Deficits in Haptic Perception and Right Parietal Theta Power Changes in Patients with Anorexia Nervosa Before and After Weight Gain

Martin Grunwald,[1*] Christine Ettrich,[2] Bianka Assmann,[2] Angelika Dähne,[2] Werner Krause,[3] Frank Busse,[4] and Hermann-Joseph Gertz[4]

[1] EEG-Research Laboratory, Department of Psychiatry, University of Leipzig, Leipzig, Germany
[2] Department of Child and Adolescent Psychiatry, University of Leipzig, Leipzig, Germany
[3] Institut of Cognitive Psychology, Friedrich-Schiller-University, Jena, Germany
[4] Department of Psychiatry, Memory Clinic, University of Leipzig, Leipzig, Germany

Accepted 5 December 2000

Abstract: **Objective:** *Our goal was to investigate whether patients with anorexia nervosa (AN) show deficits in haptic exploration tasks before and after weight gain.* **Method:** *The haptic exploration tasks consisted of palpating the structure of six sunken reliefs in sequence with both hands, eyes closed. After each exploration, the structure was reproduced on a piece of paper. A 19-channel digital electroencephalogram (EEG; linked ears) was continuously recorded during rest and haptic tasks for 10 AN patients (females, mean age: 15.90) and 10 healthy controls (CO; females, mean age: 16.14). Mean spectral power density was calculated as the mean amplitude of the spectral lines of the theta band (4–8 Hz). The AN patients were examined again after weight gain (T_0 and T_1).* **Results:** *The reproductions submitted by the AN patients were of notably poorer quality than those of the CO. Reproduction quality was unchanged after weight gain and independent of body mass index and intelligence. Mean exploration time was similiar in AN patients and CO. The analysis of spectral EEG power of both groups showed significant decrease in power data in the theta frequency band during haptic exploration compared with the rest intervals. The comparison of the theta power between CO and AN patients during haptic exploration showed major differences between the groups in both T_0 and T_1. Theta power was lower in AN patients than in the CO over the right hemisphere and right parietal regions.* **Discussion:** *The quality of reproduction of the haptic stimuli and the theta-power changes indicate a cortical dysfunction and deficits in somatosensory integration processing of the right parietal cortex in AN patients even after weight gain. © 2001 by John Wiley & Sons, Inc.* Int J Eat Disord 29: 417–428, 2001.

Key words: *eating disorders; right parietal lobe; EEG; body image*

*Correspondence to: Dr. Martin Grunwald, Department of Psychiatry, University of Leipzig, EEG Laboratory, Emilienstraße 14, D-04107 Leipzig, Germany. E-mail: mgrun@server3.medizin.uni-leipzig.de
Grant sponsor: Deutsche Forschungsinitiative Eßstörungen (DFE e.V.); Grant sponsor: Friedrich-Schiller-University Jena.

INTRODUCTION

Anorexia nervosa (AN) is characterized by a severely distorted body image (Bruch, 1973; Hsu & Sobkiewicz, 1991). Self-perceptions of body weight, shape, and dimensions are inadequate. Studies in which AN patients were asked to assess and rate defined bodily dimensions showed that they grossly misjudged their own weight and physical dimensions (Hill, 1976; Freeman, Thomas, Solyom, & Miles, 1983). This applies even more to AN patients in the acute stage of the disease than to chronically ill patients (Fichter & Meermann, 1981). However, this tendency of anorectics to overestimate their physical dimensions diminishes as their weight normalizes (Crisp & Kalucy, 1974).

A prerequisite for the adequate representation of body image is the perceptive-cognitive integration of complex sensorimotor information (Becker, Walker, & Olton, 1980; Bisiach, Capitani, Luzzatti, & Perani, 1981). This processing, in turn, is dependent on peripheral sensory structures and their inputs as well as on subcortical and cortical processing (de Renzi & Scotti, 1969; de Renzi, Faglioni, & Scotti, 1968; Corkin, 1978; Kolb, Sutherland, & Whishaw, 1983). From a psychophysiological point of view, body image is formed through cortical processing of proprioceptive, interoceptive, vestibular, tactual, and haptical information. This leads to the conclusion that the processing of tactile-haptic information is vital for body imaging.

We know very little about the significance and function of tactile-haptic information processing in shaping body image. There are indications, however, that the cortical representation of body image hinges on elementary tactile-haptic information and, furthermore, on how this information is processed (Barnard & Brazelton, 1990; Heller & Schiff, 1991). Haptic perceptions are distinguished from tactilee tasks by their active explorative movements of the exploring limb. The resulting changes in the receptors of the skin, muscles, tendons, and joints lead to successive information about the explicit/implicit explored object. This information should be integrated to explain the precise spatial characteristics and the texture of the explored object. It can be postulated that an inadequate cortical integration of this information should result in deficits in haptic perception. In patients with astereognosis, deficits in haptic perception are associated with a lesion of the right parietal cortex (Kolb & Whishaw, 1993). These patients are unable to explore and explain the structure of an object haptically with their eyes closed.

Irmela Florin (1987) observed that healthy controls and patients suffering from AN and bulimia nervosa react differently to two-point discriminations on various parts of the body. Lautenbacher, Pauls, Strian, Pirke, and Krieg (1991) were able to prove that AN patients are significantly less sensitive to pain than healthy controls. A disturbance in body image accompanies a distorted tactile-haptic perception in AN patients.

