The impact of sex and language dominance on material-specific memory before and after left temporal lobe surgery

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Summary
Recent findings raised evidence that in early-onset left temporal lobe epilepsy, women show greater functional plasticity for verbal memory than men. In particular, women with lesion- or epilepsy-driven atypical language dominance show an advantage over men. The question asked in this study was whether there is evidence of sex- and language dominance-dependent late, i.e. adult age, plasticity for verbal memory when epilepsy surgery is performed in these patients. Pre- and 1-year post-operative memory performance was evaluated in 169 patients (94 males and 75 females) who underwent left temporal lobe surgery and who had WADA testing of hemispheric language dominance prior to surgery. Verbal memory and figural memory were assessed by list-learning paradigms. According to the Bonn intra-carotid amobarbital test (IAT) protocol, patients were categorized into left dominant or atypically dominant (right, incomplete left or right, and bilateral dominant) groups. Results were controlled for the hypothesized sex differences. Thirty-four percent of men and 47% of women displayed patterns of atypical language dominance. Atypical dominance was related to an early onset of epilepsy. Men showed a larger time window for development of atypical dominance but, differently from women, the pattern of atypical dominance was more strictly determined by the age at onset of epilepsy. Atypically dominant women showed better verbal memory than typically dominant women or men. After surgery, right dominant patients had better verbal memory outcome than patients with bilateral or left language dominance who showed significant memory loss. No effect of sex on verbal memory change was found. Figural memory deteriorated in men and improved in women, when they were not left dominant. Seizure outcome had no effect on performance changes. It was concluded that better preserved verbal memory in atypically dominant women before surgery indicates greater benefit from atypical dominance in women than men with regard to the initial damage associated with left hemisphere epilepsy. Later in life, when epilepsy surgery causes additional damage, no such sex difference is observed, indicating that the women’s advantage over men is fixed to an early time window in life. Postoperative changes in figural memory suggest dynamics in crowding and suppression patterns. Whether this reflects late plasticity and compensation needs further demonstration. For clinical practice, it is important to note that incomplete right hemisphere and bilateral language dominance do not protect against verbal memory loss after left-sided temporal lobe surgery.

Keywords: sex; language dominance; memory; plasticity; epilepsy surgery

Abbreviations: DCS-R = Diagnostikum für Cerebralschädigung-revidierte Fassung; IAT = intracarotid amobarbital test; ILHD/BL = incomplete left hemisphere/bilateral language dominance; LHD = left hemisphere language dominance; L-TLE = left temporal lobe epilepsy; RHD = right hemisphere language dominance; R-TLE = right temporal lobe epilepsy; TLE = temporal lobe epilepsy


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Introduction

It is well known that temporal lobe epilepsy (TLE) affects episodic memory and that epilepsy surgery for control of pharmacoresistant seizures carries the risk of additional memory decline. Depending on the lateralization of the epileptic focus in the left or right hemisphere, material-specific impairment of verbal or figural memory can be discerned (Helmstaedter et al., 1997a; Gleissner et al., 1998). Whereas there is a strong and consistently reported relationship between left temporal lobe damage and dysfunction and impairment of verbal memory, the respective relationship between the right temporal lobe and figural or visuo-spatial memory seems far less consistent. In part, this can be explained by the confounding of figural and verbal memory in terms of verbalization techniques which help to overcome impaired figural memory performance in right temporal lobe epilepsy (R-TLE) (Helmstaedter et al., 1995). This explanation so far holds for the absence of figural memory impairment in R-TLE. It does not explain why false lateralizing figural memory performance, i.e. impaired figural memory falsely indicating right temporal lobe dysfunction, is so often seen in patients with left temporal lobe epilepsy (L-TLE). Pronounced figural memory impairment in L-TLE with relatively preserved verbal memory can be an indicator of an atypical language dominance pattern and concomitant crowding phenomena, a term which describes suppression of right hemisphere functions due to either the competition for space or to the incompatibility between different modes of information processing when verbal and visual/visuo-spatial information are processed within one hemisphere (Lansdell, 1969; Ogden, 1989; Strauss et al., 1990; Helmstaedter et al., 1994; Loring et al., 1999). In a recent study which considered not only language dominance but also sex differences in L-TLE, three out of four subgroups showed the expected verbal memory impairment (left dominant men and women, and atypically dominant men) and three out of four groups with L-TLE showed unexpected figural memory impairment (atypically dominant men and women, and typically dominant women) (Helmstaedter, 1999). Considering this, it is evident why, on the one hand, figural memory often fails to indicate lateralized dysfunction, and why, on the other hand, figural memory and not verbal memory is a classic non-specific indicator of cerebral dysfunction (see, for example, the original purpose of the Benton Visual Retention Test).

