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The effects of cognitive rehabilitation on memory outcome after temporal lobe epilepsy surgery

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Abstract

Objective. Epilepsy surgery is a valuable treatment option for patients with pharmacoresistant epilepsy, but seizure freedom is often achieved at the cost of cognitive impairments caused by surgery. The aim of this study was to investigate the short-term effects of cognitive rehabilitation on memory outcome after temporal lobe epilepsy surgery.
Methods. Two groups of patients who underwent temporal lobe resection, one followed ($n = 55$) and one not followed ($n = 57$) by postoperative rehabilitation, were evaluated with respect to memory and attention before and 3 months after temporal lobe surgery. The groups came from different epilepsy centers, but were largely matched with respect to age, sex, type of surgery, and seizure outcome.
Results. After surgery, 78% of the patients were seizure-free. Repeated-measures MANOVA revealed a significant "side × surgery" effect on verbal recognition and a "rehabilitation × surgery" effect on verbal learning and recognition. There were no effects for loss in verbal delayed recall or figural memory. Detailed analyses indicated gains as a result of rehabilitation, particularly after right temporal lobe surgery. Attention generally improved. The risk of manifesting losses in verbal memory was about four times higher without than with rehabilitation.
Conclusions. Rehabilitation can counteract the verbal memory decline that is normally seen after temporal lobe resection. Its positive effects were evident particularly with respect to the more cortically associated aspects of verbal learning rather than to the mesial aspects of long-term consolidation/retrieval. Figural memory was not affected at all, and attention improved independent of rehabilitation. Interestingly, left temporal lobe-resected patients, who were most in need of an efficacious rehabilitation, profited less than right temporal lobe-resected patients, indicating that left-sided surgery may reduce the capacity needed for efficient training of verbal memory. Thus, rehabilitation has a positive effect on memory outcome, but its usefulness for risk groups and the question of whether training should be performed after or possibly before surgery are debatable. Further research should also address different interventions, longer-term outcome, and the carryover effects on everyday functioning.

Keywords: Epilepsy; Temporal lobe surgery; Memory outcome; Cognitive rehabilitation

1. Introduction

Despite progress in the medical treatment of epilepsy with antiepileptic drugs, pharmacotherapy fails to control seizures in approximately 30% of patients [1]. For these patients epilepsy surgery is an important and very efficient treatment option. According to a recent meta-analysis [2],

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significantly improved seizure status can be achieved in about 60 to 70% of all operated patients. However, the consequences surgical intervention has on the cognitive situation of patients with epilepsy remain controversial. Successful surgery can stop the cognitive decline caused by chronic uncontrolled epilepsy or even reverse the process of deterioration [3]. On the other hand, the surgical intervention carries the risk of causing additional impairments [3,4]. It has been shown that surgery is often performed at the cost of immediate (additional) cognitive impairment, and concern has been raised that patients with surgical lesions could be at greater risk of accelerated mental aging than medically treated patients [5]. This has been demonstrated particularly with memory performance of patients with temporal lobe epilepsy who undergo surgery within the language-dominant hemisphere [6]. The negative cognitive changes after surgery can be devastating, and when, in addition, patients do not become seizure-free, they must be considered double losers [3,7].

Against this background, the question of whether cognitive impairments in patients with epilepsy can be treated by rehabilitation programs is of great importance. However, although the efficacy of cognitive rehabilitation has been demonstrated for patients with other central nervous system (CNS) lesions [8–10], these methods have rarely been evaluated in patients with epilepsy.

Studies on cognitive rehabilitation in epilepsy focus mainly on the training of attention and memory functions because these are the prevailing impairments in the focal symptomatic epilepsies. The efficacy of memory rehabilitation in patients with epilepsy, however, is controversial. Hendriks, in a review article on rehabilitation in patients with epilepsy, reported positive effects of rehabilitation when subjective memory improvement as assessed by questionnaires was the dependent measure [11]. However, as soon as objective neuropsychological tests were used as criteria, the effects were disappointing. The results regarding attention were more promising; positive effects, particularly of compensation strategies, were reported [12].

