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Angle paradigm
A new method to measure right parietal dysfunctions in anorexia nervosa

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Abstract

Background: A functional disturbance of the right parietal cortex (PC) is supposed to be responsible for the distorted body image in patients with anorexia nervosa (AN). Based on this assumption, we investigated changes in haptic perception with a new experimental design. **Method:** Thirty-two subjects (16 AN patients and 16 healthy controls) were asked to readjust a given angle adjustment without visual feedback. This arrangement allowed to measure the deviation of the adjusted angle from the locked angle on an interval scale. **Results:** AN patients performed worse when they were asked to readjust the angle with the right hand, i.e., the deviation of the readjusted angle from the given angle was higher compared to the healthy controls for right side tasks. **Conclusions:** The capacitive strain of the right PC is substantially stronger in right side tasks with the consequence that the functionally disturbed right PC of AN patients cannot provide enough processing resources. © 2002 National Academy of Neuropsychology. Published by Elsevier Science Ltd.

Keywords: Anorexia nervosa; Right parietal lobe; Haptic; Tactile; Haptic perception

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1. Introduction

Different studies confirm the hypothesis that anorexia nervosa (AN) is connected with a functional disturbance of the right parietal cortex (PC) (Bradley et al., 1997; Kinsbourne & Bemporad, 1984; Maggia & Bianchi, 1998). Furthermore, this functional deficit is supposed to be responsible for the distorted body image in AN, which Kinsbourne stated as "anorectic's neglect." Based on this assumption, further neuropsychological studies exploring perceptual–cognitive functions, especially of the right hemisphere in patients with AN (Bradley et al., 1997; Pendleton-Jones, Duncan, Brouwers, & Mirsky, 1991; Rovet, Bradley, Goldberg, & Wachsmuth, 1988), were conducted. Bradley et al. (1997) found changes in event-related potentials (ERPs) during perceptual–cognitive tasks supporting the hypothesis of a right parietal dysfunction in patients with AN. Significant differences were found in ERP amplitudes between an AN group and a control group in verbal as well as in nonverbal tasks. An interesting result of his study is that patients with AN showed no left–right asymmetry for the P3-amplitude in a nonverbal task. However, neither Bradley et al. nor Pendleton-Jones et al. (1991) found significant differences during neuropsychological examinations, that is no cognitive deficits were detected in patients with AN. By contrast, other studies (Brouwers, Duncan, & Mirsky, 1986; Laessle, Fischer, Fichter, Pirke, & Krieg, 1992; Pendleton-Jones et al., 1991; Small, Madero, Teagno, & Ebert, 1983; Szmukler et al., 1992) have shown deficits in perceptual–cognitive tasks in patients with AN. Because these deficits could not be explained by deficits of the right hemisphere alone, it remains unclear whether patients with AN show deficits in perceptual–cognitive tasks based on deficits of the right hemisphere.

This served as a background to our investigations of changes in haptic perception in AN patients. The experimental design used in our studies consisted of sheets with sunken reliefs. The participants had to explore six individual sunken reliefs, which were presented to them in random order, with their eyes closed and their arms on the table. Following the haptic explorations, all participants were asked to reproduce the structure of the stimuli as closely as possible on a sheet of paper with their eyes open. All drawn reproductions were evaluated by a visual rating. Results of a longitudinal study with AN patients showed that there are definite deficits in haptic perception, which even persisted after weight gain (Grunwald, Ettrich, et al., 2001; Grunwald, Ettrich, Krause, et al., in press). In another study, for which we used the same experimental design of the sunken reliefs, we analyzed the spectral theta power of the quantitative electroencephalogram (qEEG) during haptic exploration tasks, which showed clear changes over the right PC of patients with AN (Grunwald, Ettrich, et al., 1999). All in all, the behavioral data, as well as the EEG data, confirm the hypothesis that multisensory integration in AN is impaired due to a functional disturbance of the right PC.

The experimental design of the sunken relief sheets provided only data of a nominal scale level due to the visual rating, which must be considered as a disadvantage. For this low data level concerning the assessment of haptic perception in AN patients, we have been looking for a new experimental design which allowed the measurement of the disturbed multisensory integration process on an interval scale. Thus, we developed an experimental paradigm that provided behavioral data of an interval scale level. With regard to the task types of our previous studies, the new experimental paradigm also consisted of bimanual haptic tasks that demanded complex multisensory integration capacity of the subjects without visual information. On the background of the *direct access model* (Springer & Deutsch, 1993), the test should be organized in a way that the capacity of the right and left hemisphere varies by the same type of tasks. In this way, a varying capacity of the right and left hemisphere should be obtained while solving the tasks.

