Attention, mental speed and executive control after closed head injury
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Summary

This thesis concerns deficits of attention after a moderate to severe closed head injury. A closed head injury is the result of a sudden violent contact with a blunt surface, which leaves the skull intact but damages the brain. The severity of the injury is mainly indicated by the duration of disturbances in consciousness, the period of coma, followed by a period of PTA. In this study a group of sixty patients was investigated with a moderate to severe CHI, with PTA durations varying from 1 to 60 days. Their performance on several tests and tasks tapping attention, speed of information processing and executive functioning was compared to the performance of a matched group of healthy controls. In addition, recovery over time and final outcome were investigated. Also, more fundamental issues concerning concepts and measurement of attention were studied.

Chapter one provides a short introduction to relevant aspects of closed head injury (CHI). Firstly, definitions, some epidemiological data and major causes are mentioned. Pathophysiology and short term sequelae concerning impairments of consciousness and memory are described. This is followed by a description of the long term consequences with respect to cognitive impairments, emotional and psychosocial sequelae. Finally, an outline of the present study is provided and the main topics of this thesis are highlighted.

Chapter two is a theoretical chapter concerning attention, speed of information processing and executive functions. Main theories of attention are described in the light of the information processing approach. Especially the distinction between automatic and controlled processing of information is considered important. This leads to a more elaborate description of control of attention and its assumed connection to the frontal anatomical system. The chapter is concluded with some critical remarks concerning measurement of attention and executive functioning.

In chapter three the question whether there are deficits of attention in the subacute stage is addressed. The performance was studied of a group of 60 severely injured patients with CHI in the subacute stage of recovery (i.e. one month post injury) on a series of tests addressing focused, divided and sustained attention, and supervisory attentional control. The patients test performance was compared to that of a group of 60 healthy controls, matched on age, educational/vocational level and sex distribution. The tests were the following: the Stroop Color Word Test (Word, Color and Color Word), the PASAT (five conditions with ISI's of 3.2, 2.8, 2.4, 2.0 and 1.6s respectively), the Visual Reaction Time Task (Four Choice, Four choice with Distraction, Auditory Visual Dual task and Auditory single task), the Trailmaking test (parts A and B). Two variables indicating supervisory control were derived from other tests: the Lack of Consistency Score (15 Words test), and the Relative Perseveration Error Score (Modified Card Sorting test).
Patients performed significantly worse on each test with time pressure (those addressing focused and divided attention), indicating basic slowness of information processing, and on the self-paced tasks for supervisory attentional control. No indication was found for a sustained attention deficit, because intra-individual variability did not increase during the whole RT block of about 20 minutes.

In a subsequent analysis the influence of the demonstrated slowness of information processing and other possibly confounding cognitive factors was controlled for by means of covariance analyses. This resulted in a disappearance of group differences on tests for focused and divided attention. The only difference that remained concerned the Relative Perseveration Error Score, suggesting that supervisory attentional control is impaired in the subacute stage. However, there appear to be no specific deficits of focused, divided and sustained attention in patients with subacute CHI, other than basic slowness of information processing.

In chapter four the construct validity was examined of three aspects of attention, namely focused, divided and supervisory control of attention. Factor-analytic techniques were applied to the scores of healthy subjects on a series of neuropsychological tests tapping these aspects of attention. The two components were not found to match the hypothesized aspects and were labelled as Memory-driven Action and Stimulus-driven Reaction. A second question to be answered was whether the same components could be found in a group of patients with CHI. The analyses showed that the pattern of attentional functions found in healthy subjects had changed qualitatively in patients with CHI. A possible explanation for this result was given in terms of a shift from automatic to controlled processing in the patient group, due to their basic slowness of information processing.

In chapter five recovery of attention was examined during the first year post injury. The same patient group was assessed repeatedly with the earlier described series of attention tests. A matched group of healthy subjects was tested at the same intervals to allow to control for practice effects. The results of a multilevel analysis for longitudinal data show retest effects in all but one of the tests. Patients performed worse on all tests, but their results on each test appeared to show recovery over time. The indicator of recovery was an improvement in test performance that was greater than the retest effect shown by the controls. On most tests, the performance of the more severely injured patients was initially worse, but showed improvement over time. Test results differed with respect to changes over time, sensitivity to severity of injury, and subject specific characteristics like age and vocational level. Recovery rate was not related to age or vocational status. Despite this improvement, the patient group was still impaired 1 year post trauma on all tests sensitive to mental slowness. Outcome after 1 year, scored on a modified Glasgow Outcome Scale (the DOS), was predicted to a small extent by PTA duration and initial performance on the RT-Distraction task.