The finding which raised the issue of the present study was that women, but not men, benefit from atypical dominance with respect to verbal memory performance. Whereas men had significant verbal memory impairment independent of whether they were left hemisphere language dominant or not, atypically language-dominant women demonstrated almost normal verbal memory performance. The majority of epileptic patients with atypical language dominance have an onset of their epilepsy before puberty. As discussed earlier, the onset of epilepsy within a period of cerebral plasticity strongly suggests that atypical language dominance in left hemisphere epilepsies is a consequence of the left hemisphere lesion plus epileptic dysfunctions rather than a natural predisposition (Helmstaedter et al., 1997b).

Considering early-onset L-TLE as ‘the first hit’ of the brain, and left temporal lobe surgery as ‘second hit’ later in life, the question asked in the present study was whether language dominance and sex will also determine the memory outcome after temporal lobe surgery. In particular, we were interested in knowing whether atypically language-dominant women will again show the advantage with respect to verbal memory. This follow-up study after surgery was also stimulated by recent reports which confirmed our previous suggestion that atypical language dominance in TLE might be driven not only by structural lesions but also by epilepsy and that atypical language dominance in TLE seems to be a more dynamic process, as has been suggested (Helmstaedter et al., 1997c; Gleissner et al., 2002; Janszky et al., 2003). If atypical dominance in part depends on the degree of functional epileptic activity, a different surgical memory outcome might be expected in atypically dominant patients who become seizure free compared with those who continue to have seizures. With regard to the benefit of atypical language dominance with respect to verbal memory, a paradoxical effect can be postulated.

Methods

Patients

Patients comprised 94 men and 75 women with L-TLE who underwent epilepsy surgery for control of otherwise uncontrollable seizures. About half of the patients who entered this follow-up study overlapped with those 85 patients reported in Helmstaedter (1999). Localization and lateralization of the epilepsy were determined by pathology and the epileptogenic focus was determined by high resolution MRI and extensive interictal and ictal EEG monitoring.

As can be seen from Table 1, showing patient characteristics, groups did not differ with respect to age, years of education, intelligence (IQ) or performance in a test of attention; neither did they differ with respect to age at onset of epilepsy, underlying pathology or the type of temporal lobe surgery. More detailed information about temporal lobe surgery as performed in our centre is provided elsewhere (Clusmann et al., 2002). Dexterity and non-dexterity as assessed by the Oldfield Handedness Inventory were equally distributed in both groups.

Intracarotid amobarbital testing (IAT) for language dominance

All patients underwent left and right intracarotid injection of 200 mg of amobarbital in a 10% solution on consecutive days. The procedure was videotaped and monitored with either EEG or EcoG in order to monitor the barbiturate effect. The barbiturate effect was validated furthermore by repeatedly checking the hemiparesis.

Language testing included the following. (i) Serial speech: counting backwards immediately before the amobarbital injection and continued after the injection. (ii) Receptive speech functions I: comprehension of spoken commands. Four cards showing four objects each were presented and the patient was asked selectively to
point at a named object (e.g. ‘Point to the cat’). (iii) Receptive speech functions II: the patient was asked to perform three actions (‘press my hand’; ‘raise your arm’; ‘show your tongue’). (iv) Naming of four pictorially presented objects. (v) Repetition of two proverbs. (vi) Reading of two short sentences and a paragraph consisting of three complex sentences. (vii) Spontaneous speech: spontaneous articulation during the procedure.

Testing of language functions was performed during the maximal barbiturate effect as indicated by EEG slowing and paresis. The total performance score in either IAT is defined as the sum of subscores for performance in the individual tasks (faultless performance, 2 points; impaired performance, 1 point; complete failure, no points). The total score for each IAT can thus range between 0 and 14. Based on this semi-quantitative assessment of IAT performance, language dominance was considered a continuous variable. A lateralization index was computed according to a well established procedure which has been published previously (Kurthen et al., 1994). The lateralization index $L$ is computed according to the formula:

$$L = \frac{\text{Score IAT right} - \text{Score IAT left}}{\text{Score IAT right} + \text{Score IAT left}}$$

$L$ is corrected by multiplying by $n/m$, with $n$ being the score of the IAT with better language performance, and $m$ being the highest possible score in the IAT (here 14 points). The quotient yields a value between $-1$ and 1, with $-1$ indicating complete right hemisphere language dominance (RHD) and 1 indicating complete left hemisphere language dominance (LHD) (Kurthen et al., 1994).

