ n.s.	$F = 0.01$ n.s.
IDCI-R-p	7.57 (3.15)	12.47 (3.99)	13.30 (3.79)	7.69 (4.03)	6.71 (2.43)	10.35 (3.99)	9.06 (2.98)	8.10 (3.73)	–	$F = 21.01^{***}$ R-PHOB > PHOB	$F = 0.65$ n.s.
Clinical state											
DASS-21	14.93 (7.96)	13.43 (7.24)	11.37 (8.21)	16.10 (10.73)	24.00 (15.92)	19.11 (18.48)	20.71 (13.61)	16.95 (11.25)	8.79 (6.56)	$F = 6.85^{**}$ PHOB > CON	$F = 0.90$ n.s.
Subjective therapy success											
GSR	–	5.73 (0.60)	5.76 (0.64)	–	–	5.37 (0.79)	4.58 (1.14)	–	–	–	–

Note. DAS = Dental Anxiety Scale; HAF = Hierarchischer Angstfragebogen; DCQ = Dental Cognition Questionnaire; IDCI-R-d = Revised Iowa Dental Control Index (perceived control); IDCI-R-d = Revised Iowa Dental Control Index (desired control); DASS-21 = Depression, Anxiety, Stress Scale (short form).
$^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$.
[a] Bonferroni corrected results of $p \leq 0.05$.
[b] Mean at time-point of psychophysiological assessment i.e. at FU in R-PHOBs.
[c] Mean at time-point of psychophysiological assessment i.e. at pre-treatment in untreated- and at FU in unsuccessfully treated PHOBs.

point scale (0 = not at all/3 = almost always). In addition to the mean score, there are three 7-item subscales: depression, anxiety and stress. In the current study, we found an internal consistency of Cronbach's $\alpha = 0.90$ for the total scale, with subscales ranging from Cronbach's $\alpha = 0.90$ (depression) to 0.78 (stress).

1.4. Subjective stimulus ratings

Participants rated stimuli for valence and arousal using the Self-Assessment Manikin (SAM) pleasure and arousal scales (Bradley & Lang, 1994). The SAM-scales consist of non-verbal graphic representations that allow quick assessment of emotional reactions to an event. SAM-graphics range from a smiling, happy figure (4) to a frowning, unhappy figure (−4) when representing the pleasure dimension, and range from an excited, wide-eyed figure (9) to a relaxed, sleepy figure in the arousal dimension. Participants provided arousal- and pleasure ratings digitally using a computer-mouse cursor.

1.5. Experimental design

There was one acoustic and one visual stimulus block, both consisting of seven neutral (NEU), negative (NEG), positive (POS) and dental related (DENT) stimuli. The order of blocks was counterbalanced between participants. Within each block, stimuli were presented for 6 s each. For five stimuli of each category, presentation was accompanied by a startle noise. Startle was randomly delivered between 4.5 and 5.5 s after stimulus-onset. The order of stimulus presentation was partially randomised with no more than two stimuli of the same category following in sequence. After the presentation of a stimulus, a black screen was presented for 3 s, followed by the presentation of the SAM-scales for 3.5 s each. The participants could rate the stimulus materials by moving a cursor over the respective SAM-scale using a computer-mouse, and made their rating via a mouse-click. Ratings were followed by an inter-stimulus-interval (ISI) with a random length ranging from 9.5 to 12.5 s. During the ISI, the startle noise was additionally randomly delivered four times (ISI-startle); two times during the acoustic and two times during the visual block, with one startle appearing during the first and one during the second half of each block. The stimulus presentation was controlled using *Presentation*®-software.

1.6. Stimuli

The acoustic startle stimulus consisted of a burst of broadband 100-dB [A] white noise, presented binaurally via headphones for 50 ms with an instantaneous (maximally 0.8 ms) rise and fall time.

Neutral, positive and negative pictures were taken from the International Affective Picture System (IAPS, Lang, Bradley, & Cuthbert, 2008). The numbers were as follows: Negative (6350, 3010, 6260, 1050, 1300, 9630, 9040), Positive (8030, 5621, 4660, 4608, 8370, 2216, 2208), Neutral (7140, 7009, 7550, 7500, 5500, 7000, 7100). The dental-related pictures were taken partly from the IAPS (9582, 9584) and partly from other sources such as textbooks of dental treatments.

The affect-eliciting sounds were all presented with an intensity of 60 dB [A], representing room-level volume. Dental-related acoustic stimuli comprised seven sounds that would typically occur during dental treatment (scratching sounds caused by two dental probes during an examination, one sound generated during ultrasound-cleaning to remove tartar, two sounds of round bur drill and two kinds of high frequency turbine drills). In an earlier study

(Wannemüller, Sartory, Elsesser, et al., 2015) these sounds were rated as fear-evoking and aversive in a dental phobic sample. Sounds of all other categories were borrowed from the International Affective Digital Sound-System (Bradley & Lang, 1999). The numbers were: Negative (116, 276, 278, 290, 424, 291, 712), Positive (110, 215, 815, 201, 230, 351, 221), Neutral (132, 325, 311, 425, 262, 251, 704).

