Childs Nerv Syst (2010) 26:105–111
DOI 10.1007/s00381-009-0984-6

CASE REPORT

Rapid recovery of motor and cognitive functions after resection of a right frontal lobe meningioma in a child

Göran Carlsson · Markus Hufnagel · Olav Jansen · Alexander Claviez · Arya Nabavi

Received: 10 July 2009 / Published online: 29 August 2009

Abstract
Purpose The purpose of this study is to provide longitudinal data on neurological and neuropsychological restitution following resection of an extra-axial space-occupying lesion.
Case report A comprehensive neuropsychological test battery was utilised preoperatively and 1, 4, 11, and 24 months, respectively, after removal of a parasagittal meningioma compressing the right frontal lobe in a right-handed 6-year-old boy with average intelligence.
Results Symptoms related to brain compression (left-sided hemiparesis, diplopia) resolved shortly after surgery. Recovery of specific cognitive functions (short- and long-term memory, attention, and dichotic listening performance) was more protracted.
Conclusion Here, we illustrate the potential of a structured follow-up analysis, based on neuropsychological testing. We were able to distinguish separate time-courses for neurological functions but even more distinct within complex neuropsychological processes. This time-dependent recovery should be considered when designing longitudinal follow-up studies.

Keywords Child · Meningioma · Cognition · Neuropsychology · Dichotic listening

G. Carlsson (✉) · M. Hufnagel · A. Claviez
Department of Paediatrics,
University of Schleswig-Holstein/Campus Kiel,
Schwanenweg 20,
24105 Kiel, Germany
e-mail: gcarlsson@pediatrics.uni-kiel.de

O. Jansen
Department of Neuroradiology,
University of Schleswig-Holstein/Campus Kiel,
Schwanenweg 20,
24105 Kiel, Germany

A. Nabavi
Department of Neurosurgery,
University of Schleswig-Holstein/Campus Kiel,
Schwanenweg 20,
24105 Kiel, Germany

Introduction

Meningioma is a slowly growing and mostly benign tumour of the intracranial and intraspinal meninges, with a high risk of relapse when the tumour takes a malignant development. Common symptoms of intracranial meningioma are unilateral paresis, sensory impairments, visual and speech deficits, as well as behavioural disorders. Although meningioma is one of the most common intracranial primary tumours in adults [1], it is extremely rare in children [2, 3].

Although children with neurodevelopmental disorders frequently present with short- and long-term memory impairment, the relationship between peri-Sylvian and frontal morphology on verbal memory functioning has received little attention in the literature. Similarly, studies with dichotic listening have shown plasticity with regard to ear advantage in children with left versus right brain lesions [4]. Simple and complex reaction time tests that measure aspects of processing speed, attention, and vigilance would be particularly sensitive to brain pathology implicating frontal and parietal lobe areas [5–7], and would be crucial for assessment of recovery of cognitive functioning after surgery.

There is a lack of knowledge concerning neuropsychological functioning in children suffering from extra-axial intracranial lesions, e.g., meningioma. These lesions may compress the cerebrum, without infiltration. Subsequently functional alteration may potentially show a restitution ad integrum, providing insight into the neurological but, more

importantly, neuropsychological recovery. Albeit postoperative assessment may have been occasionally applied, a structured longitudinal analysis, including pre- and postoperative tests, provides insight into recovery potential. We present pre- and sequential post-surgery data on neuropsychological functioning to assess manual motor and sensory functions, memory, speech perception, sustained attention, and vigilance in a young boy with a right hemisphere meningioma compressing large parts of the frontal lobe. These qualities were selected since they all have been shown to be affected by early brain lesions and brain pathology, and to be sensitive to brain plasticity effects. Considering the size and the location of the tumour, together with an accomplished neuropsychological assessment, it is both a research and clinical challenge to unravel the impact on neuropsychological functions and to monitor the postoperative recovery process with repeated tests.

Case report

A 6-year-old right-handed boy was admitted because of intermittent painful walking lasting for about 4 weeks. He then developed ataxia, tended to fall towards the left side, and complained of weakness in his left arm and hand. When diplopia occurred, he was admitted in another hospital and referred for further investigation.