For the present study, patients were classified as left dominant (index $>0.8$), incomplete left dominant (0.3–0.8) bilateral (<0.3 to more than –0.3) or right dominant (index less than –0.8). There was no patient with a pattern of incomplete right dominance (–0.3 to –0.8) (see also Helmstaedter et al., 1997b).

### Memory tests

Memory was assessed by list-learning paradigms preoperatively and 1 year after surgery. The postoperative follow-up evaluations were performed using a parallel version of the tests.

### Verbal memory

In order to assess verbal learning and memory, a German adaptation of the Rey Auditory Verbal Learning test (Verbaler Lern- und Merkfähigkeitstest; Helmstaedter et al., 2001) was administered during presurgical evaluation and 1 year after surgery. This test requires learning and immediate recall of a word list in five trials, and recall of this list after distraction (learning a second list in one trial) and a 30 min delay. Finally, recognition of the target items out of orally presented alternatives is required. Measures of interest were learning capacity (total correct responses over five learning trials) and performance on delayed free recall (correct responses following distraction after 30 min), which had been demonstrated to assess left temporal lobe dysfunction reliably and also to be sensitive with respect to left temporal lobe surgery in the past. A total verbal memory score was computed by transforming the measures of learning capacity and delayed free recall to standard values. The individual scores then were added and divided by two. Transformation into standard values additionally offered the possibility of directly relating the mean performance of the different groups to normative data.

### Figural memory

The DCS-R, a revised version of the DCS (Diagnosticum für Cerebralschädigung; Lamberti and Weidlich, 1999) was chosen in order to assess visual/figural memory performance. The DCS-R requires repetitive learning and immediate reproduction of a set of
nine abstract designs in six learning trials. The measure of interest was the learning capacity, i.e. the number of correct designs at the last performed trial. This score has consistently proven to be sensitive with regard to temporal lobe dysfunction and surgery in patients with R-TLE (Helmstaedter et al., 1991; Gleissner et al., 1998).

Results

Sex and language dominance

IAT results indicated atypical dominance in 32 male patients (34.0%) compared with 35 female patients (46.6%). According to our classification system, six (6.4%) men were rated as being completely RHD for language, 14 (14.9%) as incompletely LHD, and 12 (12.8%) bilateral. In contrast, nine (12.0%) women turned out to be completely RHD, 10 (21.3%) were incomplete LHD and 16 (13.3%) had bilateral patterns ($\chi^2 = 5.87, P = 0.20$).

For the subsequent analyses, we differentiated two [completely LHD (LHD) versus not completely LHD (non-LHD)] and three groups [LHD, complete RHD (RHD) or incomplete LHD or a bilateral pattern (ILHD/BL), respectively. According to this, 100 patients had LHD, 51 patients ILHD/BL, and 15 patients RHD.

Considering atypical dominance as a function of the age at onset of epilepsy, patients with RHD (5.8 years) showed the earliest onset, followed by patients with ILHD/BL (9.5 years) and patients with LHD (11.5 years) ($F = 7.5, P = 0.001$).

Bonferroni-adjusted post hoc t tests showed that the difference between men and women was due mainly to the subgroup with incomplete left hemisphere or bilateral language representation (ILHD/BL, $t = -0.091$, NS; RD, $t = 1.016$, NS). Figure 2, which displays the results for verbal learning capacity (learning over five trials), shows that there is also a trend of a sex difference in the RHD group. Mainly because of the small sample sizes, this effect did not reach statistical significance (see Table 2 for group data).

Regardless of which classification of language dominance was chosen, ANOVA with figural memory scores as the dependent variable did not show significant differences (for group means, see Table 2).

Preoperative memory as a function of sex and language dominance

ANOVA (analysis of variance) with verbal memory total scores as dependent variable and sex and language dominance (LHD versus non-LHD) as independent variable revealed a main effect of sex ($F = 7.4, P = 0.007$), with women performing better than men, and a significant interaction sex × language dominance ($F = 8.0, P = 0.005$).

