Research Report

Decoupling Neural Networks From Reality

Dissociative Experiences in Torture Victims Are Reflected in Abnormal Brain Waves in Left Frontal Cortex

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ABSTRACT—*From a neuroscience perspective, little is known about the long-term effect of torture. Dissociative experiences and posttraumatic stress disorder are often the results of this experience. We examined psychological dissociation within a group of 23 torture victims and report its manifestations within neural networks in the human brain. In particular, we observed that dissociative experiences are associated with slow abnormal brain waves generated in left ventrolateral frontal cortex. Given that focal slow waves often result from depriving neural networks of major input, the present results may indicate decoupling of frontal affective processors from left cortical language areas. This interpretation is consistent with the fact that disturbed access to structured verbal memory concerning traumatic events is a core feature of the dissociative experience.*

From a neuroscience perspective, little is known about the long-term effect of torture. Recent events in the world have brought to the forefront the systematic use of torture to produce pathological fear and anxiety in a variety of countries (Moisander & Edston, 2003). Torture is designed to evoke helplessness and horror that are likely to result in the development of psychopathological processes, such as posttraumatic stress disorder (PTSD). During this most extreme form of human aggression, the victim is overwhelmed by fear and rendered totally helpless, left with passive avoidance (e.g., dissociation) as an important mechanism to "escape" the situation. Torture also produces a distortion of memory processes that appears to be culturally universal (Elbert & Schauer, 2002).

For the past 100 years, psychological dissociation has been discussed as a central mechanism involved in response to overwhelming situational experiences eliciting intense fear (Michelson & Ray, 1996; Spiegel & Cardena, 1991). First described by Janet in 1889 (Janet, 1889/1978), it is commonly manifested as a structured separation of such processes as memory, identity, emotions, and thoughts, which are usually experienced by an individual as an integrated whole. Torture or trauma victims often describe dissociative experiences and intrusions of horror in which they experience themselves as detached from the self, experience time in a nonlinear way, experience internal or external reality in unreal or distorted ways, and have difficulty assessing information concerning their traumatic experience in a logical and systematic manner at a later date (McNally, 2003). Using this conceptualization, we developed a short scale for assessing dissociative experiences. This scale allowed us to map these states of mind with slow-wave activity revealed using magnetic source-imaging procedures.

Abnormal slow-wave rhythms in the brain are found in a variety of developmental and degenerative disorders, in toxic and metabolic encephalopathy, and in other neurological conditions (Baayen et al., 2003; de Jongh et al., 2001, 2003; Gallen et al., 1992; Möller et al., 2003; Tanaka, Kimura, Yoshinaga, Tomonaga, & Mizoguchi, 1998; Vieth, Kober, Ganslandt, Möller, & Kamada, 2002; Vieth, Kober, & Gummich, 1996; Vieth, Kober, Kamada, & Ganslandt, 1998; Walter, 1936). More recently, we have shown abnormal slow-wave activity to also be present in conditions of psychopathology, such as depression and schizophrenia (Fehr et al., 2003; Wienbruch et al., 2003). This suggests that slow-wave activity can be produced by both structural and functional neural networks that are deprived of their inputs.

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Neural generators of slow-wave rhythms are focally concentrated and appear in the vicinity of structural lesions such as cerebral infarcts, contusions, local infections, tumors, epileptic foci, and subdural hematomas. These neural generators can be identified through magnetic source imaging by utilizing dipole density measurements from magnetoencephalography (MEG). With MEG, subsets of magnetic field sensors can be used to scan brain regions that are limited in size, to identify dipolar patterns of focally generated neural activity. In the present study, we used a 148-channel whole-head neuromagnetometer to examine dipole patterns in abnormal slow-wave activity in the delta range (1.5–4 Hz). Our previous work found that different psychopathological diagnostic groups (e.g., affective disorders, schizophrenia) are characterized by differing cortical locations of slow-wave activity, and thus this slow-wave activity can serve as a marker of dysfunctional brain activity. On this basis, we predicted that dissociative processes likewise reflect neural networks that have been cut off from major input sources and that these processes are also associated with abnormal slow-wave activity indicating dysfunctional brain areas. This study was a first attempt to map cortical areas in a population of torture victims. Our results suggest that experiences of torture may modify neural network architecture on a macroscopic scale.

METHOD

Twenty-six victims of severe torture, who were admitted consecutively between February and June 2003 at our specialized outpatient clinic for refugees in Germany, were screened for this study. Of these 26, 2 did not fulfill the criteria for PTSD according to the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV; American Psychiatric Association, 1994), and 1 gave unreliable information. The remaining 23 individuals were included in our study. All were asylum seekers and had been referred to the clinic by human-rights organizations, medical doctors, and lawyers for clinical examination and treatment.

