

Traces of fear in the neural web – Magnetoencephalographic responding to arousing pictorial stimuli

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A B S T R A C T

The concept of a 'fear network', i.e. an interconnected set of neural representations has been instrumental in explaining symptoms and their maintenance in anxiety disorders. The neural representations include both, response propositions such as flight or freezing and chunks of memory, conceptualized as Hebbian cell assemblies. Consequently, the fear network undergoes neuroplastic modifications, for instance, incremental enlargements with repeated exposure to threat and danger. This will in turn modify future processing of sensory stimuli and ultimately lead to an altered architecture of the brain's processing machinery and information processing modes. Using repeated exposure to traumatic stress as a model to study these processes, we summarize a series of magnetoencephalographic investigations from our laboratory, which demonstrate a characteristic pattern of early activation (before 100 ms latency to the eliciting stimulus) in fronto cortical circuits by high arousing, aversive pictorial and verbal stimuli in individuals presenting with posttraumatic stress disorder (PTSD). We propose that this pattern reflects a preference of stressed brains to engage a 'low road' sensory processing, which is fast but uncoupled from prefrontal regulatory control and which easily activates an alarm response, whereas less emphasis is given the more careful and contextual processing via the 'high road' along the ventral stream. As a result, the brain's architecture is changed from a careful analyzer of the environment to a rapid threat detector with a low threshold to engage in costly defense.

Keywords:
Cell assembly
Posttraumatic stress disorder

1. Introduction

1.1. The concept of a 'trauma network'

A cell assembly is composed of neurons that receive and transmit excitatory input from and to the assembly. Similarly, on a higher level, a propositional network is defined as an interconnected network of cell assemblies, which may be sensory, physiological, emotional, cognitive semantic, or motivational behavioral in nature, whereby the mutual excitatory input by these elements is also established by Hebbian learning, i.e., increasing connective strengthening with synchronous activation. When fear and anxiety become connected to this network and, hence, an alarm response constitutes the dominant action proposition of such an interconnected network, we speak of a 'fear network'. The somewhat different, less neurophysiologically based original concept of a 'fear network' was suggested by Lang (1979) and elaborated by Foa and Kozak (1986) in search of processes mediating symptoms and their maintenance in anxiety disorders. The description of propositional networks as highly interconnected nodes or chunks refers to their crucial feature that activation spreads across the nodes and elements such that activation of a few nodes is sufficient to activate

the entire network. Conveyed to the human brain, the representation of propositional networks can be understood by applying the concept of 'neuronal networks' as proposed by Hebb (1949): synaptic contacts are plastic and are modified as a consequence of simultaneous activation of the pre and postsynaptic neuron. Simultaneous activation of adjacent neurons facilitates their association in neural cell assemblies, and on a meta level simultaneous activation of cell assemblies may facilitate their association, so that activity in one facilitates activity in the other cell assemblies a 'propositional' network is born (Elbert & Rockstroh, 2004; Elbert et al., 2006). Given that cell assemblies from different sensory and association cortices are integrated into neuronal networks in the process of their formation, we may assume that perception of a single element (e.g., a specific contextual stimulus, a physiological process such as faster heartbeat or sweaty hands, a thought, impression or an emotional impulse) may start a complex response such as fear or excitement motivating approach or avoidance behavior.

It is conceivable that classical conditioning, experience and contextual learning establish the 'fear network' like any propositional network. These learning processes have been shown to involve hippocampus and parahippocampal structures, prefrontal cortex, anterior cingulate cortex and other, distinct areas of association cortices (Alvarez et al., 2008). Moreover, neuronal networks are remodeled according to principles of neuroplasticity (Elbert & Rockstroh, 2004). In humans, experience induced plasticity has been demonstrated originally for the somatosensory cortex in musicians and in blind individuals (e.g., Elbert et al., 1995,

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1998; Sterr et al., 1998). Functional reorganization has also been demonstrated for the auditory cortex (e.g., Elbert et al., 2002). Moreover, animal studies have substantiated experience dependent changes and reward modulated plasticity in the primary visual cortex (Shuler & Bear, 2006; Gavornik et al., 2009; Gilbert & Piech, 2009).