Breaking language dominance down further into LHD, RHD and ILHD/BL, the main effect for sex ($F = 5.68, P = 0.018$), with women showing better verbal memory performance than men, and the interaction sex × language dominance ($F = 3.97, P = 0.021$) were still evident.

Postoperative change in memory as a function of sex and language dominance

At the 1 year follow-up evaluation, 66% of the men and 49% of the women were completely seizure free ($\chi^2 = 4.75, P = 0.02$). Patients were rated as being completely seizure free if they had no single seizure nor any aura since surgery. Because of the different seizure outcome in men and women, this variable was controlled for by covariance analysis in subsequent analyses.

Repeated measures ANOVA with pre- and postoperative verbal memory total score as dependent variables and sex and language dominance (LHD versus non-LHD) as independent

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variables showed an interaction effect of surgical treatment $\times$ language dominance ($F = 4.55, P = 0.03$), indicating greater losses in LHD patients. Seizure outcome did not turn out to have a significant effect on memory outcome.

Breaking language dominance down further, a main effect for the repeated factor (surgical treatment, $F = 14.01, P < 0.001$), and again the interaction effect of surgical treatment $\times$ language dominance ($F = 3.07, P = 0.049$) became evident. Post hoc $t$-tests for dependent samples revealed significant performance change in the left ($t = 6.331$, two-tailed, $P < 0.001$) and the bilateral group ($t = 3.425$, two-tailed, $P = 0.001$), but not in the right dominant group ($t = 0.647$, NS) (see Table 2 and Fig. 3).

Repeated measures ANOVA with pre- and postoperative figural memory scores as dependent variables revealed a three-way interaction of surgical treatment $\times$ sex $\times$ dominance ($F = 5.07, P = 0.018$) (see Fig. 3A and B). According to post hoc $t$ tests for dependent samples, this effect was due mainly to figural memory losses in atypically dominant men ($t = 2.30$, $P = 0.02$), and due less to gains in atypically dominant women ($t = -0.80$, $P = 0.42$) or losses in left dominant women ($t = 1.42$, $P = 0.16$) (Fig. 4). Breaking language dominance down further did not reveal any additional information. Seizure outcome did not have an impact on figural memory outcome.

As already mentioned in the Introduction, a recent study by Janszky et al. (2003) caused us to hypothesize that when atypical dominance is driven by epilepsy, the dominance pattern, and therefore also its effect on material-specific memory, should change when atypically dominant patients become seizure free. In particular, we expected that benefits with respect to atypical dominance might be diminished when atypical dominance is driven by seizures and when patients become seizure free. The main analyses mentioned above did not show an effect of seizure outcome on memory when

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**Table 2**

<table>
<thead>
<tr>
<th>Sex</th>
<th>Language dominance</th>
<th>Verbal memory (mean/SD)</th>
<th>Figural memory [mean (SD)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-op</td>
<td>Post-op</td>
</tr>
<tr>
<td>Male</td>
<td>LHD ($n = 62$)</td>
<td>89.4 (10)</td>
<td>82.5 (13)</td>
</tr>
<tr>
<td></td>
<td>ILHD/BL ($n = 26$)</td>
<td>85.2 (10)</td>
<td>81.2 (10)</td>
</tr>
<tr>
<td></td>
<td>RHD ($n = 6$)</td>
<td>91.3 (11)</td>
<td>91.3 (14)</td>
</tr>
<tr>
<td>Female</td>
<td>LHD ($n = 40$)</td>
<td>89.3 (10)</td>
<td>80.9 (11)</td>
</tr>
<tr>
<td></td>
<td>ILHD/BL ($n = 26$)</td>
<td>94.7 (10)</td>
<td>89.6 (10)</td>
</tr>
<tr>
<td></td>
<td>RHD ($n = 9$)</td>
<td>97.2 (10)</td>
<td>95.7 (9)</td>
</tr>
</tbody>
</table>
seizure outcome was controlled by covariance analysis. However, we evaluated the effect of becoming seizure free or not only for atypically dominant patients. Separate $t$ tests for dependent measures showed that against our hypothesis, atypically dominant patients who did not become seizure free showed more significant losses in verbal and figural memory (verbal $t = 3.04$, $P = 0.006$, $n = 43$) than seizure-free patients (verbal $t = 1.87$, $P = 0.07$, $n = 24$).