In 1984, Kinsborne and Bemporad hypothesized that a dysfunction of the right hemisphere of the brain, especially of the right parietal cortex, is evident in patients with AN. They assumed the dysfunction to be involved in the perception of a distorted body image ("anorexic's neglect"). On the basis of this assumption, Rovet, Bradley, Goldberg, and Wachsmuth (1988), Pendleton-Jones, Duncan, Brouwers, & Mirsky, (1991), and Bradley et al. (1997) conducted neuropsychological studies exploring perceptive-cognitive functions of the right hemisphere in patients with AN. Bradley et al. (1997) found changes in event-related potentials (ERPs) during perceptive-cognitive tasks that support the hypothesis of a right parietal dysfunction in patients with AN. Finally, they found significant differences in ERP amplitudes between an AN group and a control group (CO) in verbal as well as in nonverbal tasks. AN patients showed no left-right asymmetry for the P3-amplitude in a nonverbal task. However, neither the studies of Bradley et al. (1997) nor

Pendleton-Jones et al. (1991) found significant differences during neuropsychological examination, that is, no cognitive deficits were detected in AN patients.

In contrast to these observations, other studies (Brouwers, Duncan, & Mirsky, 1986; Laessle, Fischer, Fichter, Pirke, & Krieg, 1992; Pendleton-Jones et al., 1991; Small et al., 1983; Szmukler et al., 1992) showed deficits in perceptive-cognitive tasks in AN patients, which could not be explained by deficits of the right hemisphere. The question remains: Do patients with AN show deficits in perceptive-cognitive tasks based on deficits of the right hemisphere? Taking into account the electrophysiological results obtained by Bradley et al. (1997), the neuropsychological inventories used in studies were not sensitive enough to explore the right hemispheric deficits in AN patients. It is well known that individuals with AN usually have higher IQs than age-matched CO (Blanz et al., 1997; Gordon, Halmi, & Ippolito, 1984; Ranseen & Humphries, 1992; Witt et al., 1985). The higher IQ might interfere with the perceptive-cognitive dimension and hide the right hemispheric deficits. In order to test the hypothesis of perceptive-cognitive deficits in AN patients, it is necessary to develop a test that does not allow the use of previous experience and usual strategies to solve the task. The test should be based on sensory integration and explicit spatial orientation because they involve the right hemisphere to a greater extent (Kolb & Whishaw, 1993).

Based on these assumptions, our study examines possible differences between AN patients and CO in fulfilling haptic tasks of varying degrees of complexity. We began with the premise that AN patients would recognize simple and familiar geometric designs in sunken reliefs just as well as CO by haptic exploration. We predicted that, due to diminished somatosensory integrative ability, AN patients would have problems reproducing complex haptic stimuli. We also sought to determine whether electroencephalograms (EEGs) from AN patients and CO would show any discrepancies between the two groups during haptic explorations and state of rest intervals.

It has been shown that the activity of the frontal and parietal cortex increases during haptic exploration tasks (Rescher et al., 1996; Grunwald, 1998; Grunwald et al., 1999). Task-dependent changes during haptic exploration tasks were observed in the frontal and parietal regions, particularly for the theta band. Changes in the spectral theta power activity correspond with specific kinds of information processing and memory, as well as with processes of memory loading within the scope of different cognitive paradigms (Schacter, 1977; Gevins et al., 1979; Mecklinger, 1992; Bösel, 1993; Klimesch et al., 1994). Therefore, it is conceivable that perceptive-cognitive performances are connected with changes in spectral theta power during haptic perception.

For this reason, we suspected that spectral EEG power (μV) of the theta frequency band would be significantly lower during haptic exploration than during the state of rest in both groups. As a result of increased perceptive-cognitive demand, we expected theta power over the right parietal cortex in patients with AN to be lower during testing than in the CO group. We began with the premise that the haptic reproductions and spectral EEG power would be independent of weight gain in anorectics.

METHODS

Subjects

AN Group

Ten patients with AN (females), diagnosed in accordance with ICD-10 criteria (Dilling, 1993), participated in the experiment. At the time of testing, all group members were being treated as inpatients at the Clinic of Child and Adolescent Psychiatry (University of Leipzig, Germany). Patients with bulimia nervosa or moderate binge eating and/or vomiting were excluded. Eight subjects had already been treated as inpatients in other clinics of child psychiatry and were diagnosed as suffering from AN. Two subjects were being treated as inpatients for the first time. The duration of the illness varied from 8 months to 2 years ($M = 14.5$, $SD = 5.7$).

The demographic data of the participants are listed in Table 1. The body mass index (BMI) is calculated as weight (kg) divided by the square of height (m). Whereas a BMI between 20 and 25 is considered optimal, a BMI less than 16 indicates significant undernutrition (Beaumont, Al-Alami, & Touyz, 1988). Patients were tested after hospital admission (T_0) and 1 month after being released from the hospital (T_1). The time interval between inital testing (T_0) and follow-up (T_1) ranged from 8 to 23 months, with a mean of 14.5 months ($SD = 5.7$). The mean BMI for the AN group was 15.24 (SD = 1.27) at T_0 and 16.60 ($SD = 1.71$) at T_1. Two patients from the initial testing (T_0) were being treated as outpatients at the time of T_1 testing. The IQ was measured by HAWIK (Tewes 1983) at the beginning of testing ($M = 115.20$, $SD = 7.98$).