1.7. Psychophysiological measures and data reduction

Psychophysiological data were recorded with a MP-100 amplifier system (BIOPAC® Systems, Inc.) and digitized with 16-bit. Response-scoring was conducted using the Matlab R32 (MathWorks®) and ANSLAB (Autonomic Nervous System Laboratory) biosignal analysis program (shareware version available at the software repository of the Society for Psychophysiological Research; Wilhelm & Peyk, 2005) adjunct-software.

1.7.1. Startle response (SR)

The eye blink was recorded from the m. orbicularis oculi. Two miniature electrodes (inner diameter 5 mm) were placed below the right eye according to published guidelines (Fridlund & Cacioppo, 1986) and the electromyogram (EMG) was recorded with a sampling rate of 1000 Hz. EMG signals were pass- (28 Hz - 500 Hz) and notch filtered (50 Hz). Signals were rectified and smoothed using a 10 ms (=15.9 Hz) moving average. The response magnitude (peak EMG response in microVolts) was calculated as the difference between the peak EMG response within 20–150 ms after startle-probe onset and startle baseline, scored as the mean EMG in a 50 ms time window before startle onset. According to the recommendations of Blumenthal et al. (2005) a 'response' was defined by being at least twice as high as baseline-activity, otherwise it was scored as zero. Furthermore, every startle response was visually checked to detect invalid startle responses, i.e. by involuntary blinks during the baseline-interval. Invalid startle-responses were substituted by the individual's mean raw-score for the relevant affective category. If more than three responses within one category were invalid, the startle data of the individual was not considered for analyses. Altogether, we interpolated 5.26% of all responses (176 out of 3344), 3.82% ($n = 37$) in CONs, 4.96% in PHOBs ($n = 72$) and 7.25% in R-PHOBs ($n = 67$). The individual mean of interpolated trials was 2.28 ($SD = 3.17$) ranging from 0 to 16. Means of interpolated trials did not differ between groups ($F(2,73) = 1.66$, $p = 0.20$). Technical problems during startle-recording also led to exclusion from analyses. Altogether, SR-data of 16 (17.4%) individuals (1 R-PHOBs; 8 PHOBs; 7 CONs) had to be excluded. Startle magnitude was averaged (i.e., including zero responses). In analysing SR data there is the risk that a small number of participants with unusually large blinks can disproportionately affect the outcome of SR analyses (Blumenthal et al., 2005). We therefore followed the suggestion of Blumenthal et al. (2005) and performed individual-wise T-transformations, using all blinks for a given participant as the reference distribution and reporting the results as T-scores ($mean = 50$, $SD = 10$).

1.7.2. Heart rate (HR) response

The lead II electrocardiogram was recorded using chest electrodes. The sampling rate was 512 Hz; ECG-signals were pass (0.5 Hz high - 40 Hz low-pass and notch filtered (50 Hz). R-waves were detected offline and converted into interbeat intervals (bpm). Mean HR was calculated for six one-second epochs after stimulus onset and baseline-corrected taking one second before stimulus onset into account. HR reactions were averaged within stimulus categories resulting in evoked responses to the materials.

1.8. Procedure

Participants in the PHOB-group were informed about the experimental assessment during their first diagnostic session, about one week before they were due to start a course of CBT. The experimental assessment took place before treatment started. Amongst participants who had previously received treatment, the experimental assessment took place when they returned for a follow-up appointment at eight months post-treatment to assess long-term therapy outcome. A clinical psychologist who had not conducted the dental phobia treatment conducted the follow-up diagnostics and experimental assessment. CONs participated in the experiment after a clinical psychologist had checked their potential eligibility for participation.

The experimental session was conducted in a psychophysiological Laboratory of the Ruhr-University Bochum (an unfamiliar location for all participants). After consenting to the experimental procedure, participants sat in a chair in front of a monitor-screen. After attachment of the electrodes, the room lights were dimmed and the participants were trained to use the SAM-scales. After an initial 3-min rest period the startle stimulus was administered six times for the purpose of demonstration and habituation. Afterwards, the picture stimuli were presented followed by the sound stimuli (or vice versa). Participants were informed of the change of modality after the first block. As described for standard picture-viewing paradigms (Lang, Greenwald, Bradley, & Hamm, 1993) participants were asked to rate the emotional valence and arousal during picture or sound presentation using the SAM-scales.

1.9. Statistical analyses

We conducted 3 (group) x 2 (modality) x 4 (stimulus category) repeated measures ANOVA to analyse the subjective ratings and our SR-T-score analyses. Because our individual-wise T-standardisation also included the ISI-startle responses, we included these as a fifth category in our SR-T-score analyses, resulting in a 3 (group) x 2 (modality) x 5 (category) design. For the SR analyses we additionally conducted trend-analyses within each group to check for the expected linear increasing trend (POS < NEU < NEG) in SR-responding. In a second step we substituted the NEG-with the DENT-category in order to investigate whether we would find a similar trend (i.e. whether the DENT category would be equivalent to the NEG category). In a third step we added the DENT-category as a fourth category (POS,NEU,NEG,DENT) to investigate the possibility that stimuli in the DENT category would result in even stronger responses than those in the NEG category, as might be expected amongst PHOBs.

Since the maximum HR-acceleration to an aversive stimulus and the largest difference between HR-accelerators and decelerators have been reported to occur within the fourth second post stimulus onset (Hodes, Cook, & Lang, 1985), we decided to focus on the fourth second in our HR-analyses, resulting in a 3 (group) x 2 (modality) x 4 (category) design. Because potential between-group differences in HR-responses to dental stimuli were our primary interest (in line with the stated main aim of our study, and the previous literature), we carried out between-group analyses on HR-responses to dental stimuli regardless of the outcome of the omnibus ANOVA.

