

Memory Disorders as a Function of Traumatic Brain Injury

Word Completion, Recall of Words and Actions

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Abstract. The memory performance of a group with traumatic brain injury and a matched control group was measured using the following methods: (a) word completion, (b) immediate free, final free and final forced recall of words and (c) immediate free and final free recall of subject-performed tasks (SPTs) and SPTs without motor action (SPTs-WA). The brain-injured (BI) group was significantly inferior in all the recall tests except immediate free recall of words. No difference was revealed in the word completion test. The BI group performed less well than the controls, which was presented either within (final recall) or without (word recall) time. The results were discussed in terms of the neuropsychological background of the patients in the BI group suggesting that frontal dysfunction could play a critical role. When comparing the tests within the BI group, the performance was better when cues were present and especially so for long-term memory. Motor activity also facilitated long-term memory. Finally, an attempt was made to specify conditions for guidance in the construction of training programmes.

The present study focussed on a group of traumatic brain-injured patients since memory disorders are common after traumatic brain injury. Seventy-five percent of the patients treated at the Department of Rehabilitation and Rehabilitation 1976-1982 had that diagnosis had some kind of memory problems. The purpose of the present study was to make a more detailed study to find out the cause of their memory problem.

Our theoretical basis is a theory proposed by Nilsson (12), which is made as a function of the interaction between certain demands of the task and the cognitive capacities of the individual.

The individual is assumed to recall correctly if, at the time of encoding, the construction of a code is unique in relation to other coded information. This unique code must be properly reconstructed at the time of retrieval, or the consequence will be an imperfect memory performance.

It may be assumed that patients with different kinds of brain injuries have problem with this construction/reconstruction. Due to the brain injury, the individuals cannot use all their cognitive capacities but if the demands of the task are changed, the patients stand a good chance of using intact but inactive cognitive capacities. The memory disorders can thus be reduced or even eliminated (12, 13).

One experimental paradigm used in the present study was introduced by Cohen (5) and labelled subject-performed tasks (SPTs). An SPT is an action carried out by the subject after the presentation of a short imperative. According to Bäckman & Nilsson (4), SPTs have some unique features that distinguish them from verbal materials: Multimodality and richness of aspects within each modality due to the "real-life" nature of the stimuli. It provokes discrimination and analysis in terms of colour, shape and texture as well as a motor, olfactory, gustatory and auditory encoding. Further, a variation of the SPTs was also used, introduced by Bäckman (3): SPTs without motor action (SPTs-WA). The short imperative is presented and the subject is (are) visible but no motor action is carried out.

Studies of old and young adults (3, 4) and children (7) revealed no age differences in immediate free recall (IFR) or final free recall (FNR, after 10 min) of SPTs. In recall of words, however, age differences were obtained. In a study of educable mentally retarded (6), the same result in IFR of SPTs was attained, but in FNR the retarded adults were inferior. A deterioration in performance was observed for old adults when SPTs-WA were used (3). Therefore, it was expected that the brain-injured (BI) group in this study should be inferior to
Table 1. Computed tomographic (CT) brain scan and surgery carried out on 12 subjects with brain injury

<table>
<thead>
<tr>
<th>Pa- Patient</th>
<th>CT brain scan</th>
<th>Surgery (removal of haematoma)</th>
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<tbody>
<tr>
<td>1</td>
<td>Bilateral frontal epidural haematoma</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Bilateral subdural and bilateral fronto-temporal haematoma</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Left frontal lobe low attenuation</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Bilateral subdural and bilateral frontal lobe haemorrhage</td>
<td>Yes</td>
</tr>
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<td>5</td>
<td>Left frontal lobe low attenuation</td>
<td>Yes</td>
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<td>6</td>
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<td>10</td>
<td>Left frontal intracerebral haemorrhage</td>
<td>Yes</td>
</tr>
<tr>
<td>11</td>
<td>Right hemisphere haemorrhage including the frontal lobe</td>
<td>Yes</td>
</tr>
<tr>
<td>12</td>
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the control group in recall of words and SPTs-WA, but not for SPTs. The expectation in FFR of SPTs was based on the fact that both old adults and brain-injured patients, but not the retarded adults, had a "normal" memory that was subsequently impaired.

