Chapter 4

Lateralization of Auditory Rhythm Length in Temporal Lobe Lesions.

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ABSTRACT

In the visual modality, short rhythmic stimuli have been proven to be better processed (sequentially) by the left hemisphere, while longer rhythms appear to be better (holistically) processed by the right hemisphere. This study was set up to see if the same holds in the auditory modality.

The rhythm task as originally designed by Seashore was computerized and is part of the Fepsy Neuropsychological battery. This task was performed by 85 patients with intractable temporal lobe epilepsy (left TLE=32; right TLE=53) enrolled in the Dutch Collaborative Epilepsy Surgery Program. They performed the task before and 6 months after surgery. The task consists of 30 pairs of rhythmic patterns in 3 series of 10 items. The series contains patterns of 5, 6 or 7 notes. The purpose is to indicate whether the two patterns are the same or different. Reaction times are also measured. If the hypothesis is true, the short-item sequence will be better processed by patients with right temporal lobe epilepsy (non-impaired left temporal lobe), the longer sequence better by the left temporal epilepsy group (non-impaired right temporal lobe).

No overall laterality effect on rhythm perception could be found and no difference was found between both test moments. IQ did not correlate with rhythm performance. However, there was an interaction effect of laterality and rhythm length on performance and reaction time. This effect can be explained by the increase after the operation of the score of the left focus group and a decrease in the right focus group on the longer rhythms. This effect was somewhat less strong in the reaction times: a clear tendency for faster reaction times after surgery in the left and longer reaction times in the right focus group. The effect could not be explained for by the difference in extent of resection in either temporal lobe.

This study showed that memory for and discrimination of auditory rhythm is dependent on which hemisphere is used in processing. The effect could be demonstrated for the right hemisphere, which uses a holistic processing of stimuli, which outperforms the left in rhythms consisting of a long sequence. In left temporal resections an improvement occurs on the longer rhythms and in right temporal resections the performance on the longest rhythms decrease.
INTRODUCTION

There have been differing opinions as to whether auditory rhythm perception lateralizes between the hemispheres. The instrument with which this has been measured is the Seashore Rhythm Test (Seashore et al., 1960). Since the introduction of the Seashore Rhythm Test in the Halstead Reitan battery, this test is often included in standard neuropsychological screening or in the pre/post assessments in the neurosurgery protocol.

Auditory rhythm perception as a function has been reported as being sensitive to right-temporal lobe lesions (Lezak, 1983; Golden et al., 1981; Kolb & Wishaw, 1990). Steinmeyer’s overview (1984) of 3 older studies (Shure & Halstead, 1958; Wheeler & Reitan, 1963; Golden, 1977), did not find a preferential auditory rhythm perception deficit in right hemisphere lesions. It appeared that a significant impairment could be associated with left hemisphere lesions by pooling the results of these studies. A few other studies have not shown any hemispheric difference (Sherer et al., 1991; Boone et al., 1989; Karzmark et al., 1985; Milner, 1962). A study by Reitan and Wolfson (1989) took the edge off the argument for lateralizing to the right hemisphere, by finding no sensitivity of the rhythm test in left- or right temporal lobe lesions.

In all these studies, the accuracy of the perception was deduced from the mean number of correct items, i.e. of rhythmic patterns. As the Rhythm Test consists of three subtests with increasing length of stimuli, calculating only the mean score ignores possible differences caused by the length of the auditory rhythms. It is quite possible that the length of the auditory rhythms may be of importance for a difference in right or left brain information processing. This very hypothesis was tested for the visual modality (Ben-Dov & Carmon, 1984), in a study where the stimuli were sequences of light flashes either into the left or right visual field, thus restricted to the right or left hemisphere. Subjects were ‘normal’ students without known brain damage. Increasing rhythm length resulted in a shift in cerebral dominance from left to right.

The present study was undertaken to test the same hypothesis for the auditory modality: our assumption was that shorter “rhythms” would be better processed in the left hemisphere (determined by a higher number of correct detections and a shorter reaction time), “longer rhythms” better in the right hemisphere.

METHOD

Participants

All 85 patients operated between 1986 and 1998 for their intractable temporal lobe epilepsy (TLE) were included. These patients were enroled in the Dutch Collaborative Epilepsy Surgery Program. Temporal lobe focus lateralization was assessed based on video monitoring semeiology, interictal and ictal scalp EEG, MRI and PET in selected cases. In inconclusive cases depth EEG was performed according to the method described by Van Veelen et al. (1990) and by Gerritsen et al (1995).
As shown in Table 1, there are more patients included with a right than a left temporal focus. Gender, age and age at seizure onset are uniformly spread among both groups. Patients with a right temporal focus had a higher ($p=.05$) Verbal IQ (VIQ), which is a common finding (Chelune et al., 1993; Selwa et al., 1994). Although patients with IQs as low as 70 were entered in the surgery protocol, mean IQ was higher than in most other studies. Patients were neuropsychologically tested before surgery. The interval between this pre-test and the actual surgery was variable, however not different between both lateralization groups. All patients had undergone a standard neuropsychological assessment one and a half days before surgery. They were neuropsychologically assessed 6 months postoperatively (a period in which the effects of edema have disappeared), and
two years and six years postoperatively. In this study, only the first post-operative test moment has been included to be compared with the pre-operative scores, because numbers at the other times are still relatively small.