Sixteen healthy control subjects who had ethnic backgrounds similar to those of the torture victims were recruited among university students and among the immigrant community in Germany. Control subjects were paid €25 and travel costs. The torture victims and the control subjects both participated in clinical interviews, during which self-report information such as demographic data was collected and measures of posttraumatic stress and dissociative symptoms were administered. Additional information concerning types of torture was collected from the torture victims.

The torture victims and control subjects were, on average, 35 years old ($SD = 8.4$ years) and 26 years old ($SD = 4.8$ years), respectively. Twelve of the torture victims and 8 of the control subjects were female. Most of the torture victims had fled to Germany from Turkey (15 ethnic Kurds and 1 non-Kurd). The others were from the former Yugoslavia (6) and from Algeria (1).

Twelve control subjects were from Turkey, 2 were from Morocco, and the others were from India (1), the former Soviet Union (1), and the Balkans (1). Twenty of the torture victims had been imprisoned (mean of 21 imprisonments, $SD = 53$) and had spent a mean of 63 days in total ($SD = 124$) in jail; the others were victims of war atrocities and violent expulsions. On a checklist consisting of 42 types of torture and war events, the torture victims reported having experienced a mean of 23 ($SD = 11$) different types of traumatic events. Eighty-seven percent of the sample reported severe beatings on different body parts (e.g., falaka), 79% reported physical torture (e.g., overstretching and electroshock), 83% reported psychological torture (e.g., forced witnessing of torture and mock executions), 78% reported sexual violence (e.g., rape), 83% reported severe deprivation (e.g., from light, food, and water), and 96% reported traumatic war events (e.g., being close to a shelling). The diagnosis of PTSD was confirmed by clinical judgment, using the World Health Organization (2000) Composite International Diagnostic Interview.

The dissociation scale was administered after the assessment of PTSD. The items on our scale were as follows (translated from German):

- "Do you ever find yourself in a place and not remember how you got there?"
- "Do you ever watch a film or television program and then realize that you can't remember what you've just seen?"
- "Have you ever had doubts about where you are?"
- "Do you ever feel spaced out and not responsive to outside stimuli?"
- "Do you sometimes find it difficult to remember what just happened?"
- "Do you ever experience time to go by more slowly than usual (as if things in your environment are happening in slow motion)?"
- "Do you ever listen to a person and then suddenly realize that you have not heard all or part of what was just said?"

Respondents answered these questions on a scale from 1 (*never*) to 5 (*always, every day*), basing their answers on their experience over the past 6 months. For each participant, we calculated a sum score corrected for missing items.

MEG measurements were made using a 148-channel whole-head neuromagnetometer (MAGNES™ 2500 WH, 4D Neuroimaging, San Diego, CA). Measurements were taken with subjects in supine position during a 5-min resting period included as part of a larger screening procedure for individuals seen at the clinic. Subjects were asked to relax but stay awake and fixate on a mark on the ceiling of the magnetically shielded room throughout the recording session in order to avoid eye and head movement. A video camera installed inside the chamber allowed us to monitor subjects throughout the experiment. Each individual's index points and head shape were digitized with a Polhemus 3Space® Fasttrack prior to each measurement. Head

position relative to the pickup coils of the sensor was estimated before and after each measurement. Participants were informed in detail about the procedure, and written consent was obtained from every subject prior to scanning.

Generators of focal slow waves were mapped using magnetic source imaging (e.g., Elbert, 1998). Focal slow waves were identified in a semiautomated procedure that consisted of noise reduction, decimation, digital band-pass filtering, and magnetic source imaging. Following noise reduction, data were screened for artifacts (e.g., eye blinks, muscle activity) by visual inspection, and time periods without artifacts were selected for the dipole density analysis. Data were reduced by a factor of 16 (anti-alias filters were applied automatically in the same processing step) and digitally filtered separately for the delta frequency band (1.5–4.0 Hz) using a digital band-pass filter (Butterworth filter).

Single equivalent current dipoles were fitted for each time point in the selected artifact-free segments. Criteria applied for the selection of specific dipole solutions were goodness of fit greater than .90 (to ensure the statistical significance of the source model) and dipole moment of 10 to 100 nAm root mean square (to ensure that the focal sources identified would meet neurophysiological criteria). (The criterion for dipole moment is equivalent to 0.1–1 cm^2 of activated cortex and fulfills the assumption of a point source as assumed in the source model of an equivalent current dipole in a homogeneous sphere.)