The present study was aimed at exploring the efficacy of a standard cognitive short-term rehabilitation in patients with epilepsy who underwent temporal lobe surgery for control of pharmacoresistant epilepsy and who were expected to be at risk of additional memory impairment because of the surgery. The evaluated patients were derived from two epilepsy centers (Bonn and Freiburg) that are part of a transregional research project (TR3: Bonn/Freiburg/Berlin) and that use exactly the same protocols for patient evaluation and surgery. Unfortunately, randomization of patients to rehabilitation was not possible, because only Freiburg received funding for performing rehabilitation, and this only for a specific time. Therefore, consecutive patients who underwent surgery in Freiburg received rehabilitation directly after surgery, whereas patients from Bonn served as controls without rehabilitation. Baseline and outcome measures were tests of verbal and figural learning and memory, which are characteristically impaired in patients with TLE and which, furthermore, have been shown to be sensitive to epilepsy surgery. Pre- and postoperative assessments of attention served as controls.

2. Methods

2.1. Patients

The study comprised 112 patients who had undergone temporal lobe surgery (57 on the left side, 55 on the right side) at the University of Bonn Epilepsy Department and the University of Freiburg Epilepsy Department.

All patients had pharmacoresistant focal epilepsies and underwent epilepsy surgery. Fifty-three percent of the patients were shown to have hippocampal sclerosis. The 55 patients treated at the University of Freiburg Epilepsy Department. received rehabilitation therapy at the Median Kliniken Bad Krozingen after surgery. None of the 57 patients operated at the University of Bonn received rehabilitation.

As there was no randomization of patients on treatment and as patient groups belonged to different surgical centers, the patient groups from Freiburg and Bonn were matched as far as possible with respect to gender, age at surgery, age at onset of epilepsy, side and type of surgery, handedness, and estimated IQ/education (Table 1).

The presurgical diagnostic procedure (including medical and neuropsychological examination) followed the same protocol irrespective of the center at which the patients were treated.

2.2. Surgical methods

Those patients who had hippocampal sclerosis (58%) as the sole pathology underwent selective amygdalohippocampectomy (SAH) through a transsylvian approach, and those patients with nonmesial temporal lobe lesions (42%) underwent temporal lesionectomy with exclusion of the mesial structures. Patients who had the standard two-thirds anterior temporal lobectomy were excluded from the study because no match in clinical or demographic variables could be obtained.

2.3. Neuropsychological assessment

The neuropsychological evaluation focused on tests of verbal/figural memory as representative of temporal lobe functions and on a test of attention as an indicator of extratemporal "nonmemory" functions.

Table 1
Characteristics of the patients ($n = 112$)

	No rehabilitation (Bonn)	Rehabilitation (Freiburg)
Number of patients	57	55
Sex, M/F	35/22	30/25
Handedness, right/left/ambidextrous	52/2/3	54/0/1
Type of surgery, SAH/lesionectomy	31/26	34/21
Side of surgery, right/left[a]	26/31	29/26
Seizure-free, yes/no[a]	42/15	45/9
Age[b]		
Mean (SD)	36.4 (9.7)	36.2 (9.9)
Range	17–63	18–64
Age at onset[b]		
Mean (SD)	3.9 (1.1)	3.8 (1.3)
Range	1–6	1–6
Estimated IQ (vocabulary test)	104.4 (15.4)	104.7 (12.5)

Note. Group differences between the two epilepsy surgery centers were statistically not significant ($P < 0.05$) with respect to any of the variables.
[a] χ^2 test.
[b] t test.

2.3.1. Verbal memory

Verbal memory was assessed with a verbal learning test (VLMT—Verbaler Lern und Merkfähigkeitstest) [13] requiring five trials of learning and recall of a list of 15 words, free recall immediately after distraction (learning/recall of a second list in one trial) and after a half-hour delay, and a recognition trial (selection of the original list items out of alternatives). Three scores were analyzed: "verbal learning" (total number of words correctly reproduced over five learning trials), "verbal memory" (number of words lost that were remembered between the last immediate recall and the delayed recall), and "verbal recognition" (number of recognized words minus false alarms). Recent research on this test in patients with TLE revealed that loss of learned words is a good indicator of more mesial temporal lobe function, whereas learning over five trials is a good indicator of neocortical temporal lobe function [14].

2.3.2. Figural memory

Figural memory was assessed with the revised version of a German figural design list-learning test (DCS Diagnostikum für Zerebralschädigung) [15], which in its revised version requires learning and subsequent reconstruction of nine abstract designs in six trials. Recently this test was shortened to only five learning trials. Analyses were based on learning capacity for figural material (correct designs in the last learning trial), which had been demonstrated to provide some sensitivity to right temporal dysfunction and surgery [16–18].