On examination, the boy had a markedly asymmetric gait with increased muscle tone of his left non-dominant extremities. The left foot was held in a pointed toe-position, and his left arm was flexed and pronated. Muscle strength in his left hand was slightly decreased with a discrete rigour. Standing on his left leg was possible for only a few seconds at a time; thereafter, the patient lost his balance without a falling tendency to a specific side. A left-sided hemiparesis more pronounced in the arm and face and a mild bilateral abducens paresis were diagnosed. Ophthalmoscopy revealed papilloedema. He was fully alert and cooperative without any behavioural disturbances. There was no clinical evidence for neurofibromatosis. The family history was negative with respect to the occurrence of tumours.

Apart from a slightly elevated erythrocyte sedimentation rate (25 mm/h), all other standard laboratory values were within normal limits.

Initial brain magnetic resonance imaging (MRI) disclosed a sharp-edged tumour compressing the right frontal lobe measuring 7 × 5 × 5 cm with homogeneous contrast medium enhancement. The midline was shifted, and ventricles were compressed. The superior sagittal sinus was narrowed without infiltration by the tumour (Fig. 1).

Frontal access surgery was performed, and the tumour could be completely removed. The dura was partially infiltrated, but the rims were free of tumour. Histological examination revealed an atypical meningioma (grade II according to World Health Organization classification) with meningoepitheliomatous differentiation and focally increased cell density. Mitotic activity was increased, and a focal proliferation rate of up to 20% as determined by Ki-67 antigen expression was found.

The boy's recovery after surgery was uneventful. Regular postoperative neurological examinations revealed no neurological abnormalities. The control MRI 5 months after tumour resection showed a right frontal fluid collection and collapsed cavity, where the tumour had been removed (Fig. 2). No residual tumour was detected in additional neuroradiological assessments by MRI 1, 4, and 11 months postoperatively, respectively. The boy remained in very good condition and complete remission. On routine examination 2 years after initial diagnosis, an asymptomatic local relapse (0.8 × 2 cm) became evident. Following subtotal surgical resection, the patient received fractionated stereotactic radiotherapy with 54 Gy (boost up to 63 Gy). He achieved a second remission with a present follow-up of 2 years.

Methods

Present neuropsychological assessment constitute a combination of clinical and experimental instruments including measures of intelligence, sensory-motor and visuoconstructive functions, attention, lateralized auditory perception, as well as short- and long-term memory.

The culture fair test of intelligence (CFT1) with German norms was used [8]. The purpose of this test is to obtain an adequate measure of broad fluid reasoning capacity (g-factor). This test consists of five subtests: substitution, labyrinths, classification, analogies, and matrices.

Sensory and motor functions were assessed according to the Kiddie version from the Halstead-Reitan neuropsychological test battery [9]. All T-scores were calculated from standardised age-, gender-, and lateral-preference-controlled norms. T-scores between 40 and 60 are an evidence for average performance. Graphesthesia was tested according to the routine for children between 5 and 9 years of age, i.e., writing series of O's and X's in a randomised fashion on the finger tips of the left and right hand, respectively. Grip strength was assessed according to the dynamometer test. The fine-motor function was measured by the grooved pegboard test consisting of ten pegs, which should be inserted in "keyholes" first with the dominant hand and then with the non-dominant hand. Time in seconds was noted for completion of the test. Raw scores for the dominant and non-dominant hand in both tests were converted into T-scores according to standardised norms.

The developmental test of visual-motor integration (VMI) was used to measure visual-perceptual and visual-constructive