RESULTS

Although all 23 torture victims in this study had experienced multiple forms of psychological trauma and had a current diagnosis of PTSD, their level of dissociative experiences varied (range: 10–31, $M = 23.6$, $SD = 5.0$). Control subjects scored significantly lower on the dissociation scale ($M = 13.3$, $SD = 2.8$; Wilcoxon's test: $Z = -4.736$, $p < .001$).

Dipole density was calculated for eight regions in the brain by dividing the brain along three spatial dimensions (left-right, anterior-posterior, inferior-superior). Using SPSS, we computed Pearson correlation coefficients (alpha level of $p < .05$) between dipole density coefficients and dissociation scores. The score on the dissociation scale was significantly and positively related to the density of abnormal slow-wave generators in the left ventral region of the anterior cortical structures (left ventrolateral frontal cortex), $r(21) = .41$, $p < .05$, and $r(21) = .40$ with level of PTSD partialed out. The dissociative-experiences score was also significantly and positively related to the density of abnormal slow-wave generators in the left hemisphere as a whole, $r(21) = .60$, $p < .001$, and $r(21) = .60$ with level of PTSD partialed out. The inverse relation was found for the right hemisphere as a whole, $r(21) = -.65$, $p < .001$, and $r(21) = -.61$ with PTSD partialed out, and for the right anterior superior areas, $r(21) = -.60$, $p < .002$, and $r(21) = -.61$ with level of PTSD partialed out. Further, the patient group had significantly more delta di-

poles in the left ventral region than the culturally matched control group ($n = 16$) without torture experience, $t(37) = 2.07$, $p_{rep} = .91$, $d = 0.68$. Delta dipole differences were not found in any other brain region.

DISCUSSION

We studied the relationship between dissociative experiences and a cortical measure, delta dipole density. Differential patterns of delta dipole density have been found in individuals experiencing a variety of pathological and psychopathological conditions. This suggests its usefulness in distinguishing pathological conditions across patient groups. We found the number of dissociative experiences reported to be significantly and positively related to the density of abnormal slow-wave generators in the left ventral region of the anterior cortical structures and in the left hemisphere as a whole. The inverse relation was found for the right hemisphere as a whole and for the right anterior superior areas. Statistically partialing out the level of PTSD did not influence these relations, which suggests that the level of dissociation makes a separate contribution, over and above the contribution of PTSD symptoms, to delta dipole density. This finding is theoretically consistent with the DSM-IV not including dissociation as a PTSD criterion. Further, the patient group had significantly more delta dipoles in the left ventral region than a culturally matched control group without torture experience and resultant dissociative experiences. These results indicate that disruption of networks in left ventrolateral frontal cortex is associated with dissociative experiences. It should be noted that physical torture involving head injury influences slow-wave activity, but the resulting activity is different from what we observed in both pattern and location. Further, severe physical head trauma that results in loss of consciousness does not lead to PTSD (Glaesser, Neuner, Lütgehetmann, Schmidt, & Elbert, 2004).

Although this is one of the first studies (other than single case studies) to describe torture victims from a neuroscience perspective, our results do parallel those of other more traditional cognitive and affective neuroscience studies, as well as PTSD studies. In the neuroscience literature, the left frontal region is assumed to be involved with language and executive function. Neuroimaging studies (e.g., Iadaka, Sadato, Yamada, & Yonekura, 2000) show this area to be involved with memory encoding and retrieval of verbal material, and disruptions in the networks involving these areas might help to explain why dissociative individuals lack conscious, verbal access to certain previous traumatic experiences. Recent research (Brady, Campbell, & Flaherty, 2004) has also shown left-hemispheric involvement in the recognition of one's own face and right-hemispheric involvement in the recognition of other people. We speculate that this might explain why some dissociative individuals view their own image, but not other people's images, as unfamiliar. Overall, disruption of left frontal networks in individuals who experience

fear intrusions and dissociative episodes would also be consistent with the idea that they lack the means to actively retrieve and verbally describe previous traumatic experiences.

Similar network activation patterns were seen in functional magnetic resonance imaging studies with normal volunteers who needed to keep irrelevant information out of mind (Bunge, Ochsner, Desmond, Glover, & Gabrieli, 2001) or who were instructed to suppress or respond to word pairs presented to them (Anderson et al., 2004). When participants in the study by Bunge et al. needed to keep information out of mind to avoid task interference, activation within the right middle frontal gyrus and left inferior frontal gyrus was correlated with ability to resolve interference efficiently. In the study by Anderson et al., controlling unwanted memories was associated with increased dorsolateral prefrontal activation, reduced hippocampal activation, and impaired retention of those memories. Individual differences in the ability to inhibit memories were predicted by activation of the dorsolateral prefrontal cortex and the left ventrolateral prefrontal cortex. Anderson and his colleagues suggested that people suppress unwanted memories, including traumatic ones, through the prefrontal cortex. Of course, this hypothesis needs to be tested, as these individuals were actively trying to suppress relatively meaningless word pairs, whereas torture victims are attempting to deal with overwhelming physical and emotional pain of a long-term nature.