Main effects of ANOVA are only reported if there were no higher-order interaction effects. As measures of effect-size we provide eta-square (η^2) and in the case of post-hoc comparisons Cohen's d (d). The Huynh-Feldt correction was applied if the assumption of sphericity was violated. Post-hoc group comparisons were all Bonferroni-corrected. All analyses were conducted using the IBM Statistics SPSS 23 software package.

2. Results

2.1. Subjective ratings

2.1.1. Valence

The interaction effects group x category, F (6, 264) = 7.77, p < 0.001, η^2 = 0.15, and category x modality, F (3, 264) = 6.03, p = 0.001, η^2 = 0.06, were significant, as was the group x category x modality effect, F (6, 264) = 2.26, p = 0.040, η^2 = 0.05. Only the interaction group x modality, F (2, 88) = 0.79, p = 0.46, η^2 = 0.02, was non-significant. Within both modalities we found highly significant group x category effects (visual: F (6, 264) = 8.57, p < 0.001, η^2 = 0.16, auditory: F (6, 264) = 4.40, p < 0.001, η^2 = 0.10). Within the DENT-, F (1, 88) = 27.15, p < 0.001, η^2 = 0.24, and NEG-category, F (1, 88) = 9.24, p = 0.003, η^2 = 0.10, pictures were rated more unpleasant compared to sounds by the participants. However, with regard to the POS-category participants rated the sounds more pleasant compared to the pictures, F (1, 88) = 4.22, p = 0.043, η^2 = 0.05. The NEU-category was the only category showing a significant group x modality effect, F (2, 88) = 4.15, p = 0.019, η^2 = 0.09, with participants of the PHOB-group rating neutral pictures more pleasant compared to sounds, F (1, 40) = 5.37, p = 0.026, η^2 = 0.12. Within the other categories there were no significant group × modality interaction effects, neither within the DENT-, F (2, 88) = 0.30, p = 0.74, η^2 = 0.01, nor NEG-, F (2, 88) = 0.19, p = 0.19, η^2 = 0.01, nor POS-condition F (2, 88) = 0.52, p = 0.60, η^2 = 0.01. For means, standard deviations, and post-hoc within category and group comparisons, see Table 2.

2.1.2. Arousal

We found significant group x category, F (6, 246) = 11.21, p < 0.001, η^2 = 0.22, and modality x category, F (3, 246) = 10.51, p < 0.001, η^2 = 0.11, interactions. The group x modality × category interaction, F (6, 2) = 2.08, p = 0.064, η^2 = 0.05, was not significant. Within all categories pictures were rated more arousing than sounds (DENT: F (1, 87) = 22.00, p < 0.001, η^2 = 0.20, NEG: F (1, 87) = 10.84, p < 0.001, η^2 = 0.11, POS: F (1, 85) = 7.48, p = 0.008, η^2 = 0.08, NEU: F (1, 83) = 5.09, p = 0.027, η^2 = 0.06). Only within the NEG-category there was a significant group x modality effect, F (2, 87) = 3.26, p = 0.043, η^2 = 0.07, with CONs rating the pictures more arousing compared to sounds, F (1, 27) = 7.87, p = 0.009, η^2 = 0.23. For means, standard deviations, within-group and within-category post-hoc comparisons, see Table 2.

Overall, valence ratings for dental materials of either modality did not differ between groups. Participants in the PHOB and R-PHOB group rated dental pictures as more arousing than those in the CON group, but the only difference for dental sounds was that arousal ratings were higher in the PHOB compared to the CON group. In the PHOB group, dental pictures were rated more unpleasant than negative pictures, but dental and negative sounds were rated equally unpleasant. In the R-PHOB and CON group, negative pictures and sounds were rated as more unpleasant than dental pictures and sounds. A similar pattern of findings was found for arousal ratings, with dental pictures rated as more arousing than negative pictures in the PHOB group, but not in the R-PHOB or CON groups (for further information please see post-hoc tests of Table 2).

2.2. SR-modulation

For SR T-scores, the ANOVA yielded a significant group x category effect, F (8, 292) = 2.84, p = 0.005, η^2 = 0.07, and no significant group x modality, F (4, 292) = 1.82, p = 0.132, η^2 = 0.02, or group x modality x category, F (8, 292) = 1.16, p = 0.32, η^2 = 0.03, effects.

We followed up the group × category interaction by investigating the pattern of SR T-scores across the different categories within each group.[2] These analyses showed a highly significant effect of category within all three groups (R-PHOB: F (4, 80) = 7.23, p < 0.001, η^2 = 0.27, PHOB: F (4, 128) = 10.29, p < 0.001, η^2 = 0.24, CON: F (4, 84) = 11.10, p < 0.001, η^2 = 0.35).

To investigate whether our positive and negative control stimuli evoked the expected patterns of SR, we conducted trend analyses including the POS, NEU and NEG categories within each group in a first step. These analyses showed significant linear trends towards the direction (POS < NEU < NEG) in PHOBs, F (1, 32) = 28.64, p < 0.001, η^2 = 0.47, and CONs, F (1, 21) = 22.08, p < 0.001, η^2 = 0.51. There was also a significant linear trend within R-PHOBs, F (1, 20) = 18.65, p < 0.001, η^2 = 0.48, but in addition there was also a significant quadratic trend, F (1, 20) = 10.38, p = 0.004, η^2 = 0.34 (see Fig. 1).