However, relative to the multitude of networks, which guide our behavior, a 'fear network' that is activated even in safe environments is maladaptive and even pathological, when strong interconnections, low threshold of ignition, and high resistance to extinction are out of contextual control (Foa & Kozak, 1986). Reviewing the psychophysiological literature on PTSD, Orr and Roth (2000) concluded that such heightened physiological reactivity to trauma related cues is highly indicative of a diagnosis of PTSD. The studies carried out in our laboratory confirmed this view by tracing the 'fear network' that has been formed in response to repeated exposure to traumatic stressors, ultimately resulting in PTSD.

The experience of a highly stressful or traumatic event is accompanied by extreme emotional and physiological activation. Fear of dying, horror, pain, and the feeling of helplessness, all characteristics of a psychological traumatic experience, provoke a distinct pattern of physiological and neuro endocrine responses. Whereas the stress/trauma evoked central peripheral circuits may be considered adaptive in response to imminent threat, as they activate the flight fight fright defense cascade ensuring survival, they also strongly affect the dynamic storage of these experiences in memory, as connectivity to contextual information is weakened with each new type of traumatic stressor experienced (Elbert et al., 2006). During the experience of life threat the amygdala, hippocampus, and prefrontal cortex should prompt the association of this particular traumatic stressor (e.g., hearing gun shots) with its context (e.g., a fight or a party). In the future, the implicit memory network that has formed of this experience including sensory (sound, sight smell...), physiological and emotional elements, termed 'hot' elements of the network, are related to autobiographical context information like time, date and contextual cues, the so called 'cold' memory. (Fig. 1 exemplifies the seed of a 'trauma network' according to this conceptual framework.) Additional traumatic experiences will reactivate the hot memory but inhibit the cold memory, which is not related to the present time and place context. Thus, with each new stressor, particularly when it occurs in a new context, the fear network is strengthened and the connections to

the cold memory are increasingly vague and finally lost. As a consequence, the association with danger spreads across contexts and even time as in a flashback. This forms the core of the pathological memory and behavior in PTSD (Elbert & Schauer, 2002; Elbert et al., 2006; Schauer et al., 2006; Neuner et al., 2008).

Animal studies have demonstrated that chronic or repeated severe stress promotes modification of hippocampal neurons: chronic immobilization stress, for instance, induced dendritic atrophy and debranching in CA3 pyramidal neurons of the hippocampus, whereas at the same time and in striking contrast, neurons in the basolateral complex of the amygdala exhibited enhanced dendritic arborization (Vyas and Mitra, 2002). Animal studies further demonstrated the involvement of the basolateral amygdala complex in persistence of fear memory (Poulos et al., 2009). Repeated experience of traumata will therefore result in a modification of the associative network, such that 'hot' (emotional physiological) elements are facilitated and 'cold' (autobiographical, contextual) elements are suppressed. Indeed, the work from our group has assembled considerable evidence that repeated traumatic experiences increase the risk for PTSD (Neuner et al., 2004), produce difficulties for the survivors in integrating the re-experience of the traumatic situation into their autobiography (Schauer et al., 2006), and reduce the likelihood for a remission (Kolassa et al., in press). Thus, repeated traumatic experiences are crucial for the establishment of a 'trauma network' since each traumatic experience integrates additional contextual elements into the network, while stress induced memory damage impairs subsequent learning to distinguish the traumatic context from neutral contexts. Principles of neuroplasticity suggest that repeated relevant experiences strengthen network interconnections and that repeated recall facilitates the integration of new context elements into the network. This, in turn, increases the chance that an element of the enlarged network triggers or 'ignites' activation of the whole network comprising fear responses.