CO

Ten healthy females participated in the experiment. The age difference between both groups was not significant (AN-CO: $p = .587$, Mann-Whitney-U, two tailed). Mean BMI was 22.16 ($SD = 3.01$). The IQ was measured by HAWIK (Tewes, 1983; $M = 114.69$, $SD = 13.52$). There were no significant differences concerning the IQ between CO and AN patients (AN-CO: $p = .820$, Mann-Whitney-U, two tailed). None of the CO participants suffered from any neurologic or psychologic disorder. All subjects were right-handed. The volunteer subjects received a payment of 10$ US for each session. The study was approved by the Ethics Commission of the University Leipzig.

Haptic Task

The haptic task consisted of exploring six individual sunken reliefs (13 × 13 cm), which were presented to the participants in random order (Figure 1). All participants were asked to palpate the haptic stimuli with both hands while keeping their eyes closed. Following the haptic explorations, all participants were asked to reproduce the structure of the stimuli as closely as possible on a piece of paper with their eyes open. Optimal positioning

Table 1. Data for age, body mass index (BMI), quality of reproductions (QR), exploration time (ET), and intelligence (IQ) for control group and anorexia patients as well as statistical results of inter and intragroup comparisons

	Controls ($n = 10$)		AN (T_0)		AN (T_1)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age	16.14	.74	15.90	1.97	16.90	1.97
BMI*,**,***	22.16	3.01	15.24	1.27	16.60	1.71
QR**,***	1.27	.22	2.17	.66	1.92	.61
ET***	167.58	86.13	136.80	44.15	101.38	41.63
IQ	114.69	13.52	115.20	7.98		

*Comparison anorexia patients T_0–T_1 (Wilcoxon test): $p < .05$. **Comparison controls–anorexia T_0 (Mann-Whitney-U): $p < .05$. ***Comparison controls–anorexia T_1 (Mann-Whitney-U): $p < .05$.

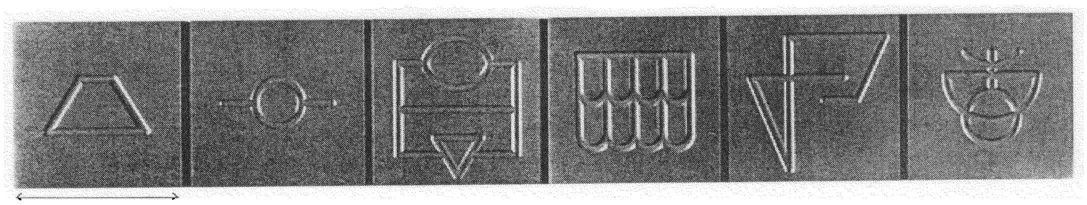

Figure 1. Six haptic sunken reliefs of varying degrees of complexity, made of hard plastic. The engraving design is 7 mm wide and 3 mm deep.

of the stimuli in relation to the fingers was allowed due to an adjustable holder. During haptic exploration, the forearms rested on a wide base in order to allow free movement of the fingers only. No arm and shoulder movements were made during haptic exploration.

The exploration time per stimulus was not limited. With the help of a strategically placed screen, the participants were prevented from gathering visual information about the stimuli. The participants were not given any feedback on the quality of their reproductions or the stimulus structure. The exploration time per stimulus was registered by means of pressure sensors (in seconds). The participants were allowed to familiarize themselves with the haptic material by looking at one sample stimulus and practicing the haptic exploration task for 1 min prior to the experiment. The test sequence is described in Figure 2.

EEG Recording

A 19-channel digital EEG (linked ears) was continuously recorded during rest and haptic tasks on 10 AN patients and 10 CO. In accordance with the international 10-20 system (Jasper, 1958), Ag-AgCl electrodes were attached to the scalp in the standard electrode positions (Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, T6, P3, Pz, P4, O1, O2). Movements of the right eye were monitored by horizontal and vertical electrodes. The signals of these electrodes were recorded on separate channels. The EEG was conducted in a Farady Cage with a digital, nonpaper EEG system by Walter Graphtek (Bad Oldesloe, Germany). The sampling rate was 333 Hz with a time constant of 0.3 s.

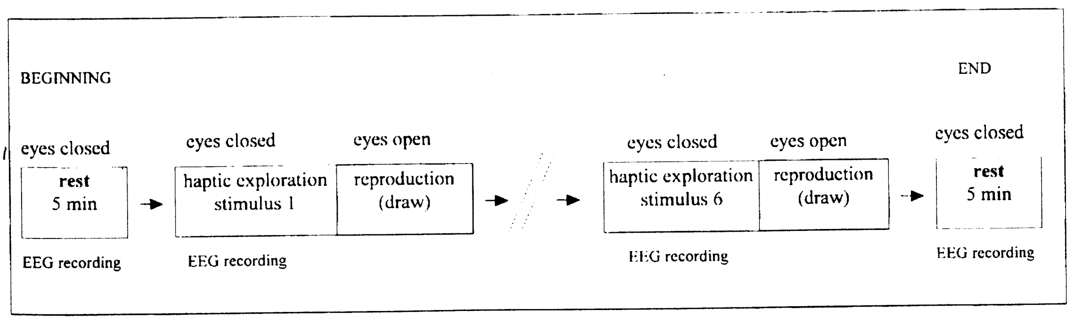

Figure 2. Test schematic. Electroencephaologram (EEG) data were recorded from 10 anorectic patients and 10 controls during rest and haptic explorations. The six reliefs were presented to the test subjects in random sequence. The stimuli were explored with both hands, eyes closed.