In a second step we substituted the NEG-category by the DENT-category to investigate whether the DENT-materials would evoke the same SR-trend (POS < NEU < DENT) as the NEG-materials in all groups. Trend analyses yielded significant linear trends in the PHOB-, F (1, 32) = 33.15, p < 0.001, η^2 = 0.51, and CON-, F (1, 21) = 12.41, p < 0.001, η^2 = 0.37, group. However, in the R-PHOB group in addition to a linear trend, F (1, 20) = 5.76, p < 0.03, η^2 = 0.22, we found a strong quadratic trend, F (1, 20) = 13.06, p < 0.001, η^2 = 0.54 (see Fig. 1).

In a third step, we included both the NEG and DENT-categories in our trend analyses (POS < NEU < NEG < DENT). Amongst PHOBs, F (1, 32) = 32.48, p < 0.001, η^2 = 0.50, and CONs, F (1, 21) = 19.38, p < 0.001, η^2 = 0.48, responses followed a linear increasing trend across the four categories. Again, R-PHOBs SR-magnitudes were best explained by a quadratic trend, F (1, 20) = 25,61, p < 0.001, η^2 = 0.56, reflecting decreasing startle responsiveness from the NEU to the DENT-category.

We further conducted pairwise category-comparisons including the DENT-category. Within the CON-group DENT-materials evoked larger SR, F (1, 21) = 7.06, p = 0.015, η^2 = 0.25, compared to NEU-materials. Within the PHOB-group the comparison was non-significant, F (1, 32) = 2.68, p = 0.112, η^2 = 0.08. Conversely, within the R-PHOB group NEU-stimuli evoked larger responses than DENT-stimuli, F (1, 20) = 9.09, p = 0.007, η^2 = 0.31. Compared to NEG-stimuli, SRs evoked by DENT-stimuli did not differ in any group (PHOB: F (1, 32) = 0.68, p = 0.75, η^2 = 0.00, R-PHOB: F (1, 20) = 0.11, p = 0.75; η^2 = 0.00, CON: F (1, 21) = 12.41, p = 0.002, η^2 = 0.37). In contrast, compared to POS-stimuli SRs of DENT-stimuli were significantly enhanced in all groups (PHOB: F (1, 32) = 33.15, p < 0.001, η^2 = 0.51, R-PHOB: (F (1, 20) = 5.76, p = 0.03, η^2 = 0.22, CON: (F (1, 21) = 0.80, p = 0.38, η^2 = 0.04).

Taken together, these analyses suggest that for the dental phobic (PHOB) and never phobic (CON) individuals, there was a tendency for increased SR with increasing 'negativity' of stimuli (whether these negative stimuli were general negative stimuli or dental-related cues). Conversely, for the remitted phobic individuals (R-PHOB), this relationship was no longer evident, with general negative and dental-related stimuli evoking equal (for negative stimuli) or lower (for dental-related stimuli) SR responses compared to neutral stimuli.

2.3. Heart rate response

At the omnibus level the group x category, F (6, 264) = 1.35,

[2] We also conducted SR-raw score analyses which did not yield any significant group effects within any single category. Results of the raw-analyses confirm the within group effects and trend directions reported here for the T-score analyses. For raw-score means (SD) and analyses please see Supplement A.

Table 2
Means (SDs) and post-hoc test results (PHOBs vs. R-PHOBs vs. CONs) of subjective ratings of the stimulus materials.