With respect to our previous studies, we expect that for bimanual haptic tasks AN patients will perform worse if the capacities of the right PC are exceeded. This effect should become obvious in a task type in which target information (with respect to information about a nominal value) have to be organized at the same time as operations of comparison ("target–actual-value-comparison") in the right hemisphere with use of the right PC. If the bimanual haptic task allows the use of the resources of both hemispheres, we expect that there are no distinctive differences between the performance of AN patients and the control group.

2. Method

2.1. Participants

Patient group: 16 patients with AN, diagnosed in accordance with ICD-10 criteria (World Health Organization, 1999), 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. The weight loss in all patients was caused by restrictive fasting. The duration of the illness varied between only a few months and several years. The AN group had a mean age of 15.31 (S.D. = 1.79) and a mean body mass index (BMI) of 14.81 (S.D. = 1.05). The BMI is calculated as: weight (kg) divided by the square of height (m). A BMI between 20 and 25 is considered optimal and a BMI less than 16 is indicative of significant undernutrition (Beaumont, Al-Alami, & Touyz, 1988). The mean IQ, as assessed using the HAWIK (Tewes, 1983), was 113.5 (S.D. = 12.35). All subjects attended high school. No patient had any abnormal neurological findings (e.g., Clinical EEG and CT/MRI were normal).

Control group (CO): 16 healthy women, mean age of 16.31 (S.D. = 1.04), mean BMI of 19.24 (S.D. = 1.67), served as a control group. The mean IQ (HAWIK) was 111.0 (S.D. = 10.48). Twelve of the 16 subjects attended high school and four of them attended junior high school.

Significant group differences (age/IQ/BMI) existed only in the BMI (t test, two-tailed; $t = -8.66$, P=.000). All subjects were dominantly right-handed as assessed according to the Traxler (1970) test for handedness.

The questionnaire for the assessment of the own body (FbeK) (Strauß & Appelt, 1983) was used to assess the disturbance of the body image in the patient group. This questionnaire considers changes in the body image with the help of four scales: Scale 1 assesses the *attractiveness/self-confidence*, Scale 2 the *outward appearance*, Scale 3 the *hypochondriac symptoms* ("Unsureness/Anxiety"), and Scale 4 the *bodily-sexual uneasiness*. The described questionnaire was used in several studies concerning AN and showed particular sensitivity on Scale 1 "Attractiveness/Self-Confidence" (Lehmkuhl, Flechtner, Woerner, & Marsberg, 1989). Our study was approved by the local Ethics Commission.

2.2. Apparatus

In our experiment, we used the following experimental setting outlined in Fig. 1, by example of a right-parallel task. It consisted of a holding device, which is adjustable in its height to keep a vertical head position (Fig. 1a) and a touch-sensitive switch (Fig. 1b) to measure the time needed to fulfill the assignment. The results of the time measurements were shown by a digital data display (Fig. 1f). The angle position was assessed by a digital measuring instrument (Fig. 1d) with an exactness of one hundredth of a degree provided by the company Nestle (Dornstetten, Germany), as well as the separate display on which the deviations of the angles were shown (Fig. 1c). The exactness of the angle measurement was one hundredth of a degree. Two metal bars ($5 \times 10 \times 240$ mm, Fig. 1e) served as angle