During the data acquisition, EEG signals were displayed online on a high-resolution color monitor and stored on an optical disk (WORM). EEG analytical software from the Institute of Physiology, Friedrich-Schiller-University Jena (Rost, Hansen, Beyer, & Weiss, 1992), was used to segment the raw EEG data and calculate mean spectral power. Artifact-free segments of 1.53 s (512 samples per channel) of the state of rest as well as of haptic exploration intervals were chosen by visual inspection and substantiated by cross-correlation analysis between relevant frontal EEG and electro-olfactogram (EOG) electrodes ($r_{crit.} < 0.5$). The remaining segments were submitted to a fast Fourier transform (FFT) analysis and smoothed with a 7-point low-pass filter (weights 1/64, 3/32, 15/64, 5/16, 15/64, 3/32, 1/64) in order to balance between resolution of the power spectra and its variance. Mean spectral power density was calculated as the mean amplitude of the spectral lines of the theta band (4–8 Hz).

Statistical Evaluation

The recorded data were evaluated with the SPSS statistical package (8.0) for Windows 95. For evaluation of the reproductions, a scale from 1 to 4 was used (1= correct reproduction of stimulus; 2 = correct reproduction of stimulus with one to three mistakes; 3 = failure to reproduce stimuli adequately, correct reproduction of single elements only; 4 = failure to reproduce stimulus or single elements correctly). Two students (A, B) who where blind to the purposes of the study evaluated each single reproduction. The inter-examiner reliability (Douglas, 1991) amounts to $k_{A/B}$ = .86. The rating scores and the exploration times of both groups were compared using the Mann-Whitney-U test (two tailed) for independent groups. The statistical comparison between the exploration times T_0 and T_1, the BMI, and the quality of reproductions for the AN patients was undertaken with the Wilcoxon test for dependent groups. The relationship between quality of reproduction and BMI was examined with a linear regression analysis. For each test, subject spectral power in every condition and each EEG channel was z transformed individually (M = 0, SD = 1). EEG power during rest and haptic tasks was determined with the Wilcoxon test for dependent samples. Comparisons of EEG power between both groups were assessed with the Mann-Whitney-U range test for independent groups. The statistical comparison between the T_0–T_1 theta power in the AN group was undertaken with the Wilcoxon test for dependent groups. The significant differences between rest and haptic exploration intervals, between the different groups, and between T_0–T_1 in the AN group are documented in a probability map as applied by Rappelsberger and and Petsche (1988) and Rappelsberger, Mayerweg, Kriegelsteiner, and Petsche (1988). A blank square indicates a significantly lower respectively decrease of power (significance level $p < .05$). A black square indicates a significantly higher respectively increase of power (significance level $p < .05$) via the corresponding electrode compared with the statistical hypothesis. The size of the squares corresponds with the reached significance level. The significance levels $p < .05$ and $p < .01$ are shown by a small and a large square, respectively. For the comparison between the state of rest and haptic exploration task, a blank square means a significant decrease of theta power during haptic exploration in contrast to the state of rest for the respective electrode. For the comparison between AN and CO, a blank square means a significantly lower theta power in AN patients than in CO for the respective electrode.

RESULTS

The reproductions submitted by the AN group were of considerably poorer quality than those of the CO group at T_0 (CO-AN_{T0}: p = .001, Mann-Whitney-U, two tailed) and

T_1 (CO-AN_{T1}: p = .005, Mann-Whitney-U, two tailed). There were no significant differences in the reproductions between T_0 and T_1 in the AN group (AN_{T0}-AN_{T1}: p = .125, Wilcoxon test, two tailed). Figure 3 shows the reproductions of the CO and AN groups at both testings (T_0 and T_1). The mean rating scores applied in evaluating the reproductions differ substantially between the two groups (Table 1). Within the CO group, the quality of reproductions differed only marginally. Within the AN group, the quality of reproductions was significantly poorer at T_0 and T_1. The linear regression between BMI and quality of reproductions (QR) showed no significant relationship (BMI/QR-AN [T_0]: r^2_{T0} = .276, p = .119; BMI/QR-AN [T_1]: r^2_{T1} = .056, p = .510; BMI/QR-CO: r^2 = .042, p = .570).

Table 1 displays the mean exploration times and statistical differences for AN patients (T_0 and T_1) and the CO group. The comparison of the group means revealed no significant differences (CO-AN_{T0}: p = .529, Mann-Whitney-U, two tailed; CO-AN_{T1}: p = .052, Mann-Whitney-U, two tailed). Based on the test results, AN patients required the same exploration time for haptic exploration tasks as CO subjects. After weight gain (T_1), the exploration time of AN patients was shorter than during the first test but did not differ significantly (AN_{T0}-AN_{T1}: p = .059, Wilcoxon, two-tailed). The linear regression between rating scores (QR) and mean exploration time (ET), figured separately for both groups, showed no significant relationship between the variables (QR/ET-anorexia [T_0] r^2_{T0} = .000, p = .969; QR/ET-AN [T_1]: r^2_{T1} = .048, p= .544; QR/ET-CO: r^2 = .039, p= .585).

The analysis of spectral EEG power of both groups showed a significant decrease in power data in the theta frequency band during haptic exploration compared with the rest intervals (Figure 4a). In both groups, the significant reductions in the theta band (indicated by blank squares in the probability map) are spread globally across the entire cortex. Theta power is diminished over the centroparietal, parietotemporal, and occipital regions in both groups. The most significant difference between the two groups is evident in the area of the frontal electrodes. The CO group showed no major variations in theta power, whereas AN patients showed an increase over Fp1, Fp2, F8, and F7. In addition, decreases of theta power in AN patients were concentrated on the right side.

