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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 assessed using the following methods (*a*) word completion, (*b*) immediate free, final free and final cued 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 relative to the control group in all recall tests except immediate free recall of words. No difference was revealed in the word completion test. The BI-group benefitted less by cues presented either at *retrieval* (final cued recall of words) or at the time of *encoding* already built-in in the stimulus (SPTs and SPTs-WA). The results were discussed in terms of the neuropathological 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, however, 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.

Key words: traumatic brain injury, memory, recall of words and actions.

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 Physical Medicine and Rehabilitation 1976–1982 with that diagnosis had some kind of memory disorder—the most frequent problem. The purpose of this study was to make a more detailed study to find out the fate of their memory problem.

Our theoretical basis is a theory proposed by Nilsson (12, 13) where memory is seen as a *function* of the interaction between certain demands of the task and the cognitive capabilities 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 capabilities but if the demands of the task are changed, the patients stand a good chance of using intact but inactive cognitive capabilities. The memory disorders can thus be reduced or even eliminated (12, 13).

One exerimental 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. This 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 object(s) 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 (FFR, 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 FFR 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 I. *Computed tomographic (CT) brain scan and surgery carried out on 12 subjects with brain injury*

Patient	CT brain scan	Surgery (removal of haematoma)
1	Bilateral frontal epidural haematoma	Yes
2	Bilateral frontal lobe hygroma	
3	Left frontal lobe low attenuation	
4	Left frontal subdural haematoma and bilateral frontal lobe hygroma	
5	Left frontal lobe low attenuation	
6	Right frontal epidural haematoma	Yes
7	Left temporal epidural haematoma	Yes
8	General brain oedema	
9	Right frontotemporal epidural haematoma	Yes
10	Left frontal intracerebral haemorrhage	
11	Right hemisphere haemorrhage including the frontal lobe	
12	Left frontal lobe low attenuation and right parietal intracerebral haemorrhage	

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, have had a "normal" memory that was subsequently impaired.

Word completion and cued recall of words constituted two other tasks used. One type of these tasks were 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 computerized tomography revealed traumatic/posttraumatic 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, 8).

None of the subjects had aphasia, according to Reinvang (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 investigation, 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 clinical and functional 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 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 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 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: 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 IFR after each list, but not so for the FFR and FCR. Before the test,

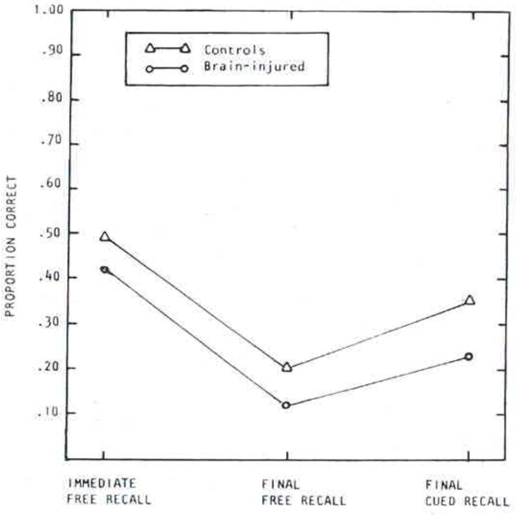

Fig. 1. Recall of words for brain-injured group and control group.

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 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 minutes.

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 IFR and worst in FFR 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, $t(22)=2.20$, $p<0.05$.

The expectation that there should be a difference between the groups in IFR was disconfirmed ($p>0.05$). In FFR and CR, however, as expected, the control group performed better than the BI-group, $t(22)=1.76$, $p<0.05$ and $t(22)=2.11$, $p<0.05$, respectively. A more liberal, one-tailed *t*-test was used for the FFR.

Thus, the results imply an increasing difference between the groups from the final free recall test to the final cued. However, the BI-group was helped by cues but not to the same extent as the control group.

EXPERIMENT 3

Method

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

Stimulus-material. Four lists with sixteen short imperatives were used. The imperatives were randomly assigned to the lists. All tasks required the use of one or two objects. Two different conditions were employed: 1) The subjects performed the tasks after the presentation of the imperative (SPTs), 2) no action was required but the object(s) was/were visible while the imperative was presented (SPTs-WA).

The conditions were randomly assigned to the four lists with the restriction that a particular condition always had to change from one list to another. Half of the subjects received one order of presentation while it was reversed for the other half. (For an example of a list, see appendix A.)

