The neurocognition of second language acquisition: The influence of proficiency level on cortical brain activation patterns

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A neurophysiological EEG imaging study was conducted to elucidate differences in neuronal network recruitment between linguistically more proficient language students and less proficient non-language students during foreign language TV-processing.

The main questions treated by this study are the following: do differences of proficiency level in speaking and understanding a second language have a neuro-biological manifestation, for example, in the form of different “brain routes” or special activity patterns. If so, this could be seen as a neuronal alteration in response to different learning conditions. If this difference in level of L2 competence does cause a distinction, to what degree and form do these two groups of “more“ or “less“ proficient language learners differ in terms of their brain activity patterns and what could this mean for the second language learning process. It is shown that different cognitive or neuro-biological language processing strategies can be made visible by a brain imaging tool like the EEG.

1. Theory

1.1. Right / Left Hemisphere and Bilingualism

In experimental neurolinguistics the role of the right hemisphere in language processing has been discussed extensively over the last decades. Especially such language-related aspects as intonation (emotional prosody), pragmatics, semantics and non-verbal communication (gesticulation and facial expressions) have been proposed to be primarily processed by the right hemisphere. (Van Lancker, 1997). Moreover, the right hemisphere has been assumed to play a key role at the beginning of the language acquisition process, when someone is beginning to learn a second language. It has been assumed that the right (non language-dominant) hemisphere “helps” the left hemisphere in so

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far as it adopts a holistic strategy to make the language learning process easier in its initial stages. The initial stages are the first years of the acquisitional process, when a learner is not yet experienced enough to develop grammatical “automatisms“ in the second language (left hemisphere) and thus resorts to imagery and holistic thinking to tackle the acquisitional problems.

According to Obler (1981) and Galloway & Krashen (1980), the initial stages of adult second language acquisition recapitulate children’s right-to-left hemispheric shift in relative hemispheric dominance during L1 acquisition. This is in line with the assumption of Paradis (1994), who states that monolingual children have to rely on right hemisphere-based pragmatic processing during their first years of language acquisition, in order to derive an interpretation for utterances in that language for which the required automatic linguistic competence has not yet been fully internalized.

Obler’s model is referred to as the Stage Hypothesis in Second Language Acquisition research. According to this model, the right hemisphere’s relative dominant functioning, during the initial confrontation with novel stimuli such as in the case of foreign orthography and semantics, would be advantageous (Gordon & Carmon, 1976; and Hardyck, 1980). For example, the right hemisphere would have a preeminence over the left hemisphere in the processing of foreign tonal patterns and intonation as well as emotional tone (Galloway, 1982). Obler’s model implies increased involvement of the left-hemisphere during later stages of the learning process, when a sophisticated level of grammatical accuracy has been gained. This may occur when a basic vocabulary of novel words must be arranged in particular word order sequences according to foreign grammatical rules. Even though not a hemispheric theory per se, it suggests that learning styles and strategies may change after initial exposure to information which may be different from later, more grammatical strategies. If Obler’s model is correct, one would expect to see greater right-hemisphere activation during the early stages of adult second language acquisition, e.g. in the first years of learning (if instruction is not very intense). This predominance ought to decline during later stages, when the person’s grammatical knowledge increases. Moreover, left-hemisphere activation for the same time and skill progression would either increase or remain the same. This is the case since students in foreign language classes engage left-hemisphere processes during language learning activities (Conesa et al., 1999). Finally, a corollary of Obler’s model is a relationship between the time of exposure / increased experience in a second language acquisitional setting and greater left-hemisphere involvement. Conversely, one would expect right-
hemisphere dominance to be associated with limited experience in the second language.

→ From this derives hypothesis 1 of the present study: The non-language students should show more activity in the right hemisphere because of their lower language proficiency level.

1.2. Cortical Efficiency

The second theoretical assumption of this study relies on the neuropsychological concept of cortical efficiency. The basic idea of this concept is that individual differences between persons with high versus low performance (either because of high or low aptitude or due to more or less training) can be indicated by the localization and the amount of brain activity. Persons of good and poor performance are thus expected to differ in their recruitment of neuronal networks or circuits.

The concept of neuronal efficiency was introduced by J. Ertl (1969) assuming that higher ability in a cognitive task is associated with more efficient neuronal processing of this task. Several functional neuroimaging studies (e.g. EEG) have tried to verify this assumption later. This very basic concept of efficient versus inefficient neuronal “wiring” can be taken as an underlying theory which can be investigated with various methods and efficiency can be seen in the light of various physiological parameters.