The correct completion and cued recall of words constituted two other tasks used. One type of these tasks was employed by Graf et al. (9) when assessing amnesic patients’ memory performance: Data showed that amnesic patients suffered in cued recall but not in word completion. In a cued recall test subjects can rely on additional information about a previously presented word: Information that is not available to amnesic patients. Word completion, however, is explained in terms of a process of activation which increases availability of the to-be-completed word. This word is not previously presented. The process of activation is considered to be spared in amnesia (9). On the basis of these results, it was expected that the BI group should be inferior in the cued recall task, but not in word completion.

EXPERIMENT 1

Method

Subjects. Twelve subjects with a brain injury caused by trauma and twelve matched (age, sex, education) controls, clinically healthy with no known history of brain injury or disease, participated voluntarily in the experiment. The average age was 32 years (range 21-63). Each group consisted of ten men and two women. The subjects in the BI group had sustained the injury 6-24 months prior to the experiment.

In all cases computed tomography revealed traumatic post-traumatic changes in the brain. It is, however, well known that the extent of traumatic brain injury cannot be gauged solely from X-ray examinations (1, 9).

None of the subjects had aphasia, according to Retra- wang (15). Two had visual perceptual disorders and two had remaining motor deficits, but none of these disorders had any effect on performance. At the time of the investi- gation, five had a good recovery, six were moderately disabled and one severely disabled, according to the original Glasgow Outcome Scale (10).

This study did not include systematic observation of the functional and formal status during the early phases after the trauma, and was thus not designed as a study of prognostic significance.

Stimulus-material. Word completion: Ten common Swedish nouns were used. Two or three letters of each word were left out but the initial letter was always pres- ent. Word-length varied between seven and eight letters. Only one correct answer was possible in the reconstruction of each word.

Procedure. The subjects were informed that the completion was to be done orally. The words were presented one by one, written on a piece of paper. Completion-time was maximized to 30 sec/word. Before the test, the sub- jects were given some words to practice on.

Design. This experiment was thus constituted by a one-variable between-groups design.

Results

Number of correctly completed words: Mean for BI-group, 5.9 and for control group, 6.6. As expect- ed, indicated by a t-test (p<0.05), there was no significant difference between the groups.

EXPERIMENT 2

Method

Subjects. The same twenty-four subjects, described in Experiment 1, participated.

Stimulus-material. Ninety-six common Swedish nouns were used, each consisting of five to eight letters. The word set was classified by fours into twenty-four semantic categories, which were randomly assigned to eight lists. The order of the twelve words in each list was then randomized with the restriction that no more than two consecutive words from the same category was allowed. The list order was identical for all subjects. The categories were also randomly assigned to three columns on a paper used in the cued recall task.

Procedure. The recall tasks were performed in this order: 1) Immediate free recall (IFR) of words, 2) Final free recall (FFR) of words, after a 10 min delay and 3) Final cued recall (FCR) of words, after another 10 min. In part one, the subjects were instructed that they were to listen to lists of words. Mention was made of the FFR after each list, but not so for the FFR and FCR. Before the test, they were given a practice list. A tape-recorder was used for list presentation and the presentation rate was one word/1.5 sec. Each list ended with a loud knock-sound followed by a 30 sec silence when the subjects were to free recall the words orally. This procedure was repeated for all eight lists.

In parts two and three, the task was to orally recall as many words as possible presented in part one. In the final cued recall task, part three, the paper with the typed words and semantic category labels was utilized and the subjects were to use the categories as cues for recall. The subjects were encouraged to include the practice words. The time allowed for the FFR and CR was maximized to five min- utes.

Design. This experiment was constituted by a general one-variable between-groups design.

Results

With respect to scoring the plural was allowed as a correct answer. Data for the recall of words are presented in Fig. 1. It is apparent from Fig. 1 that there was a main effect of type of test. Both groups performed at their best in FFR and worst in FCR with the performance in FCR falling in between. The improvement of the BI-group in FCR com- pared to FFR was especially interesting and it was statistically significant, (t=2.2, p<0.05).

The expectation that there should be a difference between the groups in FRR was confirmed (p<0.05). In FFR and CR, however, as expected, the control group performed better than the BI- group, (t=1.76, p<0.05) and (t=2.11, p<0.05, respectively). A more liberal, one-tailed t-test was used for the experiment.
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Stimulus-material. Word completion: Ten common Swedish nouns were used. Two or three letters of each word were left out but the initial letter was always present. Word-length varied between seven and eight letters. Only one correct answer was possible in the reconstruction of each word.