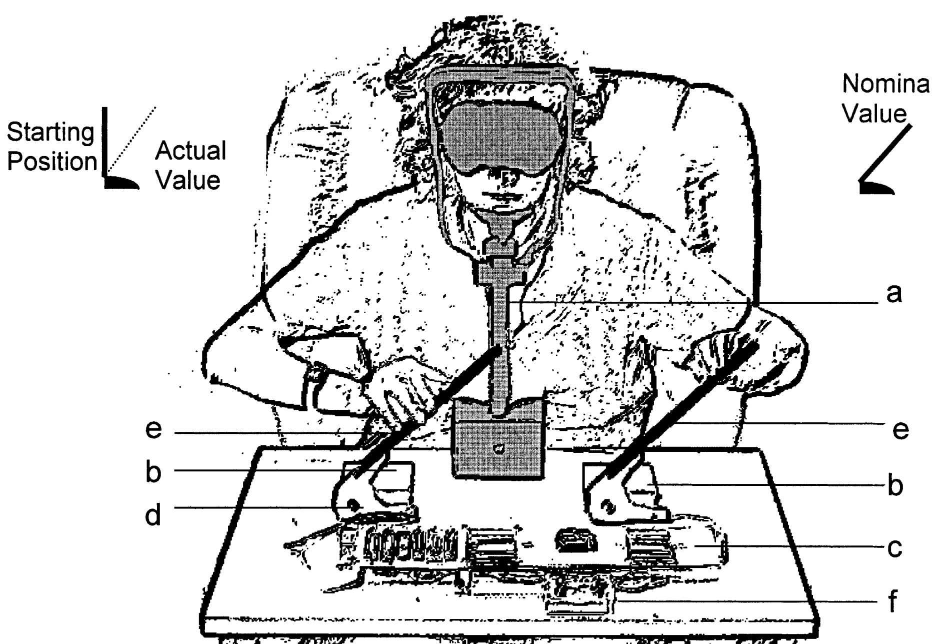

Fig. 1. Experimental arrangement (shown by a right-parallel task). (a) Holding device. (b) Touch-sensitive switch. (c) Digital data display. (d) Digital measuring instrument for the angle position. (e) Angle leg. (f) Digital data display for time measurement.

legs. The distance from the table to the end of the angle legs was 28.7 cm in the position of 90°. The distance between the angle pivots was 28 cm. After the angles were adjusted, the data were recorded manually by the experimenter. During the exploration, the left hand was only allowed to touch the left angle leg and the right hand was only allowed to touch the right angle leg. No crossovers or both-handed exploration or touch of the opposite angle leg and the tabletop at the same time was allowed. Both hands should leave the touch-sensitive switches and explore the angle position simultaneously. The time measurement started with the removal of the hands from the touch-sensitive switches and finished with the touch of both switches. The target angle leg was not moveable by the test person. The exploration was done by an up-and-down movement of one or more touching fingers on the angle leg. The hands should return to the touch-sensitive switches as soon as they finished the readjustment of the moveable angle.

The experimental design consisted of two angle legs, of which one angle leg had to be readjusted to a given angle adjustment. We distinguished between two task types — a mirror task type and a parallel task type. The assignment of the mirror task type was to readjust a given angle adjustment (target angle leg) with respect to the other angle leg (task angle leg) in a mirrored way, whereas the assignment of the parallel task type was to readjust the adjustment of the target angle with the task angle leg in a parallel way. Furthermore, we distinguished within the task types between right side and left side tasks. In right side tasks, the left angle was locked and subjects were asked to readjust the right angle. In left side tasks, the left angle had to be readjusted to the locked right angle. All in all, there were four different tasks: a right-parallel task, a left-parallel task, a right-mirror task, and a left-mirror task. Each task, in turn, consisted of five different degree adjustments. No time limit was given and no visual feedback was provided. The task types are schematically represented in Fig. 2.

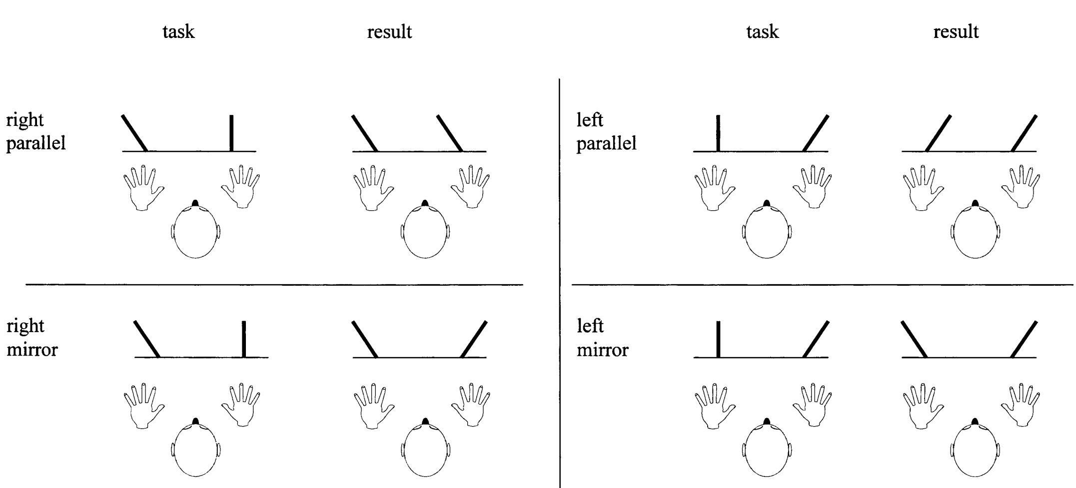

Fig. 2. Schematic description of the tasks. Upper line: the task angle has to be readjusted in a parallel way. Under line: the task angle has to be readjusted in a mirror-like way.