2.3.3. Psychomotor speed/attention

Psychomotor speed/attention was assessed with a letter cancellation test [19]. The parameter analyzed was the total number of scanned items minus the number of mistakes. Parallel test versions were used for follow-up in memory tasks. The time interval between the initial assessment (T1) and follow-up (T2) was 3 months.

2.4. Rehabilitation program

With the support of the Federal Ministry of Education and Research (BMBF) and the German Pension Insurance, the University Hospital Freiburg offered a special rehabilitation program at the Median Kliniken Bad Krozingen for patients with epilepsy who underwent epilepsy surgery. The intervention started 3 to 15 days after surgery and had a mean duration of 29.3 days in this patient group. Training goals were tailored to the needs and wishes of the individual patients [20]. The program contained the following training parts, which are based on the principles described by Prigatano [21]. The approach was holistic in that it aimed at strengthening compensation and adaptation strategies to overcome and cope with the cognitive impairments, and additionally trained the affected attention, executive, or memory functions:

- Metacognitive neuropsychological group therapy was carried out in five 1-hour sessions each week. Topics included: psychoeducation into the effects of brain functioning and cognitive deficits, learning of compensatory strategies, and exercises for attention, problem solving, and learning and mnemonics. The therapy also focuses on the transfer of learned strategies to daily living. The aim was to teach compensatory strategies and improve transfer to everyday life.
- Cognitive exercises involved repeated practice of computer-based exercises for attention, memory, and executive functions. Patients attended, on average, four to five sessions per week. Cognitive exercises used a modified form of Riglings Reha Service and Hasomeds Rehacom, both multimedia cognitive rehabilitation software designed for use with individuals with compromised brain function [22]. The focus is on the repeated training of specific cognitive deficits and was adapted to individual cognitive deficits. Six tasks were used preferentially: two tasks for training sustained visual attention, two tasks for training verbal memory, and two tasks for training visual memory. Test parameters were chosen individually to adjust the difficulty to the level each patient could manage. As soon as the patient was able to achieve 90% accuracy at a given level, the task was made more difficult. Other tasks were added as patients advanced, including a task of multiple simultaneous attention and a task for logical verbal memory. The central aim was retraining impaired cognitive function.
- Occupational therapy (business or industrial training) consists of practical exercises from typical working life (specific and general job skills, compensatory techniques to improve memory function and concentration), supervised by an occupational therapist. Patients attended three to four sessions a week focusing on tasks that required memory function, attention, and problem solving. The aim of the training was enhancing concentration, attention, and memory under conditions typically encountered at work.
- Individual counseling concerning health, coping with the disease, and changes to be expected after surgery was offered by a neuropsychologist two to three times per week. Particular emphasis was placed on the need for psychoeducation regarding the effects of cognitive deficits in daily life, the impact of personality and emotional reactions, and the individual perception of memory problems [23]. The aim was to offer strategies to solve the most commonly encountered everyday problems, with particular consideration of the roles of stress, depression, and anxiety.
- Sociotherapy included group communication and interaction in outdoor activities, sports, painting, designing, and so on.

Additionally, medical care, physical therapy, and sports therapy were offered individually when indicated.

It is essential to note that test instruments (e.g., list learning tests) that were part of the pre- and postsurgical neuropsychological evaluations were not included in the diagnostics and cognitive training used within the rehabilitation program.

2.5. Statistical data analysis

To determine whether epilepsy surgery had an effect on cognitive performance in verbal and nonverbal memory tasks or in attention, we conducted a repeated-measures MANOVA with preoperative performance and postoperative performance as within-subject factors ("surgery") and "rehabilitation (yes/no)," "side of surgery (left/right)," and "SAH (yes/no)" as between-subject factors.

"Side of surgery" was considered a between-subject factor because we had directed hypotheses for left temporal lobe resections, which characteristically lead to postoperative verbal memory decline [6]. Type of surgery was controlled because there is evidence that neocortical temporal lobe lesionectomies may have a different outcome than SAH [24].