Procedure. The subjects were informed that the completion was to be done orally. The words were presented one by one, written on a piece of paper. Completion-time was maximized to 60 sec/word. Before the test, the subjects were given some words to practice on.

Design. This experiment was thus constituted by a one-variable between-groups design.

Results

Number of correctly completed words: Mean for BI-group, 5.9, and for control group, 6.6. As expected, indicated by a t-test (p<0.05), there was no significant difference between the groups.

EXPERIMENT 3

Method

Subjects. The same twenty-four subjects, described in Experiment 1, participated.

Stimulus-material. Ninety-six common Swedish nouns were used, each consisting of five to eight letters. The words could be classified by fours into twenty-four semantic categories, which were randomly assigned to eight lists. The order of the twelve words in each list was then randomized with the restriction that no more than two consecutive words from the same category was allowed. The list order was identical for all subjects. The categories were also randomly assigned to three columns on a paper used in the cued recall task.

Procedure. The recall tasks were performed in this order: (a) Immediate free recall (IFR) of words, 2) Final free recall (FFR) of words, after a 10 min delay and 3) Final cued recall (FCR) of words, after another 10 min. In part one, the subjects were instructed that they were to listen to lists of words. Mention was made of the FFR after each list, but not so for the FFR and FCR. Before the test, they were given a practice list. A tape-recorder was used for list presentation and the presentation rate was one word/2 sec. Each list ended with a loud knock-sound followed by a 30 sec silence when the subjects were to free recall the words orally. This procedure was repeated for all eight lists.

In parts two and three, the task was to orally recall as many words as possible presented in part one. In the final cued recall test, part three, the paper with the typed and semantic category labels was utilized and the subjects were to use the categories as cues for recall. The subjects were encouraged to include the practice words. The time allowed for the FFR and CR was randomized to five minutes.

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Results

With respect to scoring the plural was allowed as a correct answer. Data for the recall of words are presented in Fig. 1. It is apparent from Fig. 1 that there was a main effect of type of test. Both groups performed at their best in FFR and worst in FCR with the performance in FCR falling in between. The improvement of the BI-group in FCR compared to FFR was especially interesting and it was statistically significant, (t22)=2.20, p<0.05.

The expectation that there should be a difference between the groups in FFR was confirmed (p<0.05). In FFR and CR, however, as expected, the control group performed better than the BI-group, (t22)=1.76, p<0.05 and (t22)=2.11, p<0.05, respectively. A more liberal, one-tailed t-test was used for the experiment.
2x12+2 split-plot ANOVA (analysis of variance) with the factors referring to groups, subjects and condition. For immediate free recall, the ANOVA revealed significant main effects of group, F(1, 22)=7.50, p<0.05, MSₑ=42.02 and conditions, F(1, 21)=5.21, p<0.05, MSₑ=7.38. The interaction was not statistically significant. For final free recall, significant main effects of group, F(1, 22)=6.29, p<0.05, MSₑ=42.24 and condition, F(1, 22)=16.46, p<0.05, MSₑ=6.38 were once again obtained. The interaction was not statistically significant.

It should be noted that there was a difference between the groups in SPTs-WA, as expected, but even so in SPTs, which was not expected. Nevertheless, the BI-group increased their level of performance for SPTs compared to SPTs-WA, implying that they did benefit from the extra information provided by the motor activity.

DISCUSSION
No difference was obtained between the groups in the word completion test. This result is in line with studies of amnesic patients using similar tasks (9, 16). Data from the other two experiments revealed an inferior level of performance for the BI-group in all recall test, except in EPR of words. Concerning recall of words the results are in good agreement with an investigation of severely head-injured patients by Brooks (2). In this study the head-injured patients were on a par with the controls in immediate

free recall but significantly inferior in delayed free recall. The most interesting part in recall of words is, however, the increasing difference between the groups in cued recall compared to free recall; a difference of the same magnitude as in recall of SPTs and SPTs-WA. The BI-group was, accordingly, relatively less helped by cues, either when they were presented at retrieval as in FCR of words or when they were built-in in the stimulus-material and present already at the time of encoding as in SPTs and SPTs-WA.