Chapter six aims to determine the locus of slowness in information processing, and the extent to which this is reflected in neuropsychological tests.
The same series of attention tests was administered to a group of 44 closed head injured patients one year posttrauma. Compared to a group of healthy controls, patients performed worse on most tests involving time pressure. Event related potentials (N2 and P3) were measured by means of an auditory ‘oddball paradigm’. These potentials indicate the early stages in information processing, namely stimulus evaluation preceding response selection and execution. Patients had significantly longer ERP latencies than healthy controls. ERP latencies were correlated with test performances and with PTA duration. PTA duration correlated significantly with P3, indicating that P3 latency is slowed in proportion to severity of injury. PTA correlated also significantly with most attention testscores, namely the Stroop scores, the PASAT, and Trailmaking Test part A. However, of the attention tests, only the scores on the Word, Color and Color-Word subtasks of the Stroop test showed a significant correlation with both ERPs. In a series of multiple regression analyses, the Stroop scores were predicted by PTA, N2 and P3. P3 latency appeared to be the best predictor in the Stroop Color subtask only. A possible explanation for this finding is that stimulus evaluation processes comprise a relatively large part of performance on this subtest. In the Stroop Color Word subtest, response related processes are supposed to determine performance to a great extent, decreasing the role of early, input related processes. The lack of significant correlations between P3 latency and the other attention tests was conceived as an indication of the relatively small role of stimulus evaluation processes in these tasks. This does not imply that these processes are not slowed in CHI, but only that the tasks used are not sensitive enough to this slowness. The Stroop test appears to be the only attention test in which perceptual slowness contributes significantly to the delay in final performance on the task.

In chapter seven the presence and nature of dysexecutive problems after CHI were studied. A series of unstructured tasks tapping executive functioning were selected. These were administered to a group of 51 CHI subjects in the chronic stage (i.e. several years post-injury) and to 45 healthy controls. These groups were part of the previously described groups. In addition the structured tests of attention and planning were administered again. Of the executive tasks, only the Executive Route Finding task showed a significant difference between both groups. A multivariate analysis on the attention tests showed a significant difference between groups, indicating that patients in the chronic stage still process information slower than controls. Within the patient group, patients with and without frontal focal lesions were compared on executive and attention tests. No differences were found with respect to the latter. However, patients with frontal lesions performed worse on a measure of the Executive Route Finding task. It is concluded that patients with CHI, especially when they have frontal damage, have to rely more heavily on externally provided cues, but this dysexecutive problem can only be demonstrated in tasks that resemble daily life tasks by providing very little structure.

In chapter eight recovery was investigated in the same group of 51 patients with a moderate to severe CHI 2 to 5 years posttrauma. Different outcome measures were applied, all based on self report. The measures covered social reintegration, quality of life and return to work. More than half of these patients reported full recovery on all
measures. The various measures correlated significantly with each other, and also with outcome measured with the DOS 1 year posttrauma, but not with PTA duration. An index in which recovery was subjectively expressed in percentage was considered a valid outcome measure, since it had the highest correlations with the other measures. Regression analyses, attempting to predict recovery on the basis of injury-related variables, biographical variables, cognitive performance on tests of attention and executive functioning, yielded no significant results. The lack of results was explained by a lack of awareness of deficit in a part of the patient group, namely severely injured subjects with focal frontal lesions. In objective terms these patients were not recovered as well as what their self-reports suggested. This conclusion was supported by t-tests between the frontal and the non frontal group: the frontal group showed the same or even better scores on the outcome measures, while being more severely injured and performing worse on a test of executive functioning.

**In chapter nine** the results of the various studies described in this thesis are discussed and general conclusions are drawn. Specific topics are the relationship between attentional deficits and speed of information processing, or, put differently, the relationship between task performance and underlying cognitive processes. It is highlighted to which extent deficits recover and which long term sequelae are found in this patient group. It can be concluded from our findings that on the long term patients on average still exhibit slower information processing and minor executive problems. The influence of patient characteristics on test performance is discussed. The possibility of predicting recovery in terms of daily life functioning from test results is critically evaluated. With respect to the theoretical questions, the results show that two components determine performance on attention tests, namely speed and control. Subsequently, it is argued that the amount of structure a task offers determines the extent to which attentional control or executive functioning is required. Finally, the implications of these findings for cognitive rehabilitation are considered.