For better comparability, all test parameters were standardized with respect to normative—not age-specific—group data obtained in 255 healthy subjects (mean = 100, SD = 10). For individual-level analyses, test performance was considered as impaired when scores ranged below the mean – 1SD. Furthermore, to determine individually significant changes in performance after surgery with or without subsequent rehabilitation, pre–post difference scores were related to "practice-corrected reliability-of-change indices" (90% confidence intervals) retained from repeated testing of 99 epilepsy patients after intervals of 3 to 24 months who had no surgical intervention or change in treatment during this period. For this analysis, the most representative parameter for each test was chosen.

SPSS for Windows (Release 10.01) was used for statistical analyses.

3. Results

3.1. Cognitive baseline performance

Although patients from both epilepsy centers did not differ on clinical and demographic variables, there was a difference in their cognitive baseline performance. With the exception of one verbal memory parameter (loss of learned items in delayed recall), patients treated in Bonn who received no rehabilitative intervention performed at a lower level in verbal learning ($F = 5.2$, $P = 0.024$), nonverbal memory ($F = 9.4$, $P = 0.003$), and attention ($F = 6.1$, $P = 0.015$) at baseline than did patients operated in Freiburg who received rehabilitation. As mentioned before, patient groups did not differ with respect to estimated intelligence or education (Table 1). Table 2a summarizes individual patients' cognitive impairments before surgery. Accordingly, 25 to 38% of the group who would undergo rehabilitation versus 49 to 59% of the patients who would not undergo rehabilitation displayed problems in attention or verbal or figural memory.

3.2. Seizure outcome

Postoperatively, 78% of patients were continuously seizure-free (not one seizure nor one aura), and 22% were rated as being not completely seizure-free. According to the matching conditions, seizure outcome did not differ between patients with and without rehabilitation. It also did not differ with the side of surgery. More importantly, seizure outcome did not affect the change in verbal memory, figural memory, or attention when considered as a between-group factor in repeated-measures analysis.

3.3. Cognitive outcome

3.3.1. Attention

Multivariate tests showed a significant main effect of "surgery" ($F = 54.9$, $P < 0.001$), in that attention performance generally increased after surgery (Fig. 1).

Interaction effects could be observed for "rehabilitation × surgery" ($F = 7.5$, $P = 0.007$), "SAH × surgery" ($F = 4.0$, $P = 0.048$), and "side of surgery × surgery" ($F = 6.4$, $P = 0.013$). Improvements were observed particularly in the group without rehabilitation, after right-sided surgery, and after lesionectomy.

On an individual level, 12% of the patients showed an improvement in attention after surgery, 2% decreased in performance, and 86% remained the same (Table 2b).

Table 2a
Number of patients impaired (score < mean − 1SD) before surgery ($n = 112$)

	Total ($N = 112$)	No rehabilitation (Bonn) ($N = 57$)	Rehabilitation (Freiburg) ($N = 55$)
Attention[a]			
[correct – errors]	39%	49%	29%
Verbal memory			
[learning: trials 1–5]*	46%	59%	31%
[memory: loss in delayed free recall][a]	48%	58%	38%
Figural memory			
[last learning trial][a]	34%	59%	25%

[a] Significant group difference, $P < 0.05$.

3.3.2. Verbal memory

Multivariate analyses showed significant main effects of "rehabilitation" ($F = 6.46$, $P < 0.001$), rehabilitated patients performing more poorly than nonrehabilitated patients; "side of surgery" ($F = 7.03$, $P < 0.001$), patients with left TLE performing more poorly than those with right TLE; and "SAH" ($F = 5.12$, $P = 0.002$), patients with mesial pathology treated by SAH performing more poorly than those with extramesial lesions treated by lesionectomy.

Additionally, there was a within-subject effect of "surgery" ($F = 4.49$, $P = 0.005$) and a significant "rehabilitation × surgery" interaction ($F = 6.22$, $P = 0.001$). Univariate analysis revealed significant "surgery" ($F = 12.4$, $P = 0.001$) and "side × surgery" ($F = 7.72$, $P = 0.007$) effects, particularly on verbal recognition. Patients recognized fewer words after surgery than presurgically. Patients with left TLE manifested a loss whereas those with right TLE maintained their performance level after surgery.

Most importantly, "rehabilitation × surgery" effects on recognition ($F = 16.67$, $P < 0.001$) and verbal learning ($F = 9.74$, $P = 0.002$) were observed. The performance level of patients who did not receive rehabilitation decreased, whereas the performance level of patients who received cognitive training remained stable or even increased. No effects could be observed with respect to verbal memory, that is, loss of words learned in delayed recall of words.