Given that our study is one of the few attempts to apply neuroscience conceptualizations to torture experiences, our results remain suggestive. Neuroimaging studies of individuals with PTSD resulting from a variety of situations have implicated prefrontal, limbic, and paralimbic structures, as well as the interior cingulate gyrus, in the recall of traumatic information (Lanius, Williamson, Densmore, & Boksman, 2004). Our present study builds on this work and suggests that over and above the presence of PTSD, the degree of dissociation may further moderate brain activation. On the behavioral level, our results are consistent with current speculation that left prefrontal activity is associated with approach activity and right prefrontal activity is associated with withdrawal and inhibition (Davidson, Pizzagalli, Nitschke, & Kalin, 2003). That is to say, with increases in dissociation and concomitant delta dipole activity, we might expect approach behaviors to be reduced and inhibitory processes to be increased. This would be particularly true in negative situations. Case studies of torture victims show that when they are reminded of previous traumatic experiences, their blood flow to the insula and prefrontal and inferior frontal areas is reduced (Fernandez et al., 2001), but these blood-flow changes are not observed following treatment. We are currently investigating the degree to which our torture victims show delta dipole changes following psychosocial treatment (Neuner, Schauer, Klaschik, Karanukara, & Elbert, 2004).

We suggest that in cases of torture, what begins as either active or passive attempts to reduce overwhelming emotions or fear eventually manifests itself as a stable disruption of left frontal networks. Our results suggest a functional disconnection between affective processing and language processing, a possibility that needs to be validated in future studies. Overall, our findings point to the conclusion that the left anterior inferior region of the brain plays an important role in dissociative experiences. Further, we show the importance of considering dissociative processes in the study of PTSD among victims of torture and other traumatic experiences.

REFERENCES

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Anderson, M., Ochsner, K., Kuhl, B., Cooper, J., Robertson, E., Gabrieli, S., Glover, G., & Gabrieli, J. (2004). Neural systems underlying the suppression of unwanted memories. *Science*, *303*, 232–235.

Baayen, J., de Jongh, A., Stam, C., de Munck, J., Jonkman, J., Trenite, D., Berendse, H., Walsum, A., Helmans, J., Puligheddu, M., Castelijns, J., & Vanderopt, P. (2003). Localization of slow wave activity in patients with tumor-associated epilepsy. *Brain Topography*, *16*, 85–93.

Brady, N., Campbell, M., & Flaherty, M. (2004). My left brain and me: A dissociation in the perception of self and others. *Neuropsychologia*, *42*, 1156–1161.

Bunge, S., Ochsner, K., Desmond, J., Glover, G., & Gabrieli, J. (2001). Prefrontal regions involved in keeping information in and out of mind. *Brain*, *124*, 2074–2086.

Davidson, R.J., Pizzagalli, D., Nitschke, J.B., & Kalin, N. (2003). Parsing the subcomponents of emotion and disorders of emotion: Perspectives from affective neuroscience. In R. Davidson, K. Scherer, & H. Goldsmith (Eds.), *Handbook of affective sciences* (pp. 8–24). New York: Oxford University Press.

de Jongh, A., Baayen, J., de Munck, J., Heethaar, R., Vandertop, W., & Stam, C. (2003). The influence of brain tumor treatment on pathological delta activity in MEG. *NeuroImage*, *20*, 2291–2301.

de Jongh, A., de Munck, J., Baayen, J., Jonkman, E., Heethaar, R., & van Dijk, B. (2001). The localization of spontaneous brain activity: First results in patients with cerebral tumors. *Clinical Neurophysiology*, *112*, 378–385.

Elbert, T. (1998). Neuromagnetism. In W. Andrä & H. Nowak (Eds.), *Magnetism in medicine* (pp. 190–262). London: Wiley & Sons.

Elbert, T., & Schauer, M. (2002). Psychological trauma: Burnt into memory. *Nature*, *419*, 883.

Fehr, T., Kissler, J., Wienbruck, C., Moratti, S., Elbert, T., Watzl, H., & Rockstroh, B. (2003). Source distribution of neuromagnetic slow-wave activity in schizophrenic patients—effects of activation. *Schizophrenia Research*, *63*, 63–71.