2.3. Procedure

The starting position of all angle legs to be adjusted by the subjects was 90°. All participants had the opportunity to familiarize themselves with the assignments during four

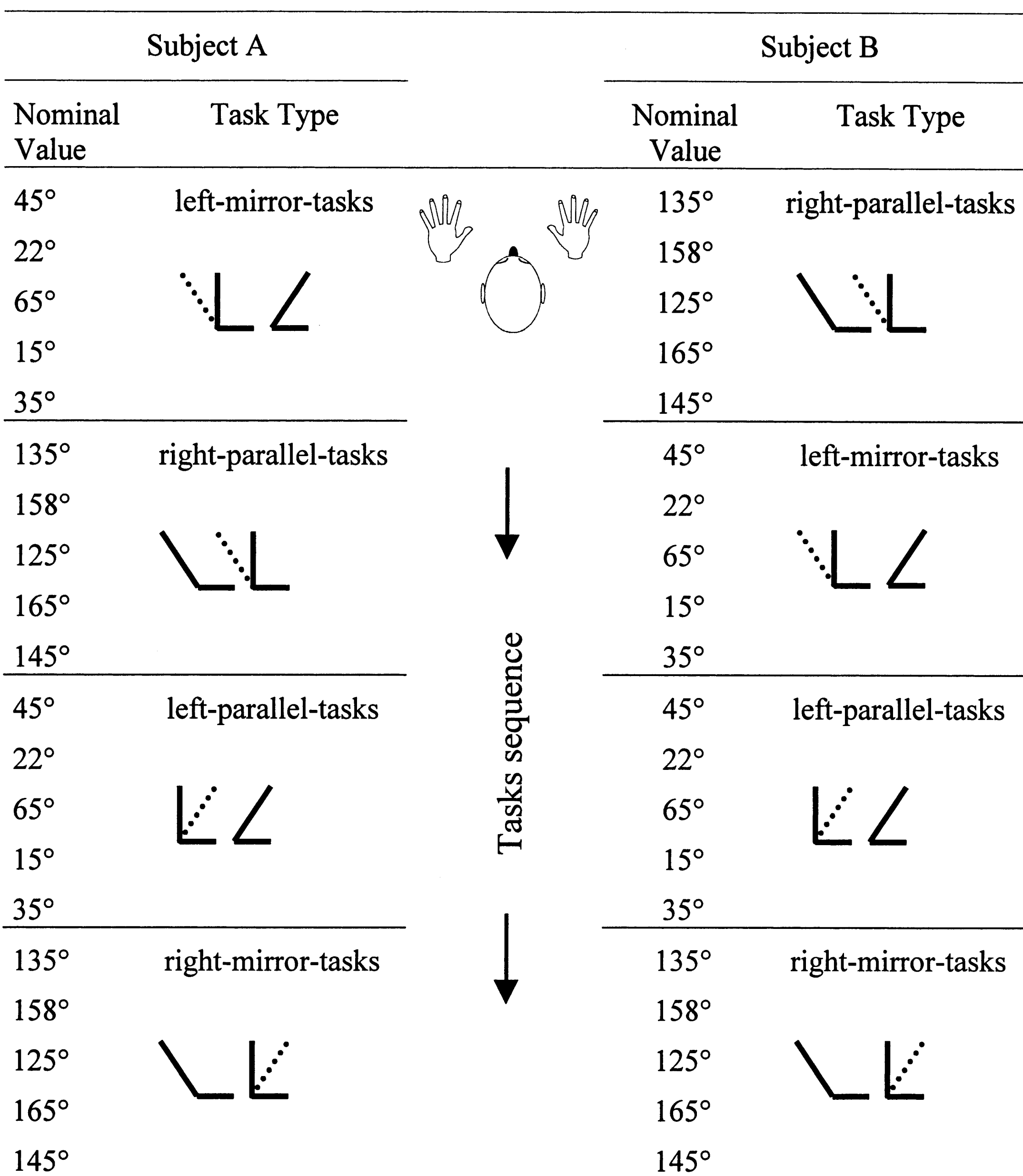

Fig. 3. Arrangement and order of the tasks for two subjects. The given angles (nominal values) are quoted in degrees.