Although no significant three-way interaction was obtained, closer examination of the data provides further insight. Fig. 2 illustrates the preoperative to postoperative changes in "learning" and "loss in delayed recall" as a function of both rehabilitation and side of surgery. Initially, we made specific assumptions about the usefulness of rehabilitative interventions in left temporal lobe-resected patients, who are particularly at risk of losses in verbal memory after surgery. When calculated separately for left- and right-resected patients, repeated-measures MANOVAs with verbal memory scores as a within-subject factor and "rehabilitation yes/no" as a between-subject factor revealed an interaction effect of "surgery × rehabilitation" on all memory parameters for right temporal lobe-resected patients ($F = 6.9$, $P = 0.001$), but not for left temporal lobe-resected patients ($F = 1.6$, $P = 0.21$). In left-resected patients the repeated factor "surgery" became significant, indicating losses after surgery.

When evaluated on an individual level, verbal learning performance deteriorated in 23% of the patients after surgery (30% of those with left TLE, 15% of those with right TLE), performance remained stable in 75%, and performance improved in 2%. In verbal delayed recall, 18% of all patients had decreased performance, 73% remained the same, and 9% improved. The relative risk of deterioration in verbal learning was about 3.4 times higher for patients who did not receive any cognitive training than for those who did (odds ratio = 3.4, χ^2 Mantel–Haenzel = 5.3, $P = 0.02$) (Table 2b). When calculated separately for left- and right-resected patients the