By measuring glucose metabolism, the concept was reintroduced and investigated extensively by the group around the American psychologist Richard Haier. Haier et al. started out by investigating the relationship between intelligence and brain glucose metabolism with the help of PET (Positron Emission Tomography). In several studies (Haier et al., 1988; Haier et al., 1992; Haier et al., 1995) they could show a negative correlation between intelligence measures and glucose consumption. More intelligent persons consumed “less energy” (meaning decreased glucose-consumption) than less intelligent persons. The brain scans during the intelligence tests indicated that higher metabolic rates (more activity) were associated with lower intelligence scores and lower metabolic rates with higher intelligence scores. The authors interpreted the results as an expression of higher cortical efficiency in performance groups with higher intelligence scores and vice versa. “Smarter brains burn less glucose” became the famous slogan that comprises the idea behind the concept of cortical efficiency in one sentence in PET terminology. Less activity of more intelligent and more effective brains is measured by the consumption of less glucose and this may in turn “reflect greater increases in
automatic processing in the high-ability subjects after practice, which would result in fewer extraneous brain areas being used for the task, and thus result in a greater decrease in Glucose Metabolic Rate (GMR). Haier et al. see these results as consistent with the “efficiency hypothesis” (Haier et al. 1992). Similar findings were reported by Parks et al. (1988), who found that verbal fluency scores were negatively correlated with brain metabolism.

It is conceivable that subjects who found the verbal fluency task to be difficult, exerted a greater degree of effort so that they evidenced the greatest amount of activation. Similarly, it is possible that those with greater verbal fluency used more efficient strategies in their cognitive operations so that little effort needed to be expended. (Parks et al., 1988; p.572)

However, not only aptitude, ability or general intelligence in problem solving strategies was measured here. There is the aspect of training and task-evoked effort in skill acquisition (e.g. playing the piano, doing mental rotation tasks). This was also interpreted as consistent with the efficiency theory and resulted in better performance after practice but lower metabolic rate. The overall pattern of inverse correlations between decrease in glucose metabolic rate following learning and higher intelligence scores, suggests that high-ability subjects may have the most gains in automatic processing. This increased automatic processing in high-ability subjects after practice would result in fewer extraneous brain areas being used for the task. This efficiency may derive from the disuse of many brain areas irrelevant for good task performance as well as the more focused use of specific task-relevant areas. Since language acquisition (with subsequent language use) can be seen as a skill which can be automatized and made more efficient by practice and, moreover, as a skill that could most efficiently and quickly be automatized in high-ability persons (language talents) – the theory of cortical efficiency could also apply to language acquisition.

Æ This leads us to the formulation of hypothesis 2: The NON-Language students should show more overall brain activity, they should activate more distinct brain areas than the more experienced and perhaps at the same time more language-talented English students, because they need more brain circuits to solve the same, but for them more difficult language tasks. The English students, on the other hand should have developed a more efficient strategy and thus use less brain tissue.
2. Method and Data Analysis

2.1. The EEG

The EEG (Electroencephalogram) measures the electrical activity of networks or large circuits of brain cells (pyramidal cells) in the outer layers of the cortex (for an overview about the EEG see H. Petsche, 1998; Reiterer, 1999).

Activated nerve-cells of the brain generate electric signals, the so-called action-potentials of postsynaptic electro-chemical processes. In the standard procedure 19 metal electrodes are glued to the scalp according to an internationally fixed positioning system (the so-called “10/20-system”) and thus the oscillatory activity of the cortex (“brain waves”) is recorded. During registration, oscillations are amplified, filtered, digitized, inspected for disturbing artifacts and analysed further.

2.2. Method of Analysis

This section gives some background information about experimental possibilities in EEG research. There are basically three distinct ways in which the raw data of the recorded EEG can be further analysed: Firstly, by measuring “ERPs” (event-related potentials, high time-resolution in the millisecond-range), secondly, DC-EEG (slow potentials – low time-resolution, high space resolution) and thirdly by employing COHERENCE ANALYSIS, a spectral-analytical method, that takes into consideration the frequency characteristics of the spontaneous EEG activity of all electrode positions and by comparing the similarity of the signal characteristics (amplitude, wave shape) and establishes correlations between several cortical areas. This method can trace cooperative processes in the cortex which occur in a certain time interval, possible from the millisecond to the minute-range. The third method (Coherence Analysis) was used in this study.

The frequency ranges (delta, theta, alpha, beta) are then closely inspected, one after the other. If the underlying cortical areas of two electrodes oscillate within the same frequency range at a given point in time, (e.g. task=2 minutes of watching TV in English) then these two parts of the brain are said to cooperate for performing this task. It is this cooperation of two different areas of the brain which is expressed by a coherence value (a kind of correlation coefficient). If coherence is high between the EEG-signals of two electrodes positioned on the scalp, there is an increased functional interplay, meaning increased activity between the neuronal assemblies generating those signals. If
coherence is low, the functional interplay between the involved areas is