training tasks, one for each task type. The subjects got visual feedback, as well as information, about their results in degrees of deviation. Afterwards, each subject was blindfolded and her hands rested on the touch-sensitive switches. Then, the experimenter adjusted the first task. Fig. 1 shows the left angle leg (as seen by the test person) which was adjusted to a defined amount (nominal value). The right angle leg had a starting position of 90°. Next, the subject was ask to adjust the right angle leg with the right hand parallel to the (left) target angle leg. Then, the experimenter read the readjusted angle (actual value) and adjusted the next task. The nominal values for the right side tasks (mirror and parallel) were: 135°, 158°, 125°, 165°, and 145°, while the nominal values for the left side tasks (mirror and parallel) were: 45°, 22°, 65°, 15°, and 35°. Thus, five different angle adjustments had to be readjusted in each task type. All subjects had to solve the tasks of one task type in the same order, but the order of the task types varied. The order of the tasks is shown for two subjects in Fig. 3. The exploration times (ET, the time needed for the readjustment of the angle leg) and the difference between nominal value and actual value (DNVAV) without considering the direction of the deviation were used for the data evaluation.

2.4. Statistical evaluation

Group differences concerning the DNVAV were evaluated multivariately by ANOVA (regression model). For the post hoc analysis, we used the *t* test for independent groups (two-tailed). Pearson’s correlation coefficient (two-tailed) was used to test the correlation between ET and DNVAV separately for each group. The correlation between DNVAV and the scale “Attractiveness/Self-Confidence” of the FbeK was tested by using the correlation coefficient by Spearman (two-tailed) because of the different scale levels of both methods.

3. Results

All results of the descriptive statistics concerning the DNVAV and all results of the ETs are shown in Table 1. The analysis of the various factors influencing the DNVAV revealed a significant effect for the factor Group [$F_{Group}(1,633)=15.37$, P=.000]. Another significant effect was shown for the factor Task (parallel tasks and mirror tasks) [$F_{Task}(1.633)=16.44$, P=.000], whereas no significant effect was shown for the factor Side (right side tasks with respect to left side tasks) [$F_{Side}(1,633)=1.46$, P=.226]. Thus, our investigation revealed a clear difference between the AN group and healthy controls because there was a generally higher DNVAV in the AN group. No significant difference in DNVAV was detected between left side tasks and right side tasks. By way of contrast, a difference in DNVAV was revealed concerning the task types (parallel and mirror) with the result that the DNVAV was higher in all parallel task types.

A significant, two-way interaction could be stated between the parameters Group and Side [$F(1,633)=3.75$, P=.053]. Only for the right side tasks, the post hoc analysis revealed a significantly higher DNVAV ([AN vs. CO] $t_{right\text{-}tasks}=4.016$, P=.000) in the AN group compared to controls. This effect occurred not in the left side tasks ([AN vs. CO]

Table 1
Means and standard deviations of the DNVAV (in degrees) and ET (in seconds) for AN patients and healthy controls

		Controls				AN patients			
		DNVAV		ET		DNVAV		ET	
Tasks		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Right + left	parallel	4.61	4.13	27.00	18.93	5.89	4.74	30.01	19.04
	mirror	3.96	3.94	24.48	13.61	4.38	3.59	26.45	17.55
	total	4.29	4.04	25.74	16.51	5.13	4.27	28.23	18.38
Right	parallel	5.00	4.33	24.42	15.38	7.76	4.98	24.68	15.59
	mirror	3.34	3.28	22.51	13.14	4.41	3.49	27.69	20.13
	parallel + mirror	4.17	3.92	23.47	14.29	5.38	4.49	27.19	17.83
Left	parallel	4.23	3.91	29.59	21.71	5.39	4.51	30.79	21.86
	mirror	4.59	4.45	26.46	13.87	4.73	3.96	25.16	17.13
	parallel + mirror	4.41	4.18	28.02	18.22	4.87	4.03	29.27	18.89

The results are shown per task type (parallel, mirror) and task side (right, left).