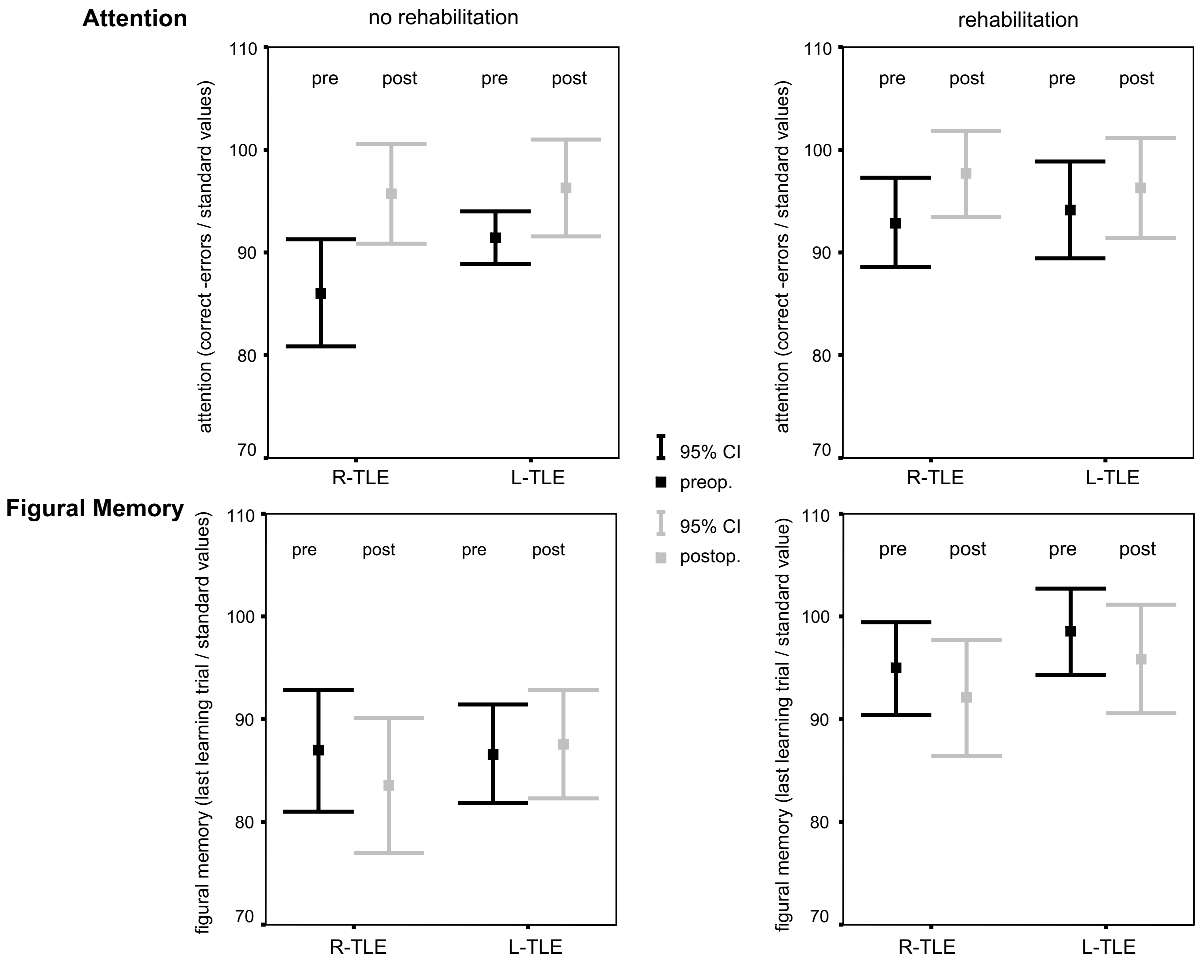

Fig. 1. Pre- and postoperative performance in attention (letter cancellation) and figural memory (learning performance DCS-R) broken down with respect to intervention (rehabilitation yes/no) and side of temporal lobe surgery (left (L)-TLE/right (R)-TLE). Scores are converted into standard values (mean = 100, SD = 10), with higher values representing better performance.

Table 2b
Individual improvement/deterioration (90% Cl) after surgery ($n = 112$)

	Total ($N = 112$)		No rehabilitation (Bonn) ($N = 57$)		Rehabilitation (Freiburg) ($N = 55$)		Odds ratio
	➚	➘	➚	➘	➚	➘	
Attention [correct – errors]	12%	2%	22%	2%	4%	2%	1.2 n.s.
Verbal memory							
[learning: trials 1–5]	2%	23%	—	33%	4%	13%	3.4 $P < 0.05$[a]
[memory: loss in delayed free recall]	9%	18%	4%	20%	15%	16%	1.3 n.s.
Figural memory [last learning trial]	20%	30%	24%	28%	16%	33%	0.79 n.s.

[a] Mantel–Haenzel statistics.

odds ratios were 11.5 (χ^2 Mantel-Haenzel = 4.83, $P = 0.028$) for the right-resected versus 1.2 for the left-resected group.

3.3.3. Figural memory

Neither a main effect nor any interaction effect was observed on figural memory performance. However, 30%