Because there is normally no risk of postoperative speech problems in the nondominant hemisphere, resections in the right temporal lobe usually are somewhat larger than in the left. In our sample the right temporal resections exceed the left by 1 cm.

A histological analysis done on the dissected brain tissue shows that the diagnosed pathology mainly (65 out of 85) consists of two types: a large group of 49 patients with exclusively mesiotemporal sclerosis (MTS) without other abnormalities and a smaller group of 16 patients with different kinds of tumors in the temporal lobe.

Stimuli
The Seashore Rhythm test is based on neuropsychological principles as originally presented by C.E. Seashore in 1939 (Seashore et al., 1960), and is part of the computerized neuropsychological battery that we developed (Alpherts, 1987; Alpherts & Aldenkamp, 1990).

Thirty pairs of rhythmic tone patterns generated by a PC were presented in 3 series of 10 items each. The first series contained patterns of 5 musical notes, the second of 6 and the third of 7. The purpose was to indicate whether the paired patterns are the same or different. In each series, half of the paired patterns are different. The duration of each note in the pattern was 70 msecs + a rest of 60 msecs, pitch was 500 Hz and interstimulus interval (ISI) was 1 sec. By means of variable “rests” added to the standard rest of 60 msec between each note a rhythmic pattern was constructed. A typical pattern from series 1 lasts 1475 msecs, from series 2 2005 msecs and from series 3 2595 msecs. Pair 4 of the first series is shown in figure 1 as an example of one item.

Fig. 1
Example of pair 4 of the first series.

<table>
<thead>
<tr>
<th>pattern 1 (1475 msecs)</th>
<th>ISI (1000 msecs)</th>
<th>pattern 2 (1475 msecs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>♦ ♦ ♦ ♦ ♦</td>
<td>♦ ♦ ♦</td>
<td>♦ ♦ ♦ ♦ ♦ ♦</td>
</tr>
<tr>
<td>t r² + 165³ tr + 165</td>
<td>tr + 330 tr</td>
<td>tr + 35 tr + 295 tr +</td>
</tr>
<tr>
<td>t r + 165 tr + 330 tr</td>
<td>tr + 330 tr + 165</td>
<td></td>
</tr>
</tbody>
</table>

1 t = tone of 70 msecs
2 r = rest of 60 msecs
3 variable “rests” in msecs
All reaction times were measured starting with the end of the second pattern. If no reaction was given within 15 seconds the item was scored as a miss and the next item was generated.

RESULTS

A repeated measurements analysis of variance was performed on the data with group differences between the TLE groups as between factor and rhythm length (5, 6 or 7 notes) and moment of testing (before or after surgery) as within factors. To check for the influence of IQ on rhythm performance, an analysis of covariance (ANCOVA) with the IQs and the difference between VIQ and PIQ as covariates was carried out. The mean rhythm scores and reaction times are shown in Table 2.

Table 2
Means and Sds of rhythm score and reaction times

<table>
<thead>
<tr>
<th></th>
<th>focus left</th>
<th>focus right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhythm length</td>
<td>5  6  7</td>
<td>5  6  7</td>
</tr>
<tr>
<td>Items correct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre surgery</td>
<td>9.2 (1.3)</td>
<td>8.6 (1.7)</td>
</tr>
<tr>
<td>After Surgery</td>
<td>9.0 (1.8)</td>
<td>9.0 (1.3)</td>
</tr>
<tr>
<td>Reaction time(^2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre surgery</td>
<td>783 (528)</td>
<td>899 (526)</td>
</tr>
<tr>
<td>After Surgery</td>
<td>792 (549)</td>
<td>831 (450)</td>
</tr>
</tbody>
</table>

\(^1\) Sds in brackets  
\(^2\) in msecs

Main effects (laterality, rhythm length, test moment).