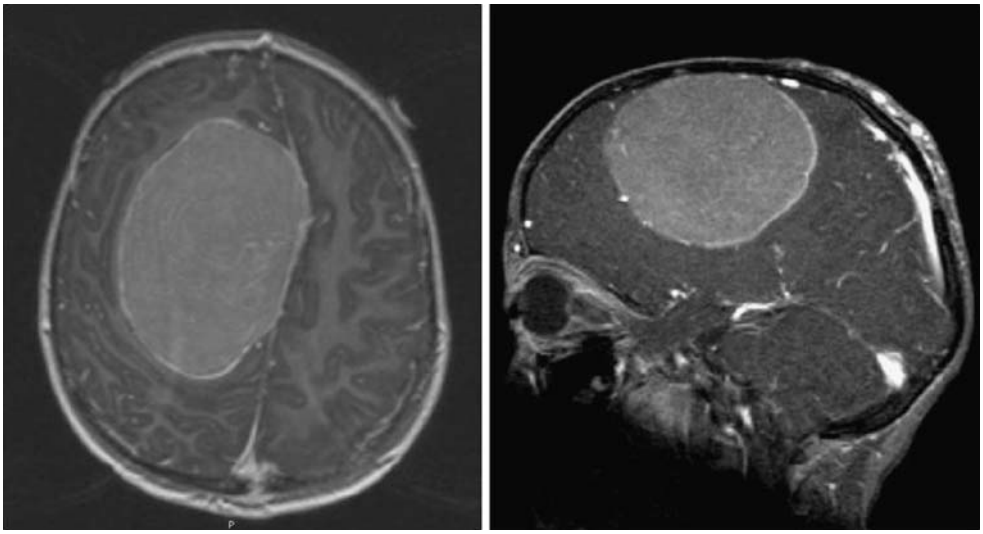

Fig. 1 Preoperative transversal and sagittal T1-weighted images with contrast show huge space-occupying extra-axial mass in the right hemisphere with attachment to the cerebral falx

abilities [10]. A developmental sequence of up to 24 geometric forms is to be copied with paper and pencil. The performances are standardised for children between 4 and 18 years of age.

The dichotic listening test is considered to measure the auditory-phonetic processing in both hemispheres by presenting two different messages simultaneously in each ear [11]. Typically, the right ear is preferred, indicating left hemisphere dominance [4]. The dichotic listening test shows a contralateral lesion effect in cases with unilateral brain lesions [12], i.e., the correct reports from the ear (e.g., left ear) contralateral to the impaired (right) hemisphere are extremely reduced relative to the correct reports from the ear (e.g., right ear) contralateral to the intact (left) hemisphere. The dichotic listening materials consisted of German spoken stimuli, digitalised and played to the subject from a CD player over headphones, and the child was invited to tell what he heard. The dichotic stimulus material consisted of the six stop-consonants /b/, /day/, /g/, /p/, /t/, and /k/ that were paired with the vowel /a/ to form six consonant-vowel syllables (/ba/, /da/, /ga/, etc.) developed by Hugdahl et al. at the University of Bergen, Norway [13, 14]. The syllables were paired with each other for all possible combinations, thus yielding 36 dichotic pairs including six homonymic pairs (/ba/-/ba/, /da/-/da/, etc). The homonymic trials were not included in the calculations. The dichotic listening data were scored as the number of correctly reported syllables from the right and left ears, respectively. In order to compare the findings with other studies, the data were converted to percentage score in the table. A laterality index was also calculated according to the formula: $[(\text{Right ear correct}) - (\text{Left ear correct})]/[(\text{Right ear correct}) + (\text{Left ear correct})] \times 100$.

Short-term memory or memory span was assessed according to the Wechsler's scales with German norms [15]. Raw scores were converted into scaled scores where scores between 7 and 13 correspond to average performance. The child has to retain an auditory presented list of random numbers, which should be immediately recalled. In the Luria's word learning task, which is a list-learning task consisting of ten common and unrelated nouns (e.g., house, forest, and cat), the subjects are encouraged to learn and