The comparison of spectral EEG power between CO and AN patients during haptic exploration showed major differences between the groups at both T_0 and T_1. Theta power was lower in AN patients (blank squares) than in the CO (Figure 4b). Especially interesting is the lower spectral power over the right hemisphere and right parietal regions. The comparison of spectral EEG power between first and second measurements in the AN group showed only minor variations during haptic exploration in comparison to the CO group (Figure 4b). Compared with the CO group, AN patients showed significantly lower theta power during haptic exploration at T_0 ($p < .05$) for the electrodes Cz, Pz, P4, T6. The electrodes O1 and O2 also had lower theta power, although it was not significant (difference on significance level $0.1 > p > .05$). A slightly higher theta power was shown for the AN group for the electrode T4. At T_1, theta power during haptic exploration was significantly lower in the AN group ($p < .05$) for the electrodes Cz, Pz, P4. Lower theta power was shown for the electrode C3 on the significance level of $0.1 > p > .05$.

DISCUSSION

The test revealed substantial differences between the AN and CO groups with regard to the quality of reproductions for haptic stimuli. Following the regression analysis, this observation is not related to BMI or exploration time. The lower quality of reproduction results in the AN group did not depend on intelligence because both groups had similiar

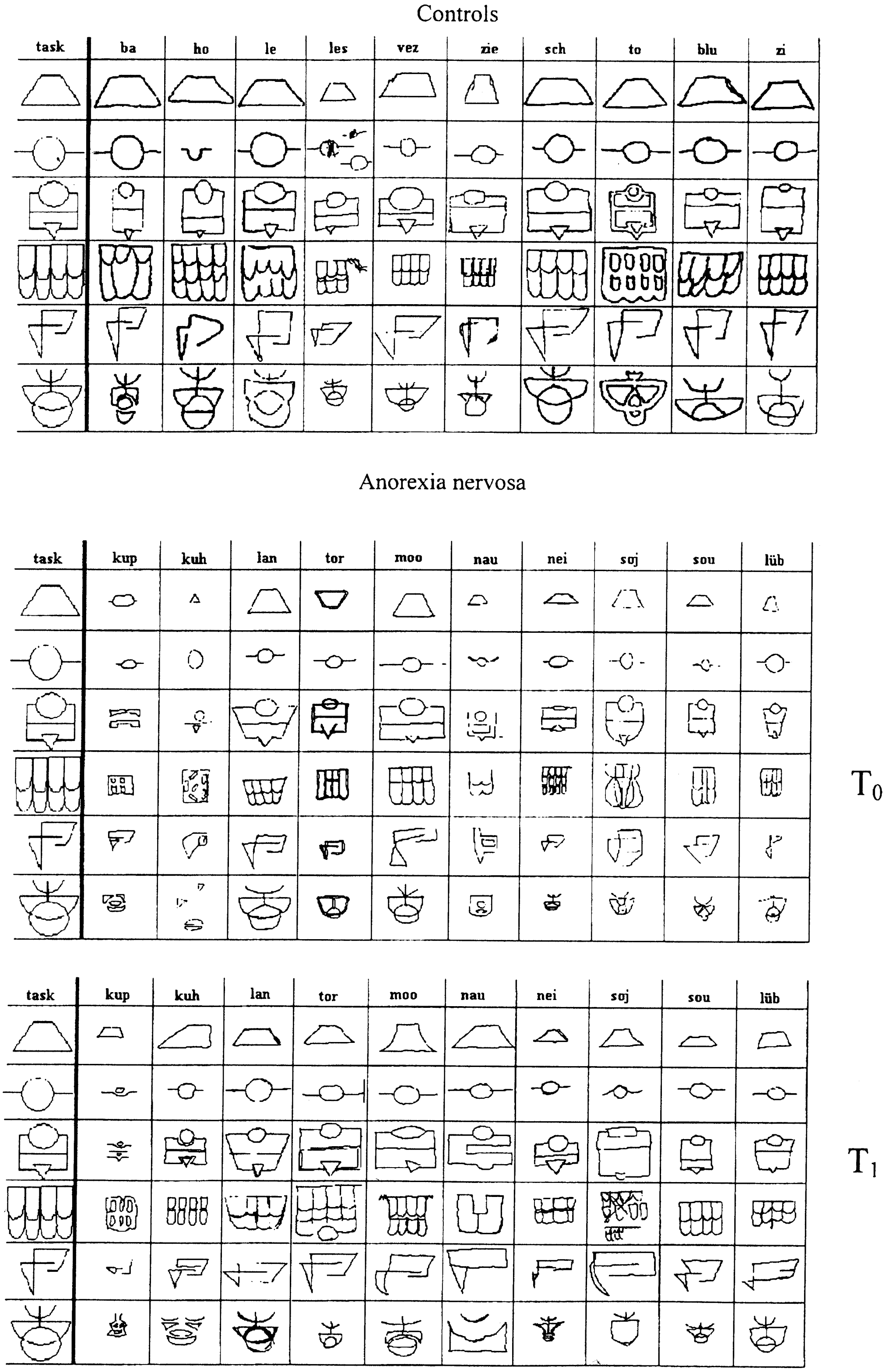

Figure 3. Reproductions submitted by healthy controls and patients with anorexia nervosa at T_0 and T_1 (reduced by 170%).