As can be seen from the results of the MANOVA in Table 3, upper section, no global effect of focus laterality was found, either on the overall rhythm score, or on reaction time: patients with left or right resections had the same overall rhythm scores and reaction times.
Table 3
Repeated Measures Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Rhythm Score</th>
<th>Reaction Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Between subjects</td>
<td></td>
</tr>
<tr>
<td>Laterality</td>
<td>1</td>
<td>.08</td>
<td>.00</td>
</tr>
<tr>
<td>within group error</td>
<td>83</td>
<td>(7.65)</td>
<td>(991330.19)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Within subjects</td>
<td></td>
</tr>
<tr>
<td>Rhythm length</td>
<td>2</td>
<td>101.2***</td>
<td>112.32***</td>
</tr>
<tr>
<td>Laterality x Rhythm length</td>
<td>2</td>
<td>.02</td>
<td>.88</td>
</tr>
<tr>
<td>within group error</td>
<td>166</td>
<td>(1.37)</td>
<td>(60573.69)</td>
</tr>
<tr>
<td>Measurement (test moment)</td>
<td>1</td>
<td>.09</td>
<td>.13</td>
</tr>
<tr>
<td>Measurement x Laterality</td>
<td>1</td>
<td>3.85*</td>
<td>2.36</td>
</tr>
<tr>
<td>within group error</td>
<td>83</td>
<td>(.91)</td>
<td>(198734.68)</td>
</tr>
<tr>
<td>Rhythm length x Measurement</td>
<td>2</td>
<td>1.89</td>
<td>2.1</td>
</tr>
<tr>
<td>Laterality x Rhythm length</td>
<td>2</td>
<td>2.33*</td>
<td>1.11</td>
</tr>
<tr>
<td>x Measurement</td>
<td>166</td>
<td>(.63)</td>
<td>(55406.98)</td>
</tr>
</tbody>
</table>

Note. Values enclosed in parentheses represent mean square errors.

* $p \leq .10$.

** $p \leq .05$.

*** $p < .001$.

As IQ is correlated with the rhythm score (Moore & Hannay, 1982), differences in IQ could be responsible for the lack of hemispheric difference on Rhythm variables (Table 4). ANCOVA with the IQs and the difference between VIQ and PIQ as covariates, however, showed only a slight drop in p-value on overall rhythm score (VIQ as covariate: $p= .35$), which was not enough to be significant, indicating no discriminating effect on laterality of resection.
Table 4
Correlations between IQ and the dependent variables (before surgery)

<table>
<thead>
<tr>
<th>Rhythm length</th>
<th>rhythm score</th>
<th>reaction time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>VIQ</td>
<td>.31**</td>
<td>.37***</td>
</tr>
<tr>
<td>PIQ</td>
<td>.40***</td>
<td>.38***</td>
</tr>
<tr>
<td>FSIQ</td>
<td>.38***</td>
<td>.42***</td>
</tr>
<tr>
<td>difference VIQ-PIQ</td>
<td>-.05</td>
<td>.04</td>
</tr>
</tbody>
</table>

** p < .01.
*** p < .001.

As could be expected, a strong rhythm length effect was found. Longer items were more difficult and required a longer reaction time.

A global measurement effect (test moment, before and after surgery) could not be established: the overall mean rhythm score before and after surgery was 8.4 (sd 1.1 vs. 1.3), the overall reaction time before surgery 936 msecs (sd 421) and after surgery 937 msecs (sd 466).

Interaction effects (laterality x rhythm length, measurement x laterality, rhythm length x measurement).

There was no global effect of rhythm length on the correct detection of rhythms regardless of focus laterality, when the pre- and post-surgery scores were pooled together.

Test moment (before vs. after surgery) had a significant effect (p<.05) on the overall rhythm score of patients with left or right foci. The mean score of the left TLE group rises from 25.1 to 25.7, the mean score of the right TLE group dropped from 25.4 to 24.9.

As resections in the right temporal lobe were larger than in the left lobe (5 cm vs. 4.1), the analysis was rerun (ANCOVA with extent as covariate). The result still shows significance (p=.046). From this, it is clear that the extent of resection does not have an effect on rhythm perception.

Figure 2 shows the results for the two three rhythms: a tendency of an interaction effect on the 6-rhythm length rhythm (p=.12), caused by an increase of the score from 8.6 to 9.0 in the left TLE group, while the scores of the right TLE group remain the same (8.8). A significant interaction effect was seen (p=.03) on the longest rhythm: an increase in the
left TLE group from 7.2 to 7.6 and a decrease in the right TLE group from 7.5 to 7.2. This confirms the second part of our hypothesis: longer rhythms are better processed in the right hemisphere.

**Reaction times**
The only main effect that was significant in reaction times was the factor “rhythm length”. Not surprisingly, longer items require longer reaction times.