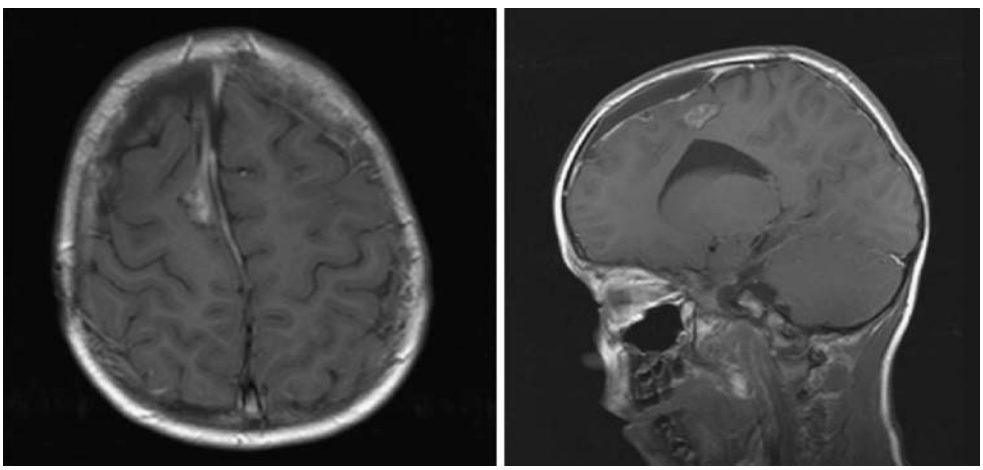

Fig. 2 Postoperative transversal and sagittal T1-weighted images with contrast show total tumour extirpation 5 months after surgery. A moderate subdural effusion with slight compression of the frontal cortex and a minor dural scar with increased enhancement are visible

recall these words [16]. This task is discontinued when ten words are acquired, if not, the learning session is terminated after the tenth trial. After 1 h, the child is asked to recall the list of words he had learned. For the repeated assessments, parallel forms of word lists were used.

Three computerised reaction time tasks with progressive complexity were used, newly implemented (Java) from an older version of this test [17]. This test was especially designed to be highly motivating and easy to perform in order to minimise confounding factors such as motor impairments and learning effects by repeated tests. The first reaction time (RT) task is a simple reaction time (SRT) task. By appearance of the target ("red monster") on the screen, the child was instructed to press the spacebar as fast as possible. The target appears randomly either to the left, middle, or to the right on the monitor. The targets are present for 600 ms. Auditory and visual feedback is given for correct and false responses, respectively. The second RT task is a choice reaction time (CRT) task. The subject was invited to "hit the red monsters but not the suns". The randomised distribution of targets and non-targets were chosen to 75% and 25%, respectively. The third RT task, a complex choice reaction time (CCRT) task, is analogues to the CRT task. The subject was instructed to hit the "red monsters but neither the suns, nor the friendly creatures". The difference between the "red monsters" and the "friendly creatures" (white, green, blue, and pink) is the colour and a slightly different form. This task consisted of 75% targets and 25% non-targets, randomly distributed. The dependent variable in these tests was mean reaction times (milliseconds). The performance was compared with standardized norms for children from kindergarten and mainstream school between 5 and 7 years of age ($N = 28$). T-scores were calculated for the three tasks pre-surgery and for all follow-ups. Average performance corresponds to T-scores between 40 and 60.

Results

Neuropsychological assessments were correspondingly performed before and at 1, 4, 11, and 24 months after brain surgery as an indication of brain plasticity and rate of recovery after brain pathology, respectively (Table 1).

Intellectual capacity The boy revealed here an average non-verbal intelligence (IQ 103) before surgery in the CFT1 test. A postoperative retest with this instrument was desisted from, as no relevant change in IQ was expected.

Graphesthesia No deficits were registered in the pre- or post-surgery assessments, indicating that post-central regions were not affected.

Grip strength Before surgery, it was not possible to validly assess grip strength in any hand, due to hemiparesis in the left hand and a bandage on the right hand. In the 1-month follow-up, average performances (T-score >50) were revealed in both hands without significant side differences (Table 1). However, in the further follow-ups, the differences between the right- and left hand continuously increased to disadvantage for the left hand. Thus, in the 24 months follow-up, the grip strength was $T = 65$ and $T = 58$ for the right and left hand, respectively.

Fine-motor function The grooved pegboard test could not be performed pre-surgery. In the first post-surgery assessment, the performance recovered to an average level in both hands. In the further follow-ups, average performances for both hands were documented without significant side differences.

Visual-constructive function The VMI revealed pre-surgery an impaired visual-motor ability. In the follow-up, these functions were normalised first in the 24 months assessment.

Auditory perception The dichotic listening test revealed in the pre-surgery session an extreme right ear advantage with an exaggerated laterality index (Table 1). In the follow-up, the laterality index and the right ear correct scores continuously decreased over the assessment period. The left ear correct scores increased at first but reached a stable level already from the 4 months assessment post-surgery. Thus, the correct scores for both ears changed and counterbalanced the extreme discrepancy between right and left ear correct scores before surgery.