			R-PHOB	PHOB			CON	Post-hoc tests		
			total	total	Unsuccess-fully treated	untreated	total	G x Cat	G[a]	Category[a]
			M (SD)	M (SD)	M (SD)	M (SD)	M(SD)			
Valence	Pictures	Pos	1.79 (1.40)	2.49 (1.32)	1.38 (1.82)	2.72 (1.10)	2.14 (0.83)	F (6, 264) =	n.s.	R-PHOB: Pos > Neu > Dent > Neg
		Neu	1.07 (1.36)	2.16 (1.63)	1.90 (1.99)	2.21 (1.58)	0.63 (1.13)	8.57, $p < 0.001$,	PHOB > R-PHOB, CON	PHOB: Pos, Neu > Neg > Dent
		Neg	−2.26 (1.48)	−0.85 (1.78)	−0.31 (2.22)	−0.97 (1.70)	−2.45 (1.79)	$\eta^2 = 0.16$	PHOB > R-PHOB, CON	CON: Pos > Neu > Dent > Neg
		Dent	−1.31 (1.27)	−1.75 (1.76)	−1.36 (1.41)	−1.83 (1.87)	−1.05 (1.41)		n.s.	
	Sounds	Pos	2.08 (1.04)	2.81 (1.14)	2.49 (1.37)	2.87 (1.11)	2.21 (0.97)	F (6, 264) =	PHOB > R-PHOB	R-PHOB: Pos > Neu > Dent > Neg
		Neu	1.10 (1.32)	1.79 (1.65)	1.41 (1.48)	1.86 (1.70)	0.97 (1.31)	4.40, $p = 0.001$,	n.s.	PHOB: Pos > Neu > Neg, Dent
		Neg	−1.60 (1.48)	-0.76 (1.55)	-0.02 (2.09)	-0.91 (1.41)	−1.90 (1.01)	$\eta^2 = 0.09$	CON < PHOB	CON: Pos > Neu > Dent > Neg
		Dent	−0.76 (1.25)	−1.03 (1.84)	-0.69 (2.11)	−1.11 (1.81)	−0.52 (1.40)		n.s.	
Arousal	Pictures	Pos	3.11 (1.56)	2.92 (1.59)	3.56 (1.79)	2.76 (1.68)	3.49 (1.77)	F (6, 255) =	n.s.	R-PHOB: Neu, Pos < Dent < Neg
		Neu	2.48 (1.67)	1.75 (1.20)	2.74 (1.73)	1.74 (1.59)	1.65 (0.99)	9.14, $p < 0.001$,	n.s.	PHOB: Neu < Pos < Neg < Dent
		Neg	6.54 (1.44)	4.80 (1.97)	5.03 (1.96)	4.51 (2.04)	5.26 (2.18)	$\eta^2 = 0.18$	PHOB < R-PHOB	CON: Neu < Pos, Dent < Neg
		Dent	5.09 (1.68)	5.61 (1.98)	5.26 (1.54)	5.32 (2.27)	3.22 (1.66)		CON < R-PHOB, PHOB	
	Sounds	Pos	2.82 (1.68)	2.32 (1.56)	2.80 (1.98)	2.48 (1.84)	3.08 (1.79)	F (6, 255) =	n.s.	R-PHOB: Pos, Neu < Dent < Neg
		Neu	2.49 (1.39)	2.20 (1.20)	3.10 (1.67)	2.11 (1.18)	1.85 (1.14)	7.14, $p < 0.001$,	n.s.	PHOB: Pos, Neu < Neg, Dent
		Neg	5.66 (1.76)	4.59 (1.86)	4.40 (1.97)	4.65 (1.98)	4.55 (1.85)	$\eta^2 = 0.15$	n.s.	CON: Neu < Pos, Dent < Neg
		Dent	4.27 (1.89)	4.89 (2.05)	4.66 (1.94)	4.69 (2.18)	3.03 (1.50)		PHOB > CON	

Note. G = group; Cat = category.
[a] Bonferroni corrected results of p < .05.

$p = 0.23$, $\eta^2 = 0.03$, and group x modality effects, $F(3, 264) = 1.42$, $p = 0.236$, $\eta^2 = 0.04$, were non-significant. The group x modality × category interaction effect, $F(6, 264) = 2.02$, $p = 0.064$, $\eta^2 = 0.04$, was also non-significant. However, because of our specific interest in group differences within the DENT-category, we carried out further post-hoc analyses.

Indeed, these post-hoc HR-analyses showed that there were no differences in any category neither in regard to group-effects (POS: F (2, 88) = 0.003, $p = 0.98$, $\eta^2 < 0.00$, NEU: F (2, 88) = 0.327, $p = 0.72$, $\eta^2 = 0.01$, NEG: F (2, 88) = 2.18, $p = 0.12$, $\eta^2 = 0.04$) nor group x modality effects (POS: (F (2, 88) = 1.05, $p = 0.356$, $\eta^2 = 0.02$, NEU: F (2, 88) = 2.05, $p = 0.135$, $\eta^2 = 0.04$, NEG: (F (2, 88) = 0.34, $p = 0.341$, $\eta^2 = 0.02$), except for the dental-category.

Within the DENT category we found a significant group, F (2, 88) = 3.14, $p = 0.048$, $\eta^2 = 0.07$, but a non-significant group x modality effect, F (2, 88) = 2.82, $p = 0.065$, $\eta^2 = 0.07$. The group main effect reflected a significant difference between PHOBs and CONs ($p = 0.047$, $d = 0.79$). When considering DENT-pictures and sounds separately (see Fig. 2), the group-difference was significant within the visual modality, $F(2, 88) = 5.13$, $p = 0.008$, $\eta^2 = 0.10$, and non-significant within the auditory-modality, F (2, 88) = 0.674, $p = 0.512$, $\eta^2 = 0.02$. For DENT-pictures, phobic-individuals displayed HR-acceleration, which differed significantly from the HR-deceleration displayed by CONs ($p = 0.013$, $d = 0.65$). The difference in HR-responding between R-PHOBs and PHOBs was non-significant, with a medium effect size w ($p = 0.07$, $d = 0.56$).

3. Discussion

By recording heart rate (HR)- and startle response (SR)-responses to phobia-related- and other affect-inducing materials amongst participants with current dental phobia (PHOB group), participants with dental phobia in remission (i.e. previously but not currently dental phobic; R-PHOB) and never-phobic control participants (CON), we aimed to replicate the finding of excessive defensive mobilization in currently dental phobic individuals during dental-related picture viewing. Furthermore, we wanted to investigate whether the remitted phobic individuals (R-PHOB), who had received a brief CBT intervention eight months prior to assessment, would still display physiological signs of excessive defensive activation, or rather show a response pattern resembling that displayed by individuals never affected by dental phobia. Due to divergent results for acoustic fear cues in dental phobia in previous research, we used both pictures and sounds as affect-inducing materials. We also used positive and general negative aversive stimuli to investigate the pattern of activation for more general defensive and appetitive responses.