Discussion

Our recent research in patients with TLE provided evidence that material-specific memory impairment in L-TLE is determined not only by the lateralization of epilepsy but also by sex and language dominance. Within a theoretical framework of material-specific memory impairment in lateralized TLE, women with L-TLE appeared less well lateralized than men and they showed greater benefit with regard to the preservation of verbal memory in the presence of atypical language dominance. Following this finding, the present study evaluated whether sex and language dominance will also determine memory outcome after left temporal lobe surgery.

First, with regards to clinical practice, we expected that sex and language dominance might be significant predictors of memory outcome after temporal lobe surgery. Secondly, the issue of early versus late cerebral plasticity was examined. In particular, we were interested in knowing whether women who show greater plasticity in response to the onset of epilepsy will also show greater benefit later in life when epilepsy surgery is performed.

First of all, the present data show that, as a trend, women with L-TLE more often displayed atypical language dominance patterns than men. This is consistent with our finding in an earlier sample of patients which also included extratemporal lobe epilepsies (Kurthen et al., 1997). Other studies have not found a sex difference in the frequency of atypical dominance (Janszky et al., 2003) or have even reported more frequent atypical patterns in men (38%) than in women (29%) (Strauss et al., 1992). Generally, statements about sex differences in hemisphere language dominance on the basis of IAT studies must be made with care because differences in patient samples, criteria for submission to IAT, IAT procedures, amobarbital doses and classification systems may contribute to different findings in different study groups. The overall frequency of ~40% patients with atypical language dominance in L-TLE is higher than previously reported by us (31%; Helmstaedter et al., 1997b) or by others (24%; Janszky et al., 2003). In part, this can be explained by a liberal definition for concluding from the IAT that there is atypical language dominance, and in part this is the result of an increasingly restrictive indication of the IAT during recent years. Submissions to the IAT dropped from 100 to 10% in the last 100 consecutive candidates for epilepsy surgery, and the number of patients with language functional MRI is steadily increasing (Helmstaedter and Kurthen, 2002; Helmstaedter, 2004). Accordingly, there are an increasing number of atypically dominant patients in the group submitted to the IAT.

In both sexes, the presence of atypical dominance was clearly related to an onset of epilepsy before puberty. However, the mean age at onset of epilepsy in atypically dominant women was ~7 years independent of the subpattern they displayed. In contrast, atypically dominant men displayed different time windows for complete RHD and incomplete or bilateral patterns. For complete RHD, the mean age at onset of epilepsy was ~3 years and thus earlier

Fig. 4 Pre- and postoperative figural memory as a function of sex and language dominance. The results indicate a significant loss in figural memory in atypically dominant men (A) and in typically dominant women (B).
than in women, and for incomplete left dominance or bilateral patterns it was ~12 years and thus later than in women. A larger time window for cerebral plasticity in men had also been reported in the study by Strauss et al. (1992), but the present data indicate that the pattern which develops makes a difference. Indeed, the time window for the development of atypical dominance appears to be larger in men but, in contrast to the situation in women, complete right dominance develops only with an earlier onset of epilepsy. As already mentioned above, results of different studies in the field cannot readily be compared because of significant methodological differences. Strauss et al. (1992), for example, chose age at onset of cerebral damage for their time scale, while in the present study, age at onset of epilepsy was used. Furthermore, due to their different criterion, Strauss et al. (1992), chose age at lesion onset categories of 1, 3 and 12 years, whereas in the present study age at onset of epilepsy was considered a continuous variable.