According to this concept, typical PTSD symptoms like intrusions can be explained as activation of the trauma related fear network by a set of isolated sensory, emotional, or physiological stimuli, not necessarily related to a single traumatic experience at that very moment, but omnipresent in everyday stimulus configurations. For instance, a mother who is excited to accompany her daughter to the first day at

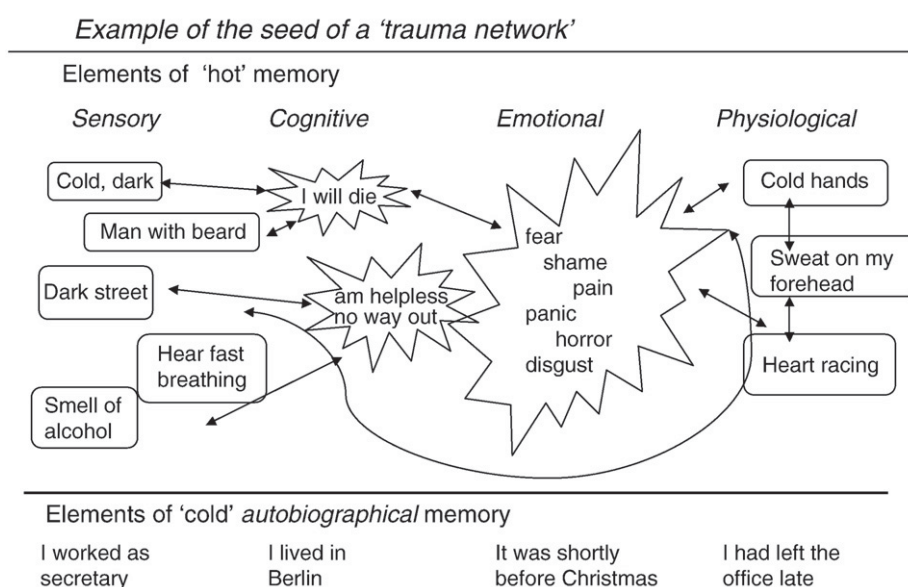


Fig. 1. Schematic outline of an exemplary network of propositions implemented as 'trauma network'. In PTSD, the border between 'hot' and 'cold' memory elements (thick black line) is firm and prevents the integration of emotional and autobiographical memories. Additional experiences add to the 'hot' elements but not to the context, thereby strengthening the separation of the two memories.

school feels her heartbeat and other signs of her physiological arousal. Seeing a man in uniform next to the school entrance and smelling the fire from a nearby chimney may be sufficient to trigger her 'fear network' and, as a consequence, enhance the startle reflex, cause intrusions and even may lead to the refusal to accompany the child again. Alternatively, the traumatized mother may have learned to suppress any emotional response and will remain numb instead of enjoying this exciting life event together with the child. As the elaboration of the context representation is impaired due to a hippocampal prefrontal failure to integrate the 'hot' emotional sensory physiological and the 'cold' contextual autobiographic representations, the symptoms persist. Moreover, avoidance symptoms prevent adequate processing of the trauma, i.e. the 'self repair' of the pathological 'fear network', thereby sustaining the PTSD symptoms (Foa et al., 1995). As individuals try to avoid the painful re experience of the traumatic experience and, thus, activation of the 'trauma network', the integration of the traumatic experience into the autobiography, that is, the distinction of the past trauma from the current context is prevented, which facilitates the maintenance of the 'trauma network' and the disorder (Elbert et al., 2006; Kolassa & Elbert, 2007).