$t_{\text{left-tasks}} = 1.381$, $P = .168$). In addition, the post hoc analysis showed no significant group differences neither for the left-parallel tasks nor for the left-mirror tasks [AN vs. CO ($t_{\text{left-parallel}} = 1.742$, $P = .083$); AN vs. CO ($t_{\text{left-mirror}} = .207$, $P = .837$)]. In contrast, significant group effects were revealed for both right side tasks — for the right-parallel tasks as well as for the right-mirror tasks [AN vs. CO ($t_{\text{right-parallel}} = 3.745$, $P = .000$); AN vs. CO ($t_{\text{right-mirror}} = 2.009$, $P = .043$)]. The effects of interaction of the parameters (Group × Task) were also significant [$F(1,633) = 4.28$, $P = .039$]. Here, the post hoc analysis revealed clear group effects for the parallel task types ([AN vs. CO] $t_{\text{parallel-tasks}} = 3.882$, $P = .000$), but not for the mirror tasks types ([AN vs. CO] $t_{\text{mirror-tasks}} = 1.414$, $P = .158$). The significant effects of interaction of the parameters [Side × Task: $F(1,633) = 12.93$, $P = .000$] indicate that the DNVAV depends on both, the side as well as the type of the tasks.

No group effects and no task effects were shown for the factor Time [$F_{\text{Group}}(1,633) = 0.916$, $P = .339$; $F_{\text{Task}}(1,633) = 1.880$, $P = .171$]. All participants needed significantly more time for the left side tasks than for the right side tasks [$F_{\text{Side}}(1,633) = 5.157$, $P = .023$]. Furthermore, there was no significant effect of interaction for Task × Side [$F(1,633) = 3.119$, $P = .078$], Task × Group [$F(1,633) = 0.188$, $P = .665$] and Side × Group [$F(1,633) = 0.978$, $P = .323$]. However, we found a significant correlation between the DNVAV and the scale values on the scale "Attractiveness/Self-Confidence" in the AN group ($r = -.567$, $P = -.022$, Spearman coefficient, two-tailed).

4. Discussion

First of all, the results show that AN patients had poorer test performances (i.e., a higher DNVAV) compared to healthy controls. However, as revealed by the analysis concerning the side of the tasks, this effect was only seen for the right side tasks. Therefore, the increased DNVAV in the AN group referring only to the right side tasks is the main result of this study. Concerning the right side tasks, the nominal values deviate from the actual values by 5.38° (S.D. = 4.49°) in the AN group and by 4.17° (S.D. = 3.92°) in the control group, while there were no group differences in the need of time. Moreover, a clear correlation was shown between the DNVAV and Scale 1 of the FbeK (body image) in the AN group. Thus, a connection is supposed between the disturbance of body image and the DNVAV in our experiment.

Our results can be explained on the grounds of the *direct access model* (Springer & Deutsch, 1993). In this model, it is assumed that sensory information is processed dominantly in that hemisphere which first receives the information. It is known that sensory and motor information of the hands, including information of its joints and muscles, reach the ipsilateral, but mainly the contralateral fields, of the motoric and sensomotoric cortex (Baraldi et al., 1999; Salmelin, Forss, Knuutila, & Hari, 1995; Schnitzler, Salmelin, Salenius, Jousmaki, & Hari, 1995; Singh et al., 1998). Thus, information about movement and position reach the contralateral hemisphere by involving the thalamic nucleus. Moreover, it is known that the information is processed by the motoric as well as the somatosensory areas of the anterior and posterior parietal lobe. Interhemispheric and intrahemispheric connections exist between these regions, providing an afferent and efferent exchange of information (Marsden et al., 2000). The posterior PC provides sensory information to the frontal cortex (Critchley, 1953; Kolb & Whishaw, 1990). Furthermore, connections exist between the posterior PC and the hippocampus, the thalamus, the spinal cord, and the basal ganglia (Birbaumer & Schmidt, 1996). Particularly, the right posterior PC organizes multisensory integration and is responsible for the production of spatial percepts (Grunwald, Weiss, et al., 1999; Grunwald, Weiss, et al., 2001; Harris et al., 2000; Karnath, 1997; Knecht, Kunesch, & Schnitzler, 1996). This warrants the assumption that the right posterior PC plays a crucial role in the comparison of nominal and actual values.