**DISCUSSION**
The purpose of this study was to take the auditory modality by using the Seashore Rhythm Test, to test the hypothesis confirmed by Ben-Dov & Carmon (1984) which showed that long rhythmic visual stimuli are better processed in the right hemisphere, whereas short stimuli are better processed in the left hemisphere. In the study of Ben-Dov and Carmon subjects were 24 students without any known neurological disease. In order to test the functioning of either hemisphere, light stimuli were flashed to one visual half field, and thus to only one hemisphere. It is not possible to test the auditory hypothesis in subjects without brain lesions, because the auditory pathways are not as separated as the visual ones. Sound presented to one ear always reaches both hemispheres in some degree. Our study was carried out with data from patients with TLE who were operated for relief of their pharmaco-resistant epilepsy in either the left or right temporal
lobe. This gave us an extra opportunity to check for differences in performance and laterality before and after surgery.

One result is that we did not find an overall effect of hemispheric laterality of the epileptogenic focus on auditory rhythm performance. This is in line with most other studies (Sherer et al., 1991; Boone et al., 1989; Karzmark et al., 1985; Reitan & Wolfson, 1989; Milner, 1962). This concluded absence of an overall laterality effect holds only for the total (summation) score. The Rhythm Task is subdivided in 3 subtests with different lengths of rhythms. Moreover, these 3 subtests differ in difficulty, as the rhythm length effect proves. The summation of scores may therefore not be accurate to assess differences in processing of rhythms of different length in either hemisphere.

Secondly, we found an effect of the side of the hemisphere where the resection took place on the performance of the subjects after the operation. If we break down the pooled results before and after surgery, an interesting interaction effect is revealed. In left TLE patients the scores on the two longest rhythms increase, in right TLE patients the score of the 6-item trials remains the same and of the 7-item trials decreases. This effect is significant for the longest trials. This means that after surgery the group with a healthy right temporal lobe (left TLE group) performed better than before surgery, while the opposite was true for the group with a healthy left temporal lobe (right TLE-group). Right sided resections are routinely larger than on the left, and could thus easily explain the difference found in performance. However, this effect remains, even where the analysis is being controlled for the extent of the resection.

As the subjects were retested after surgery, there could be a learning effect, an overall increase in performance. However, this was not found in our study. This is completely in line with the study by Boone & Rausch (1989). Their patients, an epilepsy surgery group comparable to ours, showed an overall nonsignificant decrease in rhythm score from 25.4 to 24.9. In an inspection of data (unpublished results) from our epilepsy database we could select 31 patients with epilepsy (a nonsurgical group) which were retested for various reasons (mean interval 1.2 years, not very different from this study). Their scores did not show a change (24.0 vs. 24.2). We can thus conclude that the lack of retest effect on the Seashore Rhythm Test in our patient group is not due to the effects of temporal lobe surgery.

The Seashore versions A (length 5, 6 en 7) and B (length 7, 8 en 9) have been compared in an earlier study in relation to the VIQ and PIQ (Moore & Hannay, 1982). A positive VIQ-PIQ difference was supposed to predispose for more sequential (LH) processing than parallel (RH) processing. Difference in rhythm length could enhance this effect. Subjects with high verbal IQ’s indeed performed less well on the long rhythm sequences. This effect was only found in the Seashore A version, not in the B version. We indeed found a high correlation between IQ and the rhythm score. This, however, holds for all 3 IQ scores (FSIQ, VIQ and PIQ) which led us to include IQ as covariate. We did not find a negative correlation between the VIQ-PIQ difference and longer rhythm lengths. As a consequence, the covariance analysis did not enhance significance of different rhythm performance in patients with either left or right foci.

The results of this study cannot be fully generalized to the use of the Seashore Rhythm Test as originally designed by Seashore. We used a computerized version in
which the response of the subject could last as long as 15 seconds, whereas in the original version the subject had to keep pace with the test. Items came quickly and the subject had to evaluate the stimuli quickly and prepare for the next one. However, the range of means of our reaction times (721-1244 msecs) are short. There was no tendency of patients to either wait or have longer reaction times than in the original form. In our opinion there is no real difference between the type of processing used in these two versions.

As a consequence of tissue resection some functional brain tissue may be removed, but the disturbing influence of the epileptogenic tissue will disappear. In our case it is reasonable to state that improved performance may be due to the disappearance of disturbing factors, as in left temporal lobe resections, and a decline in performance due to removal of functional tissue. As a consequence, our study illustrates that a healthy right hemisphere appears to be more suited for discrimination of longer rhythms than a healthy left hemisphere. This effect was seen only for the “longer” rhythms and not for the “shorter”, probably because the latter are too simple to discriminate for an effect to be detected (Charter & Webster, 1997).

ACKNOWLEDGEMENT

The authors are grateful to Prof. F.H. Lopes da Silva, Prof. C.B. Dodrill and Prof. A.P. Aldenkamp for their kind cooperation.