2. Methods

2.1. Measuring the 'trauma network' in the brain

If a 'trauma network' is established in the brain as an associative network of neuronal assemblies, established by learning and neuroplastic processes, the pattern of neuronal interconnections that are activated together by specific stimuli should be visible in patterns of brain activity and, hence, may be demonstrated by brain imaging processes. Several studies from our lab used noninvasive magnetoencephalographic neuroimaging methods to trace the 'trauma network'. In these studies, the MEG was recorded using a 148 channel whole head neuromagnetometer¹. As propositional networks involve both, sensory perceptual (e.g., visual) and cognitive semantic (e.g., verbal) elements, designs to determine 'trauma networks' in the brain involved pictorial stimuli and visually presented words. Designs with pictorial stimuli used colored photographs from the International Affective Picture System IAPS (Center for the Study of Emotion and Attention, 2004). Stimuli were selected according to the purpose of the specific study, but always included exemplars of the categories high arousing pleasant, high arousing unpleasant, and low arousing neutral valence according to normative valence and arousal ratings (Lang et al., 1999). Pictures were presented in pseudorandom order in passive viewing tasks for longer intervals (e.g., 660 ms with an offset to onset inter stimulus interval of 700 to 900 ms) or in a rapid serial visual presentation (RVSP) protocol (Junghöfer et al., 2001, 2006), in which pictures are presented in a continuous stream for 349 ms each (2.86 Hz). Presentation order was controlled for transition probabilities between the three stimulus categories. Junghöfer's work ensured that physical picture parameters (brightness, contrast, color distribution, complexity, number of facial stimuli presented) did not differ between stimulus categories. Participants were asked to keep their eyes focused on a small central fixation cross overlaying each picture and to attend to the picture series carefully without any additional task.

For the design using verbal stimuli, German nouns were selected on the basis of pre experimental ratings (Herbert et al., 2006) with

¹ MAGNEST™ 2500 WH, 4D Neuroimaging, San Diego, USA. Neuromagnetic data were continuously recorded with a sampling rate of 678.17 Hz and a bandpass filter of 0.1 to 200 Hz. For artifact control, the vertical and horizontal and the electrocardiogram were recorded using a SynAmps amplifier (NEUROSCAN Laboratories, Sterling, VA, USA). The subject's nasion, left and right ear canal, and head shape were digitized with a Polhemus 3Space® Fasttrack prior to each session. Data preprocessing included noise reduction, correction for heartbeat-related artifacts, filtering of continuous data with a 0.5 Hz (6 dB/octave, forward-shift) high-pass and a 40 Hz (48 dB/octave, zero-phase-shift) low-pass filter, and rejection of epochs containing eye blinks.

respect to the dimensions valence and arousal. The selected sets of words with pleasant, unpleasant and neutral meaning were matched for word length and frequency as determined by the CELEX® data base (Baayan et al., 1993).

3. Results

3.1. Tracing the 'trauma' in the brain circuitry

In normal individuals, pictures with pleasant unpleasant and neutral content reliably evoke a characteristic electromagnetic response (Keil et al., 2001, 2002; Schupp et al., 2006; Peyk et al., 2008, 2009; Junghöfer et al., 2006): Activity in secondary visual cortex is augmented as early as 150 ms after the onset of arousing pleasant and unpleasant pictures relative to non arousing neutral pictures. This activity (in electroencephalographic literature labeled 'early posterior negativity', EPN) and subsequent more anterior temporal activity at 220 310 ms after stimulus onset (in electroencephalographic literature labeled 'late positive potential', LPP) are discussed as reflecting automatic, 'bottom up' attention capture by salient stimuli. Activity after 300 ms is supposed to reflect top down attentional resource allocation processes (Codispoti et al., 2007) and evaluation of the intrinsic significance of stimuli (Schupp et al., 2006). The modulation of early cortical activation by stimulus content seems to be robust against stimulus duration and frequency, as it has been demonstrated for longer stimulus duration and rapid presentation rates between 3 and 12 Hz (Junghöfer et al., 2001; Peyk et al., 2009).