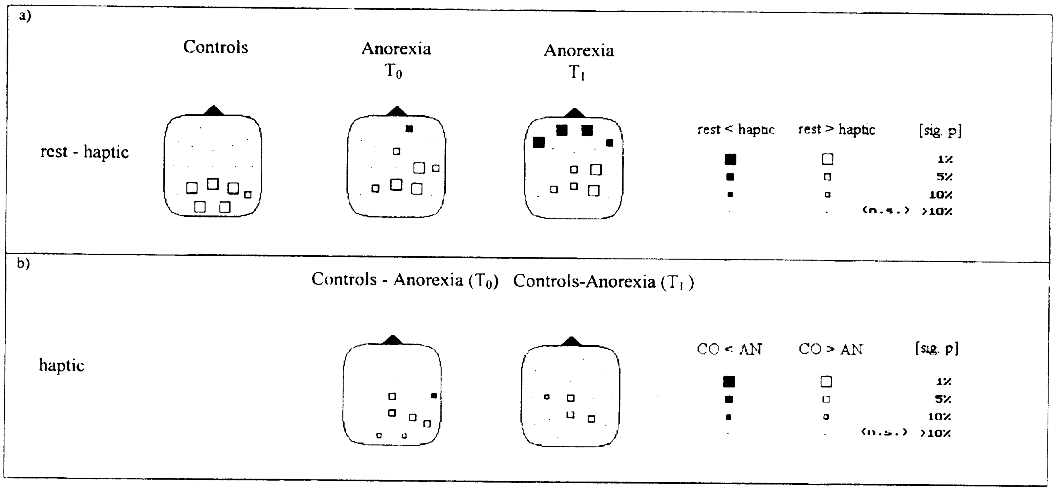

Figure 4. (a) Probability map power differences between state of rest and haptic exploration for controls and anorectic patients before (T_0) and after weight gain (T_1). Black squares indicate significant increase of theta power during haptic exploration compared with the state of rest. Blank squares indicate significant decrease of theta power during haptic exploration compared with the state of rest. (b) Probability map power differences between controls and anorectic patients during haptic exploration. Black squares indicate significantly higher power in anorectic patients compared with controls during the haptic exploration. Blank squares indicate significantly lower power in the anorectic patients compared with controls during the haptic exploration.

IQs. The lower quality of reproduction of haptic stimuli submitted by AN patients points to an altered ability in processing perceptions and somatosensory integrations (Fox, 1981; Gordon et al., 1984; Laessle et al., 1992; Ploog & Pirke, 1987; Szmukler et al., 1992). Our study, in fact, showed that there exist different qualities of reproduction in the AN group. The findings demonstrated that AN patients have greater problems with complex haptic information than CO. Based on studies in the field of Gestalt psychology, simple geometric figures are identified on the basis of only a few basic characteristics without comprehensive perceptive-cognitive operations (Appelle, 1991). With increasing complexity, however, greater demand is placed on somatosensory integration abilities, short-term memory processing, and selective attention (Gibson & Walker, 1984; Grunwald et al., 1999; Klatzky, Lederman, & Metzger, 1985). It can be deduced that AN patients are unable to forge the complex relations of individual stimuli elements into an overall concept. The haptic requirements of complex stimuli involve the simultaneous sensory integration of a multitude of pieces of information about space and dimensions. Neuropsychological studies have shown that these tasks are organized in the parietal cortex (Kolb & Whishaw, 1993; Reed, Caselli, & Farah, 1996). Lesions of the parietal cortex can result in disturbances of tactile-haptic perception (i.e., tactile agnosia, tactile aphasia; Kolb et al., 1983). It is possible that the poorer reproduction abilities displayed by AN patients originate from a functional disorder of the right parietal lobe. This hypothesis is supported by several studies (Kinsbourne & Bemporad, 1984; Rovet et al., 1988; Casper & Heller, 1991; Bradley et al., 1997).

The observation concerning the weight gain-independent poorer performance in a haptic-perceptive task may be an indication of a general deficit of integrative somatosensory processing in some AN patients. Therefore, the heterogeneity of reproduction quality in the AN group may indicate a different perceptive-cognitive and cortical development in AN patients. Further studies should be conducted to show whether this deficit in integrative somatosensory processing is a stable observation and, if so, whether the differentiation between poor and normal performance in the haptic task is of diagnostic and/or prognostic value. Based on the analysis of exploration times, AN patients spent less time completing the haptic exploration tasks than CO (which was not significant). Interestingly, however, there is obviously no correlation between reproduction quality and exploration time. Both phenomena should be interpreted separately. A possible explanation for the shorter exploration time of AN patients may be their strong desire and ambition to accomplish the task as quickly as possible. In various studies, AN patients have been characterized as high achievers, ambitious, and of sound or extraordinary intelligence (Steinhausen, 1994; Schmidt, Lay, & Blanz, 1997; Szabo & Blanche, 1997).

Our data showed that the quality of haptic reproductions in AN patients remains poorer even after weight gain. Therefore, we can assume that somatosensory deficits in AN patients are independent of nutritional state. Such somatosensory deficits could possibly be a risk factor for the development of illness. The results obtained so far support the notion that AN patients (during the acute stage of the disease and after weight gain) are impaired when processing haptic information. This may be due to a disorder of visual-spatial processing in the parieto-occipital regions (Kolb & Whishaw, 1993; Bradley et al., 1997). Furthermore, our EEG study showed that the brain electrical activity in the theta band over these areas is reduced in AN patients during haptic perception.