In general, the physiological data show the expected patterns of response within the PHOB and CON groups. With regards to startle responses, within these groups we observed a linear response-trend from attenuation on exposure to positive stimuli to potentiation on exposure to negative stimuli. A similar trend was observed when including the dental cue category in place of general negative stimuli in this trend analysis, indicating activation of the defensive system in both the PHOB and CON groups by dental-related stimuli. With regards to heart rate, exposure to positive and negative stimuli was accompanied by HR-deceleration in all groups. This indicates a state of orienting, and reflects the expected response-pattern evoked by such materials (Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, Bradley, & Cuthbert, 1990).

With regards to the heart-rate responses to the dental-related materials, our results were less clear-cut. There were no statistically significant group effects at the omnibus-level. However, within the dental category there were indications of differences between the phobic and control participants in HR response to dental-relevant stimuli. Specifically, when viewing dental-related pictures, PHOB participants demonstrated HR-increase while CON participants displayed HR-decrease. Within the PHOB-group, the HR-increase occurred exclusively in response to dental pictures but not to other negative stimuli of both modalities. Consistent with Sartory et al. (2009) and Wannemüller, Sartory, Elsesser, et al. (2015), we interpret this to represent defensive action (flight-fight) activation in participants of the PHOB-group, already described in other phobic disorders (e.g. Hamm et al., 1997). This overexcitement of the defensive system triggering context-inappropriate defensive behaviours, as observed in the PHOB-group during dental-related picture viewing, has been identified to represent the key pathological process underlying SPs (see McTeague, Lang, Wangelin, Laplante, & Bradley, 2012).

However, the present findings suggest that dental drill-sounds

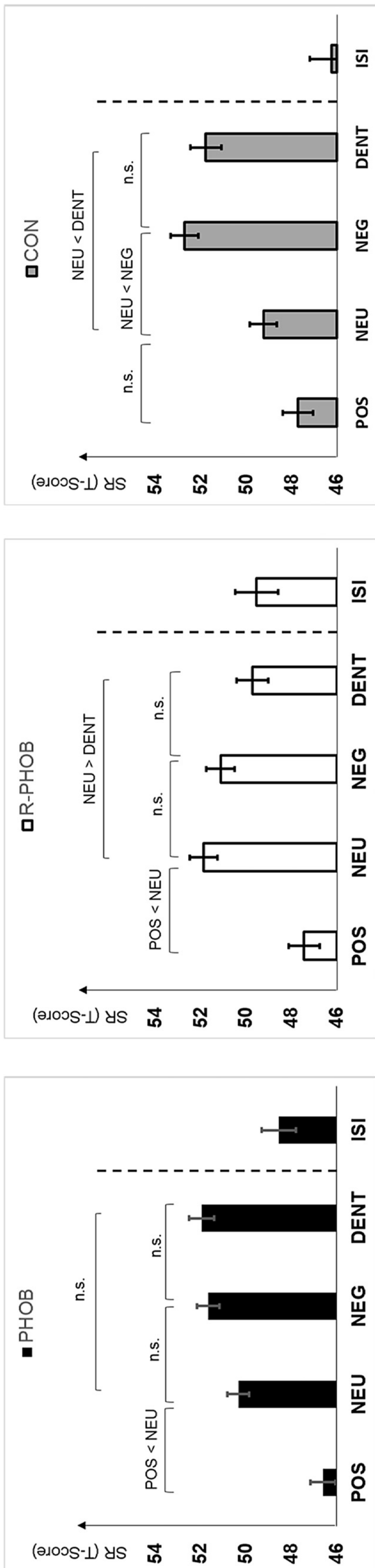

Fig. 1. T-transformed startle-responses (Means and Standard errors) of category effects within groups including significant results of pairwise comparisons. The ISI-category was excluded from pairwise-comparisons. Within all groups the comparisons between POS and NEG or DENT all were significant are not depicted in the Figures.

evoked less defensive mobilization in the PHOB-group compared to pictures. Consistently, PHOBs rated dental-sounds less unpleasant and arousing than dental pictures. Moreover, unlike for the visual category, there were no differences in ratings for negative and dental sounds. Consequently, PHOB's displayed a defensive physiological response pattern resembling a state of oriented attention with HR-decrease and SR-potentiation to both which again fits well with the PHOBs' lower arousal and valence ratings for dental-sounds, compared to pictures. However, previous studies on dental phobia have reported the converse response pattern, consisting of an accelerated HR-response and a lack of SR-potentiation during dental sound exposure (Sartory et al., 2009; Wannemüller, Sartory, Elsesser, et al., 2015). Oosterink, De Jongh, and Hoogstraten (2009) found that dental-drill sounds provoked high subjective fear levels in dental phobic patients. Some methodological differences concerning the stimulus presentation (i.e. a stimulus presentation blocked by valence vs. randomised; startle-onset at background-stimulus offset vs. variable startle presentations) might contribute to explaining this inconsistency. However, it is noteworthy that in the study conducted by Wannemüller, Sartory, Elsesser, et al. (2015), phobic participants rated the dental-related sounds, but not the pictures, as about twice as unpleasant as did phobic participants in the present study, despite the fact that both studies used the very same stimuli, presented in the same volume. However, in the Wannemüller, Sartory, Elsesser, et al. (2015) study participants were aware of an exposure-based treatment that would take place immediately after the psychophysiological assessment, which might have amplified dental-related contextual processing. Hence, one may speculate that the fear-evoking and psychophysiological effects of dental-related acoustic stimuli might be more context-dependent than those for visual stimuli, especially given that sounds could be considered to be strong cue-stimuli that occur reliably during dental surgery.