Learning and memory The patient preoperatively revealed barely an average short-term memory (Table 1). However, in the follow-up investigations, his performances recovered fast and stayed stable. Using the Luria's word learning task, the boy showed impaired functions in the acquisition as well as his delayed recall of words in the pre-surgery assessment, as he could maximally learn and recall two words. Already in the first follow-up, 1-month later, he showed average performances in the acquisition process (85%) as well as in long-term memory (80%) for the present word material. These functions remained intact in further follow-ups.

Vigilance In the pre-surgical assessments and up to 4 months post-surgery, the simple and choice reaction times in the computerised reaction time test revealed deficient performances (Table 1). However, in the long-term follow-up, i.e., from 11 to 24 months post-surgery, the reaction times were normalised in all three RT tasks, indicating an optimal vigilance from about 1 year after surgery.

Table 1 T-scores, scaled scores, or raw scores for all tests portioned into six neuropsychological functions

Functions and subtests			Before operation	After operation			
				1 month	4 months	11 months	24 months
Manual motor functions	Dynamometer (T-scores)	Left hand	<20	50	53	60	58
		Right hand	<20	53	59	66	65
	Pegboard test (T-scores)	Left hand	<20	47	57	55	59
		Right hand	<20	41	59	58	57
Visual-motor function	VMI	T-score	36	32	33	35	47
Auditory perception	Dichotic listening test	Laterality index (%)	+58.38	+30	+28.9	+27.3	+23.8
		Left ear (%)	16.67	23.33	26.7	26.67	26.67
		Right ear (%)	53.33	43.33	48.3	46.67	43.33
Short-term memory	Digit-span	Scaled scores	7	9	12	10	10
Learning memory	Acquisition	% correct	23%	84	82	87	91
	D-recall	% correct	0%	80	90	90	90
Vigilance	SRT	T-scores	29	26	39	43	50
	CRT	T-scores	31	34	38	47	50
	CCRT	T-scores	32	33	45	52	45

CCRT complex choice reaction time, *CRT* choice reaction time, *SRT* simple reaction time, *VMI* visual-motor integration

Discussion

Before the resection of this extensive meningioma compressing the anterior portion of the right hemisphere, the neurological findings mainly indicated abnormally high brain pressure and particularly a compression of the right frontal lobe. In the neuropsychological assessment, the right hemisphere affection was concomitant with a distinct left-sided manual motor impairment, i.e., hemiparesis, together with a pronounced right ear advantage in the dichotic listening test and an overall impaired cognitive processing. A strong right ear advantage is a valid indicator that the left hemisphere is the speech-dominant hemisphere in children with right hemispheric lesions [18, 19] or right-sided focal epilepsy [4]. The pronounced reduction of the left ear correct score preoperatively presupposes presence of specific right hemisphere impairments, according to the "contralateral lesion ear effect" [11]. This phenomenon has also been confirmed in other studies on child patients with unilateral brain lesions [19].

Post-surgery, the left ear correct score showed a continuous recovery up to about half a year after treatment, concomitant with improved vigilance. From the increase in laterality index alone from pre- to final postoperative follow-up, it is not possible to conclude if the change occurred to the right or left ear stimulus. The analysis of the right and left ear scores separately revealed, however, that most of the change occurred to the left ear stimulus, which would imply an improved functional integrity, e.g., according to a recovered arousal level of the right hemisphere. If there was a learning effect in the repetitive confrontation with this test-material, it is not expected that the right ear correct score would decrease, but rather increase. The reduced right ear correct score is neither an indication of worse ability to perceive speech sounds in the left hemisphere nor an indication of a reorganisation of speech to the right hemisphere. Increased left ear correct scores rather indicated an improved discriminative capability of the right hemisphere, however, at lower than the expected level.

The strengths of the present study were the unique anatomical location as well as the extraordinary extension of the tumour, covering large parts of the prefrontal cortex, with midline shift and ventricular compression. In functional terms, large parts of the dorsolateral prefrontal cortex were affected, with possible effects on major motor and vital cognitive functions related to short-term and working memory [20], attention [6], and executive functions [21, 22].

The dichotic listening test is able to determine cerebral speech dominance quite well, and thus tapping primarily temporal lobe function. However, the functional integrity of the extra-temporal regions must also be taken into consideration to predict the speech dominance. Thus, the dichotic listening test in its simplicity may be an excellent method to refer brain tumours or insults to a specific hemisphere, especially when the tumour develops fast. Slowly developing brain tumours do not show similar clear-cut symptoms [23].