The differences between AN patients and CO between T_0 and T_1 are relatively stable. The theta power over the right parietal cortex during haptic perception is markedly lower in AN patients compared with CO. This indicates that this brain region processes the incoming information inadequately. The lower theta power of AN patients can be interpreted as an irregular activation in the process of multisensory integration. The small changes in the topographic distribution of theta power differences over the two times of measurement indicate that these findings are independent of weight. The relatively clear topographic arrangement of activation differences affirms the hypothesis of right parietal dysfunction in AN patients.

In future studies, haptic reproduction abilitities of AN patients could be used to identify subtypes of eating disorders. However, in order to make any qualified statements on the special nature of this haptic disorder, comparable studies must be performed on patients suffering from other psychiatric disorders. The ability to process tactile-haptic information must be thoroughly researched in long-term studies during childhood and adolescence. Only then will we be able to ascertain whether tactile-haptic disorders are part of the predisposition or sequels of the illness.

ACKNOWLEDGMENTS

The authors thank I. Thomas, G. Kruse, U. Kraft (University of Leipzig), and L. Knaupe (Friedrich-Schiller-University Jena) for their technical support. They also thank Rita Wallace and Erik Eek for language advice.

REFERENCES

Appelle, S. (1991). Haptic perception of form: Activity and stimulus attributes. In M.A. Heller & W. Schiff (Eds.), The psychology of touch (pp. 169–187). Hillsdale, NJ: Erlbaum.

Barnard, K.E., & Brazelton, T.B. (Eds.). (1990). Touch: The foundation of experience. Arlington, VA: National Center for Clinical Infant Programs.

Beaumont, P., Al-Alami, M., & Touyz, S. (1988). Relevance of a standard measurement of undernutrition to the diagnosis of anorexia nervosa: Use of Quetelet's body mass index (BMI). International Journal of Eating Disorders, 7, 399–405.

Becker, J.T., Walker, J.A., & Olton, D.S. (1980). Neuroanatomical bases of spatial memory. Brain Research, 200, 307–321.

Bisiach, E., Capitani, E., Luzzatti, C., & Perani, D. (1981). Brain and conscious representation of outside reality. Neuropsychologia, 19, 543–552.

Blanz, B.J., Detzner, U., Lay, B., Rose, F., & Schmidt, M.H. (1997). The intellectual functioning of adolescent eating disorder patient is above-average. European Child and Adolescent Psychiatry, 6, 129–135.

Bösel, R. (1993). Cerebral theta rhythms support context-dependent discrimination performance. Kognitionswissenschaft, 3, 83–94.

Bradley, S.J., Taylor, M.J., Rovet, J.F., Goldberg, E., Hood, J., Wachsmuth, R., et al. (1997). Assessment of brain function in adolescent anorexia nervosa before and after weight gain. Journal of Clinical and Experimental Neuropsychology, 19, 20–33.

Brouwers, P., Duncan, C.C., & Mirsky, A.F. (1986). Cognitive and personality concomitants of eating disorders. Journal of Clinical and Experimental Neuropsychology, 8, 135.

Bruch, H. (1973). Eating disorders. New York: Basic Books.

Casper, R.C., & Heller, W. (1991). "La douce indifference" and mood in anorexia nervosa: Neuropsychological correlates. Progress in Neuropsychopharmacology and Biological Psychiatry, 15, 15–23.

Corkin, S. (1978). The role of different cerebral structures in somesthetic perception. In E.C. Carterette & M.P. Friedman (Eds.), Handbook of perception (volume 6). New York: Academic Press.

Crisp, A.H., & Kalucy, R.S. (1974). Aspects of the perceptual disorder in anorexia nervosa. British Journal of Medical Psychology, 47, 349–361.

De Renzi, E., Faglioni, P., & Scotti, G. (1968). Tactiles, spatial impairment and unilateral cerebral damage. Journal of Nervous and Mental Disorders, 146, 468–475.

De Renzi, E., & Scotti, G. (1969). The influence of spatial disorders in impairing tactual discrimination of shapes. Cortex, 5, 53–62.

Dilling, H. (Ed.) (1993). World Health Organization: The ICD-10 Classification of Mental and Behavioural Disorders. Clinical Discriptions and Diagnostic Guidelines. Bern, Göttingen; Toronto: Huber.

Douglas, G.A. (1991). Practical statistics for medical research. London: Chapman & Hall.

Fichter, M.M., & Meermann, R. (1981). Psychopathometry of Anorexia nervosa. In R. Meermann (Ed.), Anorexia nervosa (pp. 17–81). Stuttgart: Enke.

Florin, I. (1987). A study of body perception of test persons with Anorexia nervosa and Bulimia nervosa. In W.D. Geber (Ed.), Behaviour medicine: Results and perspectives of interdisciplinary research (pp. 473–480). Weinheim: Edition Medizin.

Fox, C.F. (1981). Neuropsychological correlates of anorexia nervosa. International Journal of Psychiatry in Medicine, 11, 285–290.

Freeman, R.I., Thomas, C.D., Solyom, L., & Miles, I.E. (1983). Body image disturbances in anorexia nervosa: A reexamination and a new technique. In P.L. Darby, P.E. Garfinkel, D.M. Garner, & D.V. Coscina (Eds.), Anorexia nervosa. Recent developments in research (pp. 117–126). New York: Liss.

Gevins, A.S., Zeitlin, G.M., Doyle, J.C., Yingling, C.D., Schaffer, R.E., Callaway, E., & Yeager, C.L. (1979). Electroencephalogram correlates of higher cortical functions. Science, 203, 665–667.