The data derived from TLE patients analysed with respect to sex and language dominance fully confirm our previous finding that left temporal women with atypical language dominance show better preserved verbal memory function than left dominant women with L-TLE or men with L-TLE with either dominance pattern (Helmstaedter, 1999). Despite the left temporal lobe lesion or focus, verbal memory in atypically language dominant women was largely unimpaired and within a normal range. Our former findings with respect to figural memory (only left hemisphere dominant men were not impaired in this domain) were confirmed only as a trend. Left temporal patients generally scored poorly in figural memory as a group, but the group differences observed in the smaller sample in 1999 remained largely the same. Looking more closely at subgroups, women compared with men, and RHD patients compared with patients with other dominance patterns showed poorer figural memory performance. The figural memory data thus reflect the known pattern of suppression of originally right hemispheric processed functions in patients with a lesion- or epilepsy-driven inter-hemispheric language transfer (Lansdell, 1969; Ogden, 1989; Strauss et al., 1990; Helmstaedter et al., 1994; Loring et al., 1999). They furthermore replicate our previous finding of a sex difference in figural memory in left dominant patients, with women showing the poorest performance (Helmstaedter, 1999). The effects were not as pronounced as those observed with the smaller sample in 1999, presumably because of a change in our routinely performed neuropsychological test battery, this time only the performance in design learning (DCS-R) was taken into consideration, and not a combined measure of design learning and visual retention (Benton Visual Retention Test). In our previous report, we speculated that the poor figural memory in left dominant women might also reflect a suppression pattern or crowding effect due to the women’s principal disposition to show greater interhemispheric plasticity for language. Recent studies, which demonstrate menstrual cycle-dependent changes in language processing, with greater bilaterality during the luteal phase on the one hand (Fernandez et al., 2003) and poorer performance in mental rotation or perceptual priming at the same time (McCormick and Teillon, 2001; Maki et al., 2002), increase the likelihood that our assumption might indeed be correct.

The present study so far replicates the finding of greater compensating capacities in atypically dominant women with L-TLE. Regarding the question of whether women will also display greater benefit from atypical dominance when surgery is performed, the data indicate that this is obviously not the case. Independent of sex, all except right dominant patients showed losses in verbal learning and memory. There was no sex difference and those patients with incomplete left dominance or bilateral patterns did not show a significant benefit from the fact that they had at least some language transfer. Losses in this group were marginally less significant than in the left dominant group, although in a larger sample the incomplete left or bilateral group might take an intermediate position. One can thus conclude that preserved verbal memory in the presence of L-TLE in women is fixed to an early time window when atypical dominance is developing, and that after this period only patients with complete RHD are protected against late left temporal lobe damage. As far as this can be inferred from postoperative changes in material-specific memory performance, the data did not confirm our hypothesis that seizure- or epilepsy-driven atypical dominance and associated memory patterns change when patients become seizure free. Atypical dominant patients who continued to have seizures did not show less, but rather greater losses in verbal and figural memory, than seizure-free patients.

As regards the group with L-TLE, the drop in verbal memory after surgery reflects what is already well established (Lee et al., 2002). Figural memory did not change after left temporal lobe surgery. However, a closer look shows that this is true only for LHD men. Atypically dominant men showed a significant deterioration after surgery, atypically dominant women tended to improve, and left dominant women showed slight worsening. Seizure control did not make a difference. Thus, if we consider figural memory to be a right hemisphere function which can be suppressed or sacrificed for the preservation of language-related memory, these postoperative changes can be interpreted as indicating dynamics in suppression and crowding patterns, and thus processes of late functional plasticity. The results provide evidence of further compensation mechanisms in atypically dominant men, also questionable in left dominant women, and in atypically language dominant women the data indicate a release effect as we have described with single cases before (Gleissner et al., 2002). Although this argumentation is speculative and the mechanism is as yet poorly understood, figural memory and thus the non-dominant temporal lobe system show astonishing dynamics in response to left temporal lobe damage. The postoperative findings together with the preoperative findings can serve as an explanation for
why the relationship between the right temporal lobe and figural memory is so inconsistent in different studies.

In conclusion, the present study confirms previous suggestions that atypical dominance appears to be more frequent in women than in men, but that, independent of this, women clearly benefit more from atypical dominance than men. The data do not provide evidence of a late greater functional plasticity for verbal memory in women. Conversely, it is indicated that incomplete hemispheric shifts of language do not prevent patients from memory loss and that the atypically dominant women’s advantage over men is fixed to an early time window in childhood. However, there is evidence of late functional plasticity and reversible suppression patterns indicated by the dynamics in figural memory performance after left-sided surgery. A direct effect of seizure control on suppression or crowding patterns of memory could not be demonstrated. Longitudinal observations in TLE patients have demonstrated that changes in memory can be expected several years after surgery and that seizure control and reserve capacities are crucial for this development (Helmstaedter et al., 2003; Rausch et al., 2003). The 1 year follow-up interval in the present study may not be sufficient to finally settle the question of long-term late plasticity after surgery.

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