Interestingly, and in contrast to both other groups, amongst the remitted participants who no longer had dental phobia (R-PHOB group), we did not find any physiological indicators of defensive activation, i.e. SR-potentiation or HR-increase, during exposure to dental-related materials. Rather, R-PHOBs displayed a reverse pattern of lowered SR-responses to dental-related, compared to neutral stimuli and a quadratic trend in SR-response to the POS – NEU – NEG and, to an even stronger extent, POS – NEU – DENT materials. This could potentially be interpreted as resembling fear inhibition within the R-PHOB group.

On a neural level there is growing evidence that the inhibition of subcortical fear responses is driven by an inhibitory effect of infralimbic regions of the ventral medial prefrontal cortex (vmPFC) on amygdala activity, which is known to decrease the expression of infrahuman conditioned fear responses (Beretta, Pantazopoulos, Caldera, Pantazopoulos, & Paré, 2005; Milad, Vidal-Gonzalez, & Quirk, 2004). For example, rats with the largest increase in neuron activity in the infralimbic regions of the vmPFC after extinction training showed the least freezing to a conditioned fear stimulus in one study (Milad & Quirk, 2002). Potentially, the inhibition of defensive responsiveness we observed in R-PHOBs might represent the peripheral-physiological correlate of this inhibition in humans.

The mechanism by which exposure-based CBT might lead to fear inhibition in R-PHOBs is likely to consist of fear extinction and inhibitory learning (see Bouton, 1993). In terms of fear extinction, participants of the R-PHOB group might have learned that the presence of dental-related fear cues no longer signals threat and have formed a new CS-US association, such that dental-related cues no longer elicit defensive activation. The SR-alleviating properties of fear extinction have previously been described (e.g. Norrholm et al., 2006) in human conditioning-experiments.