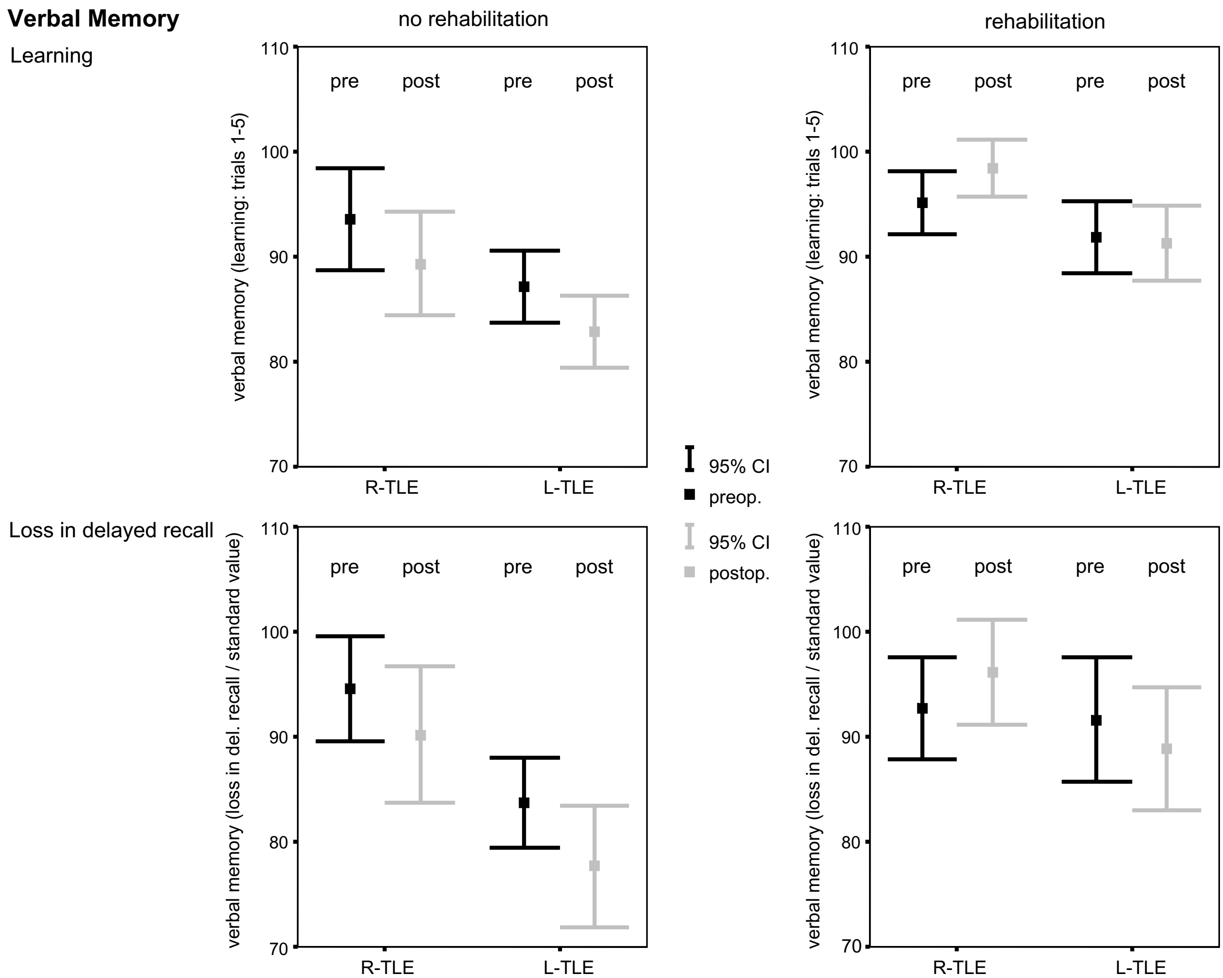

Fig. 2. Pre- and postoperative performance in verbal learning (learning over five trials) and memory (loss of learned items after a half-hour delay) broken down with respect to intervention (rehabilitation yes/no) and side of temporal lobe surgery (left (L)-TLE/right (R)-TLE). Scores are converted into standard values (mean = 100, SD = 10) and reversed in polarity (loss after delay) so that higher values represent better performance.

(37% of those with right TLE, 23% of those with left TLE) of the patients showed a clinically relevant decrease in nonverbal memory performance, 20% improved, and 50% remained the same (Table 2b, Fig. 1b).

4. Discussion

The present study was designed to determine whether postoperative cognitive rehabilitation can counteract the verbal memory decline often observed as a negative side effect of left TLE surgery. As would be expected, the patients with TLE evaluated had already exhibited impaired performance in verbal and nonverbal memory, as well as in attention, before surgery. On an individual level, impaired performance was observed in 30–50% of the patients, verbal memory being most frequently affected. Baseline performance differed for patients with different types of surgery; that is, patients who underwent SAH performed more poorly on memory tasks than patients who had lesionectomy, which can best be explained by different pathology, that is, mesial hippocampal sclerosis versus neocortical lesions, respectively. So far, this is consistent with previous reports on cognitive impairment in TLE [25–27].

In the total group, without particular consideration of the rehabilitative intervention, surgery caused a verbal memory decline in 30% of patients who underwent left-sided surgery, but also in 15% of patients who had right-sided surgery. Attention generally improved after surgery irrespective of the side of surgery, but on an individual level, this result was of minor relevance. No relevant changes were seen with respect to figural memory. This is also largely consistent with previous reports on the short- and long-term risks and benefits of temporal lobe surgery. Neither seizure outcome nor type of surgery had a measurable effect on the 3-month short-term follow-up assessment.