Measures of memory did hardly add any information to the tumour location in this boy. The acquisition of a word list is considered to take special demand on left frontal regions, whereas the right dorsolateral frontal areas and bilateral parietal areas are required in the recall process [24]. Before surgery, the boy showed deficits in short-term memory,

immediate recall after the first presentation of the word list, as well as the overall acquisition- and delayed-recall process. On the other hand, after the removal of the brain pressure, the verbal short-term memory, the acquisition process, and long-term memory instantly normalised, which should be referred to the general impact of high brain pressure.

Measures of vigilance did not either add definite information on the tumour location in our patient. However, the removal of the brain pressure and eventually the specific impact on the right frontal lobe did show a relatively slow recovery. A slower recovery of vigilance and attention may indicate that these functions may be related to some remaining defective structures in the frontal lobes. This assumption was also confirmed by the MRI examination 11 months postoperatively (Fig. 2). Here, a remaining structural lesion in the coronal image is observed, which indirectly suggest that frontal structures are associated with slower recovery of vigilance. Considering this, the assumed localisation of vigilance and attention to the right frontal lobe dysfunctions match up with recent empirical findings [5, 25–27]. This may imply that an optimal restitution of attention in a slightly injured frontal lobe may not be reached until 1 year after surgery in this 6-year-old boy. However, it may be argued that there is a learning effect when repetitive test trials are performed, but the present reaction time tasks are so simple that the learning effect is considered minimal. The simplicity of these tests is considered as rather boring when they are presented repetitively. According to this, gains in vigilance and attention may not be explained by learning or motivation, but rather as a solid expression of recovered attention post-surgery.

The grip strength and fine-motor functions recovered immediately after surgery. However, the visual-constructive functions were not normalised until the 2-year follow-up examination, showing that executive functions demand more time to recover after a chronic cerebral compression.

Present cognitive and motor findings are giving some hints on a frontal involvement. Long-term follow-up investigations of children with brain tumours who received radiation therapy may later show deleterious effects on vigilance and attention through disruption of normal prefrontal development [28]. However, this boy did not receive radiation therapy during the assessment period.

The recovery process for vigilance functions according to the present reaction time tasks was rather slow, which coincides with the slower restitution rate of left ear correct scores in dichotic listening and visual-constructive functions implying a delayed restitution of cognitive and executive functions according to the present comprehensive neuropsychological assessment.

In conclusion, in this report on a 6-year-old boy after complete resection of a large tumour in the right frontal lobe, all neurological and several neuropsychological impairments promptly recovered already at 1 month after surgery, especially for the manual motor and memory functions, when the acute brain pressure was eliminated. The slower recovery of executive functions, vigilance, and auditory perception according to dichotic listening test to the contralateral side of the main cerebral impact may indicate that these functions have been impaired by the chronic compressive forces on the frontal lobes, and thus need more time to recover.

This rare case with a large extra-axial lesion provides insight into the neuropsychological recovery pattern caused by non-invasive lesions. The thorough neuropsychological work-up documents the necessity for longitudinal analyses of patients harbouring extra-axial, space-occupying lesions, to appreciated actual and potential recovery.

Acknowledgements This research was gratefully supported by Barnhuset in Göteborg, Sweden, to GC. We gratefully acknowledge Prof. Kenneth Hugdahl, Department of Biological and Medical Psychology, University of Bergen, Norway, and Division of Psychiatry, Haukeland University Hospital, Bergen, Norway, for his support and critical reading.

Disclosure The authors do not report any conflict of interest concerning materials or methods used in this study or the findings identified in this paper.