Procedure. The tests were carried out in the following order: 1) IFR of SPTs and SPTs-WA and 2) FFR of SPTs and SPTs-WA. The subjects were instructed that short imperatives would be presented and that the conditions listed above would change from one list to another. Attention was drawn to the IFR after each list, but no mention was made of the FFR. Practice lists were administered before the actual experiment started. The presentation rate was one task/10 sec. The end of each list was indicated by the experimenter as he made a visible start of a stop-watch simultaneously with a verbal command to free recall the imperatives orally. The time for IFR was maximized to 160 sec. This procedure was repeated for all four lists.

Following the recall of the fourth list, the subject was engaged in conversation with the experimenter for ten minutes after which the subjects were given ten minutes to finally recall as many imperatives as possible from all four lists. The subjects were encouraged to include the practice lists.

Design. This experiment employed a general 2×2 mixed design with the factors referring to group and condition. The first factor varied between subjects and the second within subjects.

Results

With respect to scoring the answers were considered correct only when both the action and the object was recalled accurately. Data for the recall of SPTs and SPTs-WA are presented in Fig. 2. The data show a superiority for the control group in IFR and FFR for both conditions. Looking specifically at the BI-group, however, the performance for SPTs was generally better than for SPTs-WA.

These data were evaluated by means of a

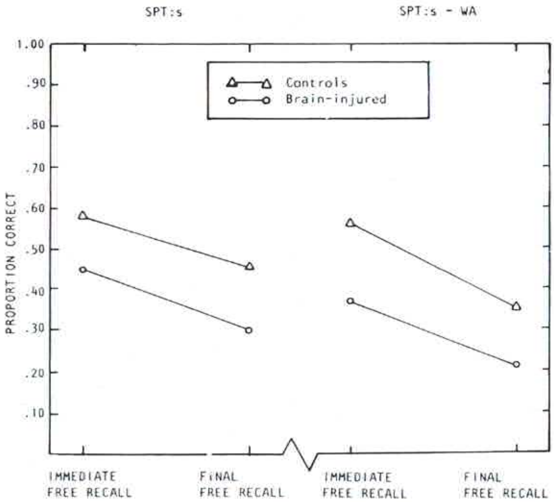

Fig. 2. Recall of SPTs and SPTs-WA for brain-injured group and control group.

2×12×2 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, $p<0.05$, $MS_e=42.02$ and conditions, F (1, 22)=5.21, $p<0.05$, $MS_e=7.38$. The interaction was not statistically significant. For final free recall, significant main effects of group, F (1, 22)=6.29, $p<0.05$, $MS_e=42.24$ and condition, F (1, 22)=16.46, $p<0.05$, $MS_e=6.38$ 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 IFR 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 considered to be insensitive to differences in age and IQ (3, 4, 6, 7). We can only speculate in the neuropathological background as to the fact that the BI-group performed worse on recall of SPTs than old clinically healthy subjects and educable 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 patients 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 attempts to induce stable voluntary attention with the aid of spoken instructions often prove ineffective (11).

On this hypothesis, the multimodality and richness 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 modality—the auditory—was used. The patients in the BI-group thus became less disturbed and the performance in IFR consequently equals that of the control group.

When comparing the tests within the BI-group, the level of performance was higher in SPTs than SPTs-WA, implying a great importance of motor action. Performance in FFR of SPTs was also better than for words, 0.30 and 0.12 respectively, while it was approximately the same in FFR ofSPTs-WA and FCR of words, 0.21 and 0.22, respectively. Thus, to accomplish better long-term memory effects 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 constructing 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 retrieval, offer cues that are compatible with the imposed structure. By optimizing compatibility 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 according 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 premorbid knowledge of the patient is available. Make thorough interviews with the patient and his/hers relatives to find out what strategies and mnemonics he/she used before the trauma in order to improve the construction and enhance the efficiency of the training programme.

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Appendix A. *Example of a list with sentences used in recall of SPTs and SPTs-WA*

1. Fold the serviette	Serviette
2. Put the cloth on the head	Cloth
3. Press the button	Electrical switch
4. Place the magnet against the eyes	Magnet
5. Hang the measuring-tape around the neck	Measuring-tape
6. Blow the whistle	Whistle
7. Roll the cap on the table	Cap
8. Put the key in the padlock	Key and padlock
9. Crush the plastic	Small plastic bag
10. Comb your hair	Comb
11. Put the coin in the purse	Coin and purse
12. Put a hand in the envelope	Envelope
13. Brush your nose	Small brush
14. Throw the rubber in the air	Rubber
15. Bounce the ball	Ball
16. Pick your teeth	Toothpick