It has been suggested that affect related information can be conveyed to emotional structures like the amygdala via direct projections from the sensory thalamus with response latencies around 20 30 ms (LeDoux, 2000). Since the thalamic inputs to the amygdala weakly encode stimulus properties, signals are processed rapidly but imprecisely via this fast subcortical ('low road') pathway. More elaborate signals from association areas of sensory cortices reach the amygdala with a temporal delay via a slower cortical route ('high road'; LeDoux, 2000, 2007). However, the amygdalae, as centers of widely distributed emotional networks, share numerous, mainly reciprocal connections with orbitofrontal and medial prefrontal cortex and the entire ventral visual stream (Freese & Amaral, 2005), which may facilitate processing in these areas. These anatomical and functional connections suggest that initial stimulus evaluation may be dominated by affect categorization, allowing for rapid preparation of basic motivational systems before conscious recognition and evaluation of stimulus significance and its contextual relations. The reciprocal connections of the amygdala with prefrontal and secondary sensory cortex areas should support affective evaluation not only at longer latency 'high road' processes, but already at early 'low road' processing stages mediated by top down influences of prefrontal cortex. In a series of human studies, Junghöfer and colleagues related event related potentials to these different 'roads' of affective information processing (recent summary by Putsche, submitted for publication).

Studies from our lab demonstrated activity even before 100 ms after picture onset as well as frontal dominance in individuals suffering from PTSD (Junghöfer et al., 2003; Borgelt et al., submitted for publication). In Borgelt et al.'s study the early (70 100 ms) orbitofrontal response to aversive pictures was related to the severity of hyperarousal symptoms ($r = .6$) in PTSD clients (see Fig. 2). Irrespective of this early activity and similar to healthy subjects, PTSD subjects also displayed facilitated sensory processing of affective pictures between 170 210 ms in posterior regions (the magnetic EPN complement). We view these results as indicative of a hypersensitive alarm system in PTSD that is tuned for the rapid, preconscious detection of potentially threatening stimuli even before detailed analyses in the visual streams and a contextual embedding as result of the ventral stream are completed.

We assume that each sensory stimulus bearing emotional and motivational features may activate the 'low road', which may then