Gibson, E.J., & Walker, A.S. (1984). Development of knowledge of visual-tactual affordances of substance. Child Development, 55, 453–460.

Gordon, D.P., Halmi, K.A., & Ippolito, P.M. (1984). A comparison of the psychological evaluation of adolescents with anorexia nervosa and of adolescents with conduct disorders. Journal of Adolescence, 7, 245–266.

Grunwald, M., Weiss, T., Krause, W., Beyer, L., Rost, R., Gutberlet, I., & Gertz, H.J. (1999). Power of the theta waves in the EEG of human subjects increases during recall of haptic information. Neurocience Letters, 260/3, 189–192.

Heller, M.A., & Schiff, W. (Eds.). (1991). The psychology of touch. Hillsdale, NJ: Erlbaum.

Hill, O.W. (1976). Anorexia nervosa. Modern Trends in Psychosomatic Medicine, 3, 382–403.

Hsu, L.K.G., & Sobkiewicz, T.A. (1991). Body image disturbance: Time to abandon the concept for eating disorders. International Journal of Eating Disorders, 10, 15–30.

Jasper, H.H. (1958). The ten twenty electrode system of the International Federation. Electroencephalography and Clinical Neurophysiology, 10, 371–375.

Kinsbourne, M., & Bemporad, B. (1984). Lateralization of emotion: A model and the evidence. In N.A. Fox & R.J. Davidson (Eds.), The psychobiology of affective development (pp. 259–291). Hillsdale, NJ: Erlbaum.

Klatzky, R.L., Lederman, S.J., & Metzger, V.A. (1985). Identifying objects by touch: An "expert system." Perception and psychophysics, 37, 299–302.

Klimesch, W., Schimke, H., & Schwaiger, J. (1994). Episodic and semantic memory: An analysis in the EEG theta and alpha band. Electroencephalography and Clinical Neurophysiology, 91, 428–441.

Kolb, B., Sutherland, R.J., & Whishaw, I.Q. (1983). A comparison of the contributions of the frontal and parietal association cortex to spatial localization in rats. Behavioral Neuroscience, 97, 13–27.

Kolb, B., & Whishaw, I.Q. (1993). Fundamentals of human neuropsychology. New York: Oxford Press.

Laessle, R.G., Fischer, M., Fichter, M.M., Pirke, K.M., & Krieg, J.C. (1992). Cortisol levels and vigilance in eating disorder patients. Psychoneuroendocrinology, 17, 475–484.

Lautenbacher, S., Pauls, A.M., Strian, F., Pirke, K., & Krieg, J.C. (1991). Pain sensitivity in anorexia nervosa and bulimia nervosa. Biological Psychiatry, 29, 1073–1078.

Pendleton-Jones B., Duncan, C.C., Brouwers, P., & Mirsky, A.F. (1991). Cognition in eating disorders. Journal of Clinical and Experimental Neuropsychology, 13, 711–728.

Ploog, D.W., & Pirke, K.M. (1987). Psychobiology of anorexia nervosa. Psychological Medicine, 17, 843–860.

Rappelsberger, P., Mayerweg, M., Kriegelsteiner, S., & Petsche, H. (1988). EEG-mapping: Application to spatial imagination studies. Journal of Psychophysiology, 2, 153–154.

Rappelsberger, P., & Petsche, H. (1988). Probability mapping: Power and coherence analyses of cognitive processes. Brain Topography, 1, 46–53.

Reed, C.L., Caselli, R.J., & Farah, M.J. (1996). Tactile agnosia. Underlying impairment and implications for normal tactile object recognition. Brain, 119, 875–888.

Rescher, B., & Rappelsberger, P. (1996). EEG changes in amplitude and coherence during a tactile task in females and males. Journal of Psychophysiology, 10, 161–172.

Rost, R., Hansen, E., Beyer, L., & Weiss, T. (1992). EEG topography software for description of central nervous activation. In W. Haschke, E.J. Speckmann, & A.I. Roitbak (Eds.), Slow brain potentials and magnetic fields (pp. 137–145), Jena: Friedrich Schiller Universität Press.

Rovet, J., Bradley, S., Goldberg, E., & Wachsmuth, R. (1988). Hemispheric lateralization in anorexia nervosa. A pilot study. Journal of Clinical and Experimental Neuropsychology, 10, 24.

Schmidt, M.H., Lay, B., & Blanz, B. (1997). Does cognitive performance of adolescents with anorexia nervosa change with treatment. Zeitschrift für Kinder-und Jugendpsychiatrie, 25, 17–26.

Steinhausen, H.C. (1994). Anorexia and bulimia nervosa. In M. Rutter, E. Taylor, & L. Hersov (Eds.), Child and adolscent psychiatry: Modern approaches (pp. 425–440). Oxford: Blackwell Scientific.

Szabo, C.P., & Blanche, M.J.T. (1997). Perfectionism in anorexia nervosa. American Journal of Psychiatry, 154, 132.

Szmukler, G.I., Anrewes, D., Kingston, K., Chen, L., Stargatt, R., & Stanley, R. (1992). Neuropsychological impairment in anorexia nervosa: Before and after refeeding. Journal of Clinical and Experimental Neuropsychology, 14, 347–352.

Tewes, U. (1983). HAWIK-R: Hamburg-Wechsel Intelligence Scale for Children. Test manual. Bern: Huber.

Witt, E.D., Ryan, C., & Hsu, L.K. (1985). Learning deficits in adolescents with anorexia nervosa. Journal of Nervous and Mental Disease, 173, 182–184.