For right side tasks, this means that information about the nominal values of the left hand is mainly represented in the right hemisphere. Simultaneously, the dynamic actual value is compared to the constant nominal value by coworking of the sensomotoric and the PC of the right hemisphere. Thus, in the right hemisphere two processes are done simultaneously when it comes to solving rights side tasks (Fig. 4). By way of contrast, during left side tasks, nominal values are encoded in the left hemisphere since here the nominal value is assessed by the right hand and the actual value is readjusted by the left hand. The operations of comparison as well as the control of the readjustment movements of the left hand occur in the right hemisphere, which receives the nominal value information by the commissures. Thus, task sides are substantially different concerning the capacitive strain of the right PC in proceeding and integrating the multisensory information. Right side tasks require from the right PC the organized analysis of the nominal values and of the deviation values as well as of the decision procedures in cooperation with the frontal cortex. All these processes will be affected if a functional disturbed right PC provides not enough processing resources. Thus, the distinctively increased DNVAV as shown in the AN group can be interpreted as a consequence of this disturbance.

On the other hand, the demand structure of the left side tasks leaves more resources to the right PC, because the right PC does not have to encode the nominal value. The

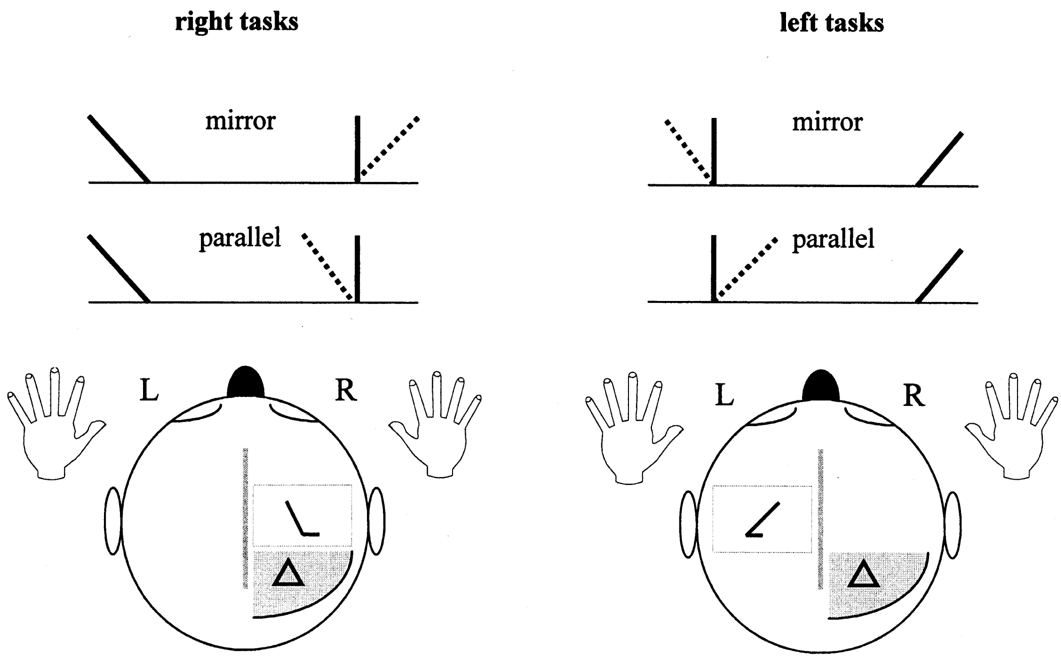

Fig. 4. Schematic description of the representation of the nominal value information in the right left hemisphere respectively relating to the task side. At right side tasks the nominal value is encoded in the right hemisphere, whereas at left side tasks the nominal value is encoded in the left hemisphere. The right PC serves as a processor for the integration of sensoric information and compares the nominal to the actual value. This illustration points out the higher capacitive strain of the right PC during the right side tasks compared to the left side tasks.

nominal value is encoded in the left hemisphere and reaches the right posterior PC by the commissures (Hansson & Brismar, 1999; Oliveri et al., 1999). This explanation for the obvious deficits in solving the right side tasks as shown in AN patients remains speculative because of the lack of neurophysiological data. Functional imaging techniques could clear up whether the cortical activation patterns during the solution of haptic perception tasks support our interpretation or whether other respectively additional processes are responsible for the observed deficits.

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