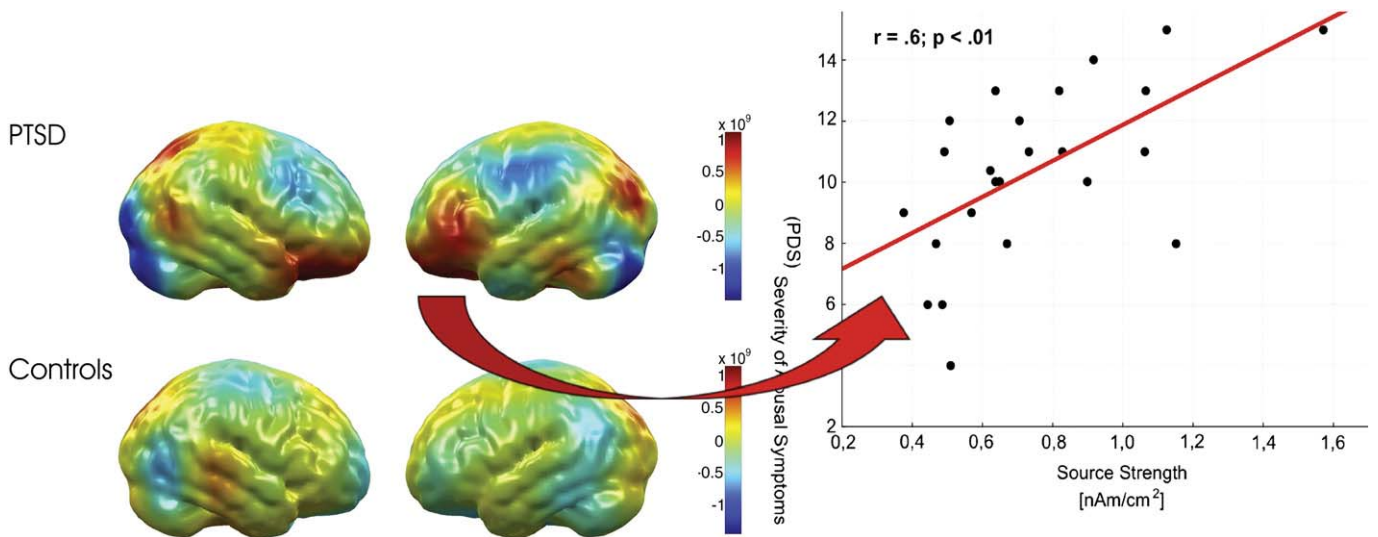


Fig. 2. Left: dipole activity projected on a standard cortical sheet in response to aversive pictures in individuals with diagnosis of Posttraumatic Stress Disorder (PTSD, top) and non-PTSD controls (bottom); color shading represents intensity of source activity with red and yellow colors indicating more pronounced activation. Graphs show an enhanced early (70–100 ms) activation in prefrontal, notably orbitofrontal regions that appears in PTSD clients but not controls in response to aversively arousing pictorial stimuli. Right: the intensity of this activation correlates with the severity of hyperarousal symptoms as measured by the CAPS-scale (each dot in the scatterplot denotes a patient).

activate action dispositions that include cortico limbic circuitry. The pronounced early response to aversive stimuli in stressed or traumatized individuals may indicate a lowered threshold for the 'low road' activation as a consequence of trauma. We propose that this experience shaped preference for the 'low road' results from trauma induced functional reorganization of the processing streams. In the reported studies, the experimental stimuli were not related to the individual traumatic experiences of the subjects, and hence, they did not directly activate intrusive memories. Still, the fact that generally aversive, potentially threatening stimuli activated fronto limbic action dispositions within milliseconds points to a reorganized processing machinery, which results in a low threshold to trigger an alarm response and enhanced readiness to respond. As the selected IAPS pictorial stimuli had been selected from commonly present cues (magazines, news etc.), we may assume that a brain tuned to quickly "smell" danger and impending threat and hence, automatically and rapidly responds to all potentially threatening cues consistently reactivates the 'trauma network' and, hence supports the persistence of PTSD.

The early prefrontal activation to aversive stimuli seems particularly prominent in individuals suffering from PTSD. Using similar stimulation protocols with clients with psychiatric diagnoses like affective disorders, schizophrenia, borderline personality disorder, who were screened for adverse experiences in childhood demonstrated suppressed posterior activity to emotional pictures around 200 ms (EPN complement; Weber et al., 2009; Matz et al., 2010) but an early frontal activity to aversive pictures could not be verified in this sample. Similarly, Catani et al. (2009) found reduced steady state visual evoked field amplitudes over posterior areas in response to aversive pictures in survivors of war and torture, two thirds of them fulfilling DSM IV criteria for PTSD compared to non traumatized control subjects. In addition, PTSD subjects exhibited augmented activity in superior parietal regions specifically in response to aversive stimuli, which were related to dissociative symptoms and torture severity.

Taken together, the pattern of activity suggests a low threshold for defense in response to visual stimuli with aversive content, particularly evident in individuals, who have suffered repeated and extreme traumatic event. It is compelling to consider this pattern as an indication of a 'trauma network'. The very early activity evoked by potentially threatening signals parallel to occipital activity may also reflect modulation of sensory input by frontal eye fields (FEF), as animal studies demonstrated the impact of FEF on higher order visual areas (Ekstrom et al., 2008) and on sensitivity among visual cortex neurons

(Reynolds & Chelazzi, 2004). Thus, it seems possible that FEF have become part of the 'trauma network' supporting enhanced sensitivity for target detection, in this case potentially threatening targets. It may be interesting to investigate such potential relationships further, as intervention techniques, like EMDR, indicate that manipulation of eye movements may interact with reactivation of the trauma network. Future studies are needed to clarify whether dampened activity in posterior regions at somewhat later latencies indicate pathological inhibition of cortical reactivity to aversive stimuli in visual sensory areas as a consequence of the rapid frontocortical alarm response (Adenauer et al., 2009) or whether only particularly intense 'trauma networks' in severely traumatized individuals can be detected by EEG or MEG.