However, the performance of the BI-group compared with the control group was worse than expected for SPTs. Recall of SPTs has been consid- ered to be insensitive to differences in age and IQ (1, 4, 6, 7). We can only speculate in the neurologi- pathological background as to the fact that the BI-group performed worse on recall of SPTs than old clinically healthy subjects and edible mentally retarded. We are well aware that the diffuse, non X-ray verifiable effects of cerebral trauma, e.g. shearing/stretching of nerve fibers, might be one explanation of the disorder. However, another speculative explanation might be disclosed by the relatively pronounced frontal brain damage in the brain-injured subjects (see Table I). This explanation is reinforced by the fact that the only patient (no. 7) whose X-ray did not explicitly show frontal damage exhibited a dissociation for IFR of words. He was the only patient who did not show a recency effect, that is, words at the end of the list were not recalled better than those in the beginning or in the middle (cf. Brooks (2) and Parker & Serrats (14)).

According to Luria (11), frontally damaged pa- tients cannot form a stable and active intention to memorize and cannot by themselves find ways of assisting the memorizing. In the more severe cases, the patients do not use aids suggested to them particularly effective (e.g. semantic category cues). Many also exhibit instability of attention and at- tempts to induce stable voluntary attention with the aid of spoken instructions often prove ineffective (16).

On this hypothesis, the multimorality and rich- ness of aspects in the SPTs, that were assumed to give additional information to the BI-group, also caused disturbances at the time of encoding and the effect was therefore reduced. This disturbance at encoding implies that patients with frontal dysfunction cannot select the most relevant features of the presented stimuli. In recall of words, only one mo- dality—the auditory—was used. The patients in the BI-group thus became less disturbed and the per- formance in IFR consequently equals that of the control group.

When comparing the texts within the BI-group, the level of performance was higher in SPTs than SPTs-WA, implying a great importance of motor action. Performance in FPR of SPTs was also better than for words, 0.30 and 0.12 respectively, while it was approximately the same in FFR of SPTs-WA and FCR of words, 0.21 and 0.22, respectively. Thus, to accomplish better long-term memory ef- fects for the BI-group, additional information is needed preferably, in terms of motor activity.

CLINICAL IMPLICATIONS
In the following an attempt is made to specify some conditions, which for instance the occupational therapist has to take into account when construct- ing training programmes for patients with traumatic brain injury: a) Cued recall improves performance compared to free recall. Patients may be trained with material that is structured in advance or they may be taught to impose the structure themselves. If possible, direct the attention of the patient to the structure already at the time of encoding. At re- trieval, offer cues that are compatible with the im- pressed structure and compatible in this sense, memory performance may be promoted. b) SPTs give better long-term memory effects owing to the motor action involved. SPTs may also be combined with cues. Structure the actions accord- ing to e.g. the objects used (tools used in a kitchen, by a carpenter etc). In analogy with (a) retrieval may be optimized. (c) To the extent that the patient is unimpaired in tasks like word completion this is a hint that the prelearned knowledge of the patient is available. Make thorough interviews with the pa- tient and his/her relatives to find out what strategies and reminiscences he/she used before the trauma in order to improve the construction and enhance the efficiency of the training program.

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We thank Ate R. Fugl-Meyer and Lars Bäckman for constructive suggestions for improvement on this manu- script.

REFERENCES

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Fig. 2. Recall of SPTs and SPTs-WA for brain-injured group and control group.

2×2×2 split-plot ANOVA (analysis of variance) with the factors referring to groups, subjects and condition. For immediate free recall, the ANOVA revealed significant main effects of group, F (1, 22)=7.50, p<.01, MSW=.42.02 and conditions, F (1, 22)=5.21, p<.05, MSW=.73. The interaction was not statistically significant. For final free recall, significant main effects of group, F (1, 22)=6.29, p<.05, MSW=.42.24 and condition, F (1, 22)=16.46, p<.005, MSW=.63.8 were once again obtained. The interaction was not statistically significant.

It should be noted that there was a difference between the groups in SPTs-WA, as expected, but even so in SPTs, which was not expected. Nevertheless, the BI-group increased their level of performance for SPTs compared to SPTs-WA, implying that they did benefit from the extra information provided by the motor activity.