Alternatively, inhibition of defensive activation during dental-

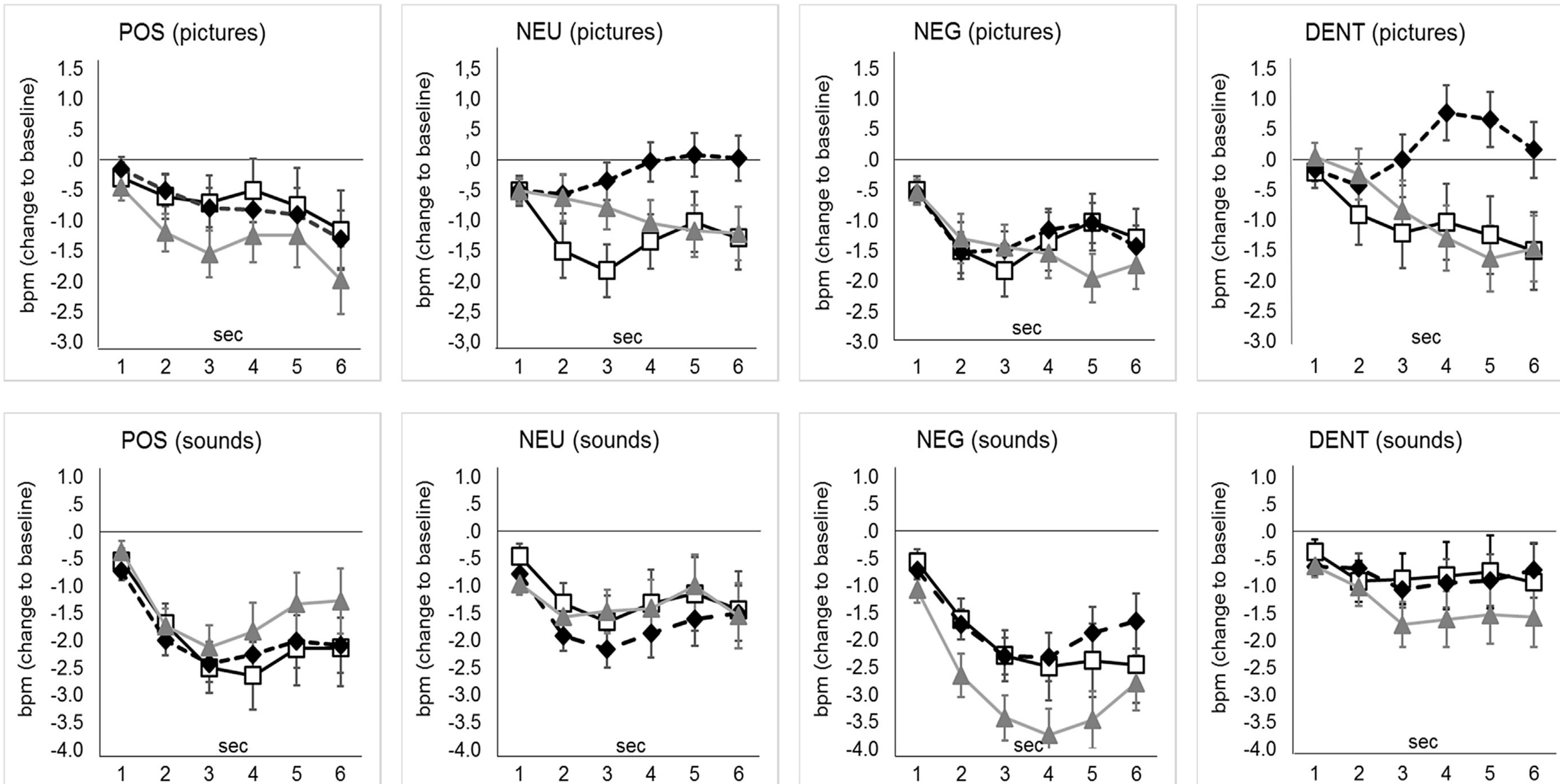

Fig. 2. Evoked heart rate responses to the affect-inducing pictures and sounds of phobic (PHOB), remitted phobic (R-PHOB) and control individuals (CON).

related picture viewing in R-PHOBs could also result from directly applying bodily or cognitive coping-strategies learned during CBT. Those strategies consisted of applied relaxation, relaxed breathing and the use of helpful thoughts, with some of which focused directly on bodily responses (e.g. 'Now I can do something against my fear by concentrating on relaxed breathing'. The startle inhibiting effects of pleasant imagery (e.g. Vrana, Roodman, & Beckham, 1995) or pleasant relaxation (e.g. Cook, Hawk, Davis, & Stevenson, 1991) are well described, and since SR-amplitudes to the negative materials were, surprisingly, not enhanced in R-PHOBs, one might speculate that this may result from a more generalized application of such coping strategies. However, we note that R-PHOBs did not show general hypo-responsiveness as their appetitive responses to the positive materials were unaffected.

Interestingly, the patterns of subjective responses were not completely consistent with the idea of inhibited defensive activation amongst R-PHOBS, as suggested by the physiological data. R-PHOBs did rate dental-related pictures and sounds as less unpleasant or arousing than general negative materials, in contrast to PHOBs, who showed the reverse pattern. However, there was no difference between R-PHOBs and PHOBs in their arousal or unpleasantness ratings for dental stimuli, and control participants rated dental stimuli equally unpleasant. Thus, these dental stimuli were equally subjectively aversive for all participants, and these subjective ratings did not reflect the widely differing physiological responses we observed between groups. This finding supports the notion of Bradley et al. (2001) that reports of emotion are not direct readouts of activity in emotional circuits. Our results suggest that they also might reflect evaluation of the stimuli themselves rather than just evaluation of the emotional responses evoked by the stimuli. Alternatively, this result might reflect that amongst R-PHOB the effects of the CBT intervention on physiological and subjective fear expression were partially desynchronized (see Rachman & Hodgson, 1974 for a detailed description), with larger effects of CBT on physiological responding in R-PHOBs.

Some findings and flaws in our study limit the generalization of the results. As already mentioned, in our HR-analyses the relevant group x modality x category interaction-effect was non-significant on the omnibus level. The same was true for some of our pairwise SR-magnitude category comparisons (e.g. the SR-response to dental-related materials compared to neutral materials in PHOB). Nevertheless, we found robust trend effects concerning our SR-analyses, and the group differences concerning HR-response yielded medium to high effect sizes within the dental category, especially for pictures. This suggests that our study was underpowered to unequivocally support all of our conclusions. Given that we applied a Bonferroni correction for our pairwise comparisons, this means testing against an effective significance level of 0.017, and thus we would have had 80% power to detect only large between-group effect sizes (e.g. $d = 0.80$ to $d = 0.94$ depending on the groups compared) within any stimulus category and modality. Future studies investigating these phenomena would benefit from a larger sample size in order to be able to detect more subtle between-group differences. Furthermore, we applied a cross-sectional study design assessing the individuals eight months post-treatment. This means that we do not know if the effects found do in fact reflect a change caused by the therapeutic intervention, and if so whether they were immediate or delayed. Moreover, due to our design it could be that the SR-pattern we observed amongst R-PHOBs was driven by enhanced responses to the NEU-materials rather than inhibited defensive mobilization in that group. However, this seems unlikely, particularly given that SR-raw score analyses did not show enhanced SRs of R-PHOBs within the NEU-category compared to the other groups. Further, the subjective ratings of valence and arousal suggest that R-PHOBs did in fact rate the NEU-stimuli as neutral and non-arousing.

To summarise, amongst patients suffering from dental phobia we found some evidence for a pattern of psychophysiological responding to dental-related pictures that reflects inappropriate defensive mobilization. Amongst never phobic control participants, the physiological response pattern and subjective evaluation for dental-related stimuli seemed to equal the response for general aversive stimuli, with these participants displaying signs of a mild activation of the defensive system in response to both. Notably, however, amongst remitted phobic individuals we observed complete absence of physiological defence responding to dental-related stimuli, and signs of physiological fear inhibition, eight months after the completion of a brief CBT-based treatment. Successful inhibitory learning from CBT or the effects of coping strategies during exposure might be the underlying factors for the observed response pattern. However, more research on defence responding after fear treatment is needed to illuminate the possible impacts of CBT on psychophysiological defence mobilization.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.brat.2016.12.009.

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