Neural 'trauma networks' have also been examined using verbal stimuli as a trigger. In normal subjects, Kissler and her group (Kissler et al., 2007; Herbert et al. 2006) demonstrated similar modulation of cortical activity by emotional stimulus content for verbal similar to that reported by Schupp or Peyk and colleagues for pictorial material. This encouraged them to target the 'trauma network' using emotional words. In her thesis Balliel (2008) examined male and female adolescent refugees either having a PTSD diagnosis, or having experienced traumata but not presenting PTSD. Using a stimulation design similar to that used with pictorial stimuli (Jungthöfer et al., 2003), nouns denoting pleasant, unpleasant and neutral content were visually presented on a TV screen at 1 Hz frequency. As described for pictorial stimuli, more pronounced activation between 80 and 105 ms after stimulus onset to unpleasant than to neutral words was evident in adolescents with PTSD, while no modulation of early activity by word meaning was evident in non PTSD subjects. Refugee children without PTSD showed a similar temporal course of affective word processing as described for healthy adults: Around 200 ms after stimulus onset, enhanced cortical responses to affective words were localized in left temporo parietal regions, peaking around 250 ms in response to pleasant and unpleasant words. In contrast, responses around 200 ms and thereafter were smaller and not modulated by arousal in PTSD subjects, who had shown the pronounced early activation.

If the neuronal 'trauma network' in PTSD is related to disturbed episodic memory systems consequent to stress induced alterations in amygdala, hippocampus and prefrontal cortex, repeated reactivation of the 'trauma network' as in PTSD would produce structural alterations on the microscopic level (e.g. change in synaptic connectivities, change in dendritic and axonal branching, change in supporting glial cells and even vascularisation) that when large enough may also be detectable on

the macroscopic scale (Elbert & Rockstroh, 2004). Eckart et al. (submitted for publication) investigated PTSD related structural alterations in traumatized refugees with and without PTSD, and non-traumatized controls. PTSD clients (and to a lesser extent traumatized controls) showed reduced volumes in the bilateral isthmus of the cingulate, in the bilateral, lateral orbitofrontal cortex, in the left rostral middle frontal cortex and the right inferior parietal cortex. Whereas these results and those indicating reduced hippocampal volume in individuals with PTSD (e.g. Karl et al., 2006; Bonne et al., 2008) emphasize the association between structural changes, traumatic stress and psychological functioning (PTSD), they do not allow conclusions about causal relationships: Cumulative traumatic stress may have produced structural alterations in hippocampus, the isthmus of the cingulate and the lateral orbitofrontal cortex and these alterations may constitute a structural characteristic of a 'traumatized brain' mediating the psychopathology of PTSD; but it is equally possible that suffering from PTSD related symptoms and behavior results in behavioral and cognitive processing styles that produce these structural alterations. Most likely, both processes are interrelated promoting a vicious circle beyond a certain severity of cumulative exposure to traumatic stress.

3.2. Modification of the 'trauma network'

If the formation of a 'trauma network' follows principles of neuroplasticity, the same principles might be exploited to modify a 'trauma network'. Thus, modification by treatment might serve as further support for the concept of a 'trauma network'. If the 'trauma network' is related to trauma induced memory dysfunction, the restoration of memory should change the 'trauma network' and if the 'trauma network' constitutes a crucial element in the maintenance, this change should affect PTSD symptoms.