DISCUSSION
No difference was obtained between the groups in the word completion test. This result is in line with studies of amnesic patients using similar tasks (9, 16). Data from the other two experiments revealed an inferior level of performance for the BI-group in all recall test, except in FPR of words. Concerning recall of words the results are in good agreement with an investigation of severely head-injured patients by Brooks (2). In this study the head-injured patients were on a par with the controls in immediate free recall but significantly inferior in delayed free recall. The most interesting part in recall of words is, however, the increasing difference between the groups in cued recall compared to free recall; a difference of the same magnitude as in recall of SPTs and SPTs-WA. The BI-group was, accordingly, relatively less helped by cues, either when they were presented at retrieval as in FCR of words or when they were built-in in the stimulus-material and present already at the time of encoding as in SPTs and SPTs-WA.

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LEISURE TIME PHYSICAL ACTIVITIES AND THE RESULTS OF SURGERY OF LUMBAR DISC HERNIATION

Hannu Alaranta,1 Matti Hurme2 and Sirrika-Liisa Karppi3

The Rehabilitation Research Centre of the Social Insurance Institution, Turku, Finland and
the Turku City Hospital, Turku, Finland

ABSTRACT: The aim of this study was to elucidate the consequences of leisure time physical activities on the one-year results of surgery of lumbar intervertebral disc herniation. Pre-operative leisure time physical activities and severity of occupation handicap were analyzed from 212 patients. Only to a certain degree the findings support the claim that high preoperative level of physical activities during leisure time is linked with good postoperative results.

Key words: intervertebral disc displacement, leisure time, lumbar region, physical activity, prognosis, surgery

Studies from many industrialized countries reveal an increasing incidence and prevalence of low back pain (2, 5). A physically active life style is generally recommended to prevent low back pain (10, 11). Some scientific reports of prospective studies support the above recommendations (3, 7, 14, 15, 17, 18). For example, in a prospective study of 1652 firefighters Cody et al. (3) demonstrated that an increasing level of fitness gives a graded and significant protective effect against low back pain. However, the relations of leisure time physical activities and low back pain are not always clear (4, 12, 20).

The present study was a part of a larger prospective project of the Rehabilitation Research Centre of the Social Insurance Institution, the Turku University Central Hospital and the Turku City Hospital. The aim of the whole project was to examine the rehabilitation process with one-year follow-up of patients operated on for lumbar disc herniation (1, 6). The study was carried out between May 1980 and October 1983. The particular purpose of this report was to elucidate the consequences of leisure time physical activities on the result of surgery for lumbar intervertebral disc herniation.

MATERIAL AND METHODS
The patients selected had had no previous spinal surgery, were under 55 years of age, had not yet retired and resided within the district of the Turku University Central Hospital. A total of 220 consecutive patients fulfilled the above criteria and were operated on for lumbar disc herniation. The operative finding was extrusion in 17%, prolapse in 65% and protrusion of the intervertebral disc in 18% of the 220 cases. Eight of the cases failed to attend the one-year postoperative evaluation. The final study group of 212 patients (mean age 39.3 yrs, range 16-54) included 101 females and 111 males.

The team of a physician, surgeon, social worker and a psychologist evaluated each patient’s occupation handicap using the modified WHO scales (1, 19).

The preoperative handicap was estimated according to the medical history of patients based on both an interview and medical records. It was estimated for the time preceding the acute sciatica attack leading to operation. On the average, the acute preoperative sciatica period had lasted for three months. The postoperative handicap was defined according to a clinical examination and the interviews. It was defined for the period of one year after surgery.

Pre- and postoperatively the patients completed a questionnaire concerning, among other things, their leisure time physical activities. The activities were graded in three classes: 1) low: passive in leisure time physical activities; 2) moderate: no regular hobby of leisure time physical activities but otherwise physically active: gardening, picking berries, repairing furniture, hunting, etc.; and 3) high: regular hobby of leisure time physical activities: jogging, swimming, cycling, skiing, swimming etc.

Questions on preoperative leisure time physical activities were concerned with the time preceding the acute sciatica attack leading to operation. Postoperative leisure time physical activities were inquired about one year after surgery.

RESULTS
Table 1 shows the results of all patients (n=212) operated on for lumbar disc herniation, expressed as changes in the severity of pre- and postoperative occupation handicap.

The preoperative leisure time physical activities were low in 19%, moderate in 57% and high in 24%. The corresponding postoperative rates were 28% low, 53% moderate and 19% high activity.

For further analysis the occupation handicap was...