Taking rehabilitative care into consideration, the postoperative short-term intervention had a significant and positive effect, particularly on verbal learning and memory performance. The effect, however, was not universal. Before delving into this point in detail, it is important to keep in mind that in this study, intervention (rehabilitative care) and the epilepsy center (Bonn, Freiburg) were confounded. Although both centers share the same preoperative evaluation protocol and although neurosurgeons, neurologists, electrophysiologists, and neuropsychologists from both centers once worked together in one center, this must be considered a potential source of a bias. Although both groups were matched with respect to clinical and demographic characteristics, there were some differences in baseline performance: patients operated in Freiburg were already better at baseline, and one might well say this is the reason for the better outcome. However, within a memory outcome prediction model that considers the adequacy of the to-be-resected tissues and reserve capacity as determinants of postoperative memory, better baseline memory performance may also be an indicator of greater losses. Furthermore, the study design does not allow detachment of the effects of specific cognitive training from the effects of other rehabilitation procedures. Rehabilitation comprised group therapy as well as individual interventions, and rehabilitation was not restricted to memory training but also included training of executive and attention functions, as well as work-related training, psychosocial therapy, and counseling. However, as for the effects of rehabilitation on memory performance, it is important to note that list learning, used as a baseline and an outcome measure before and after surgery, was not trained during rehabilitation.

Returning to the results, rehabilitation had a positive effect on verbal memory outcome. Without the intervention, the relative risk of a decline was nearly fourfold. As observed in the figures and tables, rehabilitation counteracted verbal memory decline and partly improved this performance. The finding, however, that a training effect was significant in patients with right TLE, whereas it was less evident in patients with left TLE, is remarkable. The best explanation for this result is that after right temporal lobe surgery, left hemisphere learning capability is still available and can be recruited for training. In contrast, when surgery is performed in the left hemisphere, this capability is additionally impaired. Thus, as for verbal memory performance, rehabilitation appears to be able to improve patients' use of left temporal lobe structures, but it appears to be unable to induce significant reconstitution or compensation by recruiting areas or functions not involved in verbal memory before.

In this respect another finding from this study is important. An effect of rehabilitation was seen mainly with respect to functions that reflect more neocortical aspects of memory, that is, verbal learning, and not those aspects more closely related to mesiotemporal hippocampal functioning, that is, loss of newly acquired information over time [28,29]. This observation is in line with the hypothesis that differential plasticity and reserve capacity are associated with these two aspects of memory [12,30]. Thereafter, mesial memory functions are more bilaterally disposed and compensatory capacity depends on the functional integrity of the contralateral mesial structures independent of age and performance in IQ or other cognitive domains. Reserve capacity of neocortical verbal memory functions, in contrast, is more unilaterally disposed and more dependent on age and compensatory intellectual capacity, as well on capacity for attention or language or executive functions (planning, categorization, fluency, flexibility).

As for attention, performance improved independent of cognitive training. Previous research has demonstrated that nonmemory function deficits obviously have the potential to recover after surgery without any interventions, an effect that has been interpreted in terms of a release due to control of epileptic dysfunction [3,10,31,27]. Accordingly, the attention deficit before surgery was due less to structural abnormalities than to functional origin. In the present patient sample, this release effect, which was highly significant in right temporal lobe-resected patients without rehabilitation, overshadowed the expected training effects.

In conclusion, this study confirms that patients with TLE and particularly those who undergo surgery on the left side are at risk of additional postoperative memory decline. There are shortcomings to this study, namely, the short follow-up interval and the fact that patients could not be randomized on training. The findings show, however, that rehabilitative care including cognitive short-term training resulted in significantly better verbal memory outcome. This is based on improvements observed in the patients with right TLE, who had mostly unimpaired left temporal lobe (memory) function before surgery. Thus, patients with right TLE with verbal memory problems appear to be a group that responds well to cognitive rehabilitation. The fact that cognitive rehabilitation had limited effects in the group with left TLE with more expressed pre- and postoperative problems shows that the rehabilitative strategy was not that effective for this patient subgroup. Thus, additional research to determine which type of training may help and when such interventions are indicated in the course of the disease is necessary. The results, for example, encourage the study of the differential effects of "forced use" versus "meta-cognitive strategies." Furthermore, if left temporal lobe impairment caused by surgery conflicts with its postoperative treatment, then an intervention before surgery or, even better, early after epilepsy onset appears more promising. A respective randomized trial on pre- versus postoperative rehabilitation versus no rehabilitation in patients with left TLE would be greatly appreciated. Finally, it must be made explicit that the results of this study say nothing with respect to the beneficial effects of postoperative rehabilitative care on coping with impairments, emotional adjustment, or psychosocial integration or reintegration in the long run. However, this was explicitly not the core of this study and should also be considered a topic of future research projects.

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