References

1. Marosi C, Hassler M, Roessler K, Reni M, Sant M, Mazza E, Vecht C (2008) Meningioma. Crit Rev Oncol Hematol 67:153–171
2. Rushing EJ, Olsen C, Mena H, Rueda ME, Lee YS, Keating RF, Packer RJ, Santi M (2005) Central nervous system meningiomas in the first two decades of life: a clinicopathological analysis of 87 patients. J Neurosurg 103:489–495
3. Gupta R, Suri V, Jain A, Sharma MC, Sarkar C, Singh MM, Joshi NP, Puri T, Julka PK (2009) Anaplastic meningioma in an adolescent: a report of a rare case and brief review of literature. Childs Nerv Syst 25:241–245
4. Hugdahl K, Carlsson G, Uvebrant P, Lundervold AJ (1997) Dichotic-listening performance and intracarotid injections of amobarbital in children and adolescents. Preoperative and postoperative comparisons. Arch Neurol 54:1494–1500
5. Posner MI, Petersen SE (1990) The attention system of the human brain. Annu Rev Neurosci 13:25–42
6. Fan J, McCandliss BD, Fossella J, Flombaum JI, Posner MI (2005) The activation of attentional networks. Neuroimage 26:471–479
7. Hugdahl K, Westerhausen R, Alho K, Medvedev S, Laine M, Hamalainen H (2009) Attention and cognitive control: unfolding the dichotic listening story. Scand J Psychol 50:11–22
8. Cattell RB, Weiss HR, Osterland J (1997) CFT1—Grundintelligenztest Skala 1. Testzentrale, Göttingen
9. Trites RL (1977) Neuropsychological test manual. Technolab, Montreal
10. Beery KE (1989) The VMI-developmental test of visual-motor integration. Modern Curriculum Press, Cleveland, OH

11. Kimura D (1961) Some effects of temporal-lobe damage on auditory perception. Can J Psychol 15:156–165
12. Niccum N, Speaks C (1991) Interpretation of outcome on dichotic listening tests following stroke. J Clin Exp Neuropsychol 13:614–628
13. Hugdahl K, Andersson L (1986) The "forced-attention paradigm" in dichotic listening to CV-syllables: a comparison between adults and children. Cortex 22:417–432
14. Hugdahl K, Bodner T, Weiss E, Benke T (2003) Dichotic listening performance and frontal lobe function. Cogn Brain Res 16:58–65
15. Wechsler D (1999) WISC-III: Wechsler intelligence scale for children. Huber, Göttingen
16. Carlsson G (1997) Memory for words and drawings in children with hemiplegic cerebral palsy. Scand J Psychol 38:265–273
17. Rugland AL (1990) Neuropsychological assessment of cognitive functioning in children with epilepsy. Epilepsia 31(Suppl 4):S41–S44
18. Carlsson G, Hugdahl K, Uvebrant P, Wiklund LM, von Wendt L (1992) Pathological left-handedness revisited: dichotic listening in children with left vs right congenital hemiplegia. Neuropsychologia 30:471–481
19. Hugdahl K, Carlsson G (1996) Dichotic listening performance in a monozygotic twin pair with left- and right-sided hemiplegia. Neurocase 2:141–147
20. Rypma B, Berger JS, D'Esposito M (2002) The influence of working-memory demand and subject performance on prefrontal cortical activity. J Cogn Neurosci 14:721–731
21. Anderson V, Jacobs R, Harvey AS (2005) Prefrontal lesions and attentional skills in childhood. J Int Neuropsychol Soc 11:817–831
22. Godefroy O (2003) Frontal syndrome and disorders of executive functions. J Neurol 250:1–6
23. Desmurget M, Bonnetblanc F, Duffau H (2007) Contrasting acute and slow-growing lesions: a new door to brain plasticity. Brain 130:898–914
24. Tulving E, Kapur S, Markowitsch HJ, Craik FI, Habib R, Houle S (1994) Neuroanatomical correlates of retrieval in episodic memory: auditory sentence recognition. Proc Natl Acad Sci U S A 91:2012–2015
25. Deutsch G, Papanicolaou AC, Bourbon WT, Eisenberg HM (1987) Cerebral blood flow evidence of right frontal activation in attention demanding tasks. Int J Neurosci 36:23–28
26. Posner MI (1994) Attention: the mechanisms of consciousness. Proc Natl Acad Sci U S A 91:7398–7403
27. Arruda JE, Walker KA, Weiler MD, Valentino DA (1999) Validation of a right hemisphere vigilance system as measured by principal component and factor analyzed quantitative electroencephalogram. Int J Psychophysiol 32:119–128
28. Briere ME, Scott JG, Nall-Knapp RY, Adams RL (2008) Cognitive outcome in pediatric brain tumor survivors: delayed attention deficit at long-term follow-up. Pediatr Blood Cancer 50:337–340