Fernandez, M., Pissiota, A., Frans, O., von Knorring, L., Ficher, H., & Fredrikson, M. (2001). Brain function in a patient with torture related post-traumatic stress disorder before and after fluoxetine treatment: A positron emission tomography provocation study. *Neuroscience Letters*, *297*, 101–104.

Gallen, C., Schwartz, B., Pantev, C., Hampson, S., Sobel, D., Hirschkoff, E., Rieke, K., Otis, S., & Bloom, F. (1992). Detection and localization of delta frequency activity in human strokes. In M. Hoke, S. Erné, Y. Okada, & G. Romani (Eds.), *Biomagnetism: Clinical aspects* (pp. 301–305). Amsterdam: Excerpta Medica.

Glaesser, J., Neuner, F., Lütgehetmann, R., Schmidt, R., & Elbert, T. (2004). Posttraumatic stress disorder in patients with traumatic brain injury. *BMC Psychiatry*, *4*, 5.

Iadaka, T., Sadato, N., Yamada, H., & Yonekura, Y. (2000). Functional asymmetry of human prefrontal cortex in verbal and non-verbal episodic memory as revealed by fMRI. *Brain Research: Cognitive Brain Research*, *9*, 73–83.

Janet, P. (1978). *L'automatisme psychologique*. Paris: Société Pierre Janet. (Original work published 1889)

Lanius, R., Williamson, P., Densmore, M., & Boksman, K. (2004). The nature of traumatic memories: A 4-T fMRI functional connectivity analysis. *American Journal of Psychiatry*, *161*, 36–44.

McNally, R.J. (2003). Psychological mechanisms in acute response to trauma. *Biological Psychiatry*, *53*, 779–788.

Michelson, L., & Ray, W. (1996). *Handbook of dissociation: Theoretical, empirical, and clinical perspectives*. New York: Plenum.

Moisander, P.A., & Edston, E. (2003). Torture and its sequel—a comparison between victims from six countries. *Forensic Science International*, *137*, 133–140.

Möller, M., Kober, H., Ganslandt, O., Begerow, A., Vieth, J., & Fahlbusch, R. (2001). Abnormal neuronal activity in brain tumor patients localized by magnetoencephalography. In J. Nenonen, R.J. Ilmoniemi, & T. Katila (Eds.), *Biomag2000* (pp. 428–430). Espoo, Finland: Helsinki University of Technology. (Available from http://biomag2000.hut.fi/papers/0428.pdf)

Neuner, F., Schauer, M., Klaschik, C., Karanukara, U., & Elbert, T. (2004). A comparison of narrative exposure therapy, supportive counselling and psychoeducation for treating posttraumatic stress disorder in an African refugee settlement. *Journal of Clinical and Consulting Psychology*, *72*, 579–587.

Spiegel, D., & Cardena, E. (1991). Disintegrated experience: The dissociative disorders revisited. *Journal of Abnormal Psychology*, *100*, 366–378.

Tanaka, A., Kimura, M., Yoshinaga, S., Tomonaga, M., & Mizoguchi, T. (1998). Quantitative electroencephalographic correlates of cerebral blood flow in patients with chronic subdural hematomas. *Surgical Neurology*, *50*, 235–240.

Vieth, J., Kober, H., Ganslandt, O., Möller, M., & Kamada, K. (2002). The clinical use of MEG activity associated with brain lesions. In J. Nenonen, R.J. Ilmoniemi, & T. Katila (Eds.), *Biomag2000* (pp. 387–394). Espoo, Finland: Finland University of Technology. (Available from http://biomag2000.hut.fi/papers/0387.pdf)

Vieth, J., Kober, H., & Gummich, P. (1996). Sources of spontaneous slow waves associated with brain lesions, localized by using the MEG. *Brain Topography*, *8*, 215–221.

Vieth, J., Kober, H., Kamada, K., & Ganslandt, O. (1998). Normal and abnormal MEG activity in border zones of brain lesions. In Y. Koga, K. Nagata, & K. Hirata (Eds.), *Brain topography today* (pp. 39–46). Amsterdam: Elsevier.

Walter, G. (1936). The location of cerebral tumors by electroencephalography. *Lancet*, *8*, 305–308.

Wienbruch, C., Moratti, S., Elbert, T., Vogel, U., Fehr, T., Kissler, J., Schiller, A., & Rockstroh, B. (2003). Source distribution of neuromagnetic slow wave activity in schizophrenic and depressive patients. *Clinical Neurophysiology*, *114*, 2052–2060.

World Health Organization. (2000). *Composite International Diagnostic Interview*. Geneva, Switzerland: Author.