The 'narrative exposure therapy' (NET; Schauer et al. 2006; Neuner et al., 2008, 2009) targets the restructuring of the 'trauma network'. In NET, the patient, with the assistance of the therapist, constructs a chronological narrative of her/his life story with a focus on the traumatic experiences. Empathic understanding, active listening, congruence and unconditional positive regard are key components of the therapist's behavior. The autobiography is recorded by the therapist in written form and corrected and filled with details with subsequent readings. Aim of this procedure is to transform the generally fragmented reports of the traumatic experiences into a coherent narrative. For traumatic experiences the therapist asks in detail for emotions, cognitions, sensory information (visual, auditory, tactile, olfactory and gustatory) and physiological reactions, probes for respective observations, records these information meticulously and links them to episodic facts, namely time and place. The patient is encouraged to relive these emotions while narrating without losing the connection to the here and now, i.e., with a permanent reminder that the feelings and physiological responses result from memories. The exposure to the traumatic experience is terminated only, when the related fear reaction presented and reported by the patient is significantly diminished. In this way, the narrative is driven forward in a supportive but rather directive guiding by the therapist, in order to counter avoidance and to recover the full implicit information of the traumatic experience. At the end of treatment the patient receives the written report of his biography. If requested by the client, this document may be used for rights advocacy. Clinical controlled trials with PTSD clients have documented the efficiency of NET to reduce PTSD symptoms and improve social functioning in trauma victims (Neuner et al., 2004, 2008, 2009; Schauer et al., 2006; Bichescu et al., 2007, Schaal et al., 2009).

Adenauer et al. (submitted for publication) evaluated visual steady state magnetic fields after 10 sessions of exposure treatment (NET) in survivors of organized violence diagnosed with PTSD compared to clients, who were assigned to a waiting list condition. Brain activity measured four months after treatment showed an increase of occipital activity in response to aversive pictures

compared to neutral pictures following NET, which was not evident in the waiting list group. Since PTSD subjects had exhibited reduced posterior activity before treatment (Catani et al., 2009), this increase of posterior activity indicates normalization. Changes in brain activity measures were accompanied by a significant reduction of PTSD symptom severity in the NET group, whereas symptoms persisted in the waiting list condition. If, as suggested before, the dampened posterior activation by aversive visual stimuli reflects pathological inhibition of emotional visual processing, triggered by preceding hyper reactivity to potentially threatening stimuli, these results suggest that exposure therapy resolves this pathological inhibition and modifies fronto cortical 'top down' regulation. Moreover, a 6 month follow up measurement of oscillatory patterns of brain activity measured during rest showed that patterns became more similar to that of normal control in the NET group but not in a unsuccessfully treated control group (treatment as usual; Schauer et al., 2006). This indicates that the successfully treated clients exhibited normalization of their default network and with it of their brain's processing architecture.

4. Conclusion

The preceding review encourages the hypothesis that the described PTSD specific patterns of electromagnetic responses and structural deviancies represent a 'trauma network' in the brain. Rapid activation by various arousing, potentially threatening stimuli is in line with the concept of an enlarged associative network and a lowered 'ignition' threshold; this pattern might represent the ignition of the 'trauma network', that activates action dispositions like fear or anger for defense or avoidance behavior. When subjects listen to threat related questions or when individual script driven rehearsing prevents the avoidance of ongoing emotional processing, frontal activity emerges around 300 ms (Wessa et al. 2006), which may represent the ongoing activity of the 'trauma network'. Our concept of a 'trauma network' represented in brain activity patterns is indirectly supported by the lack of differential electrocortical responses to emotional versus neutral stimuli in psychopaths (Williamson et al., 1991), who are assumed to suffer from a lack of empathy and fear and, thus, from a missing 'fear network'. Other salience related networks may function in similar ways. For instance, panic related words provoke activity around 200 ms in panic clients, which has been attributed to rapid automatic processing (Pauli et al., 2005). Future studies are needed to specify how networks are established by individual experience and learning processes and how specifically they relate to psychopathological processes. The principles of neuroplasticity may provide useful guidance for the study of the traces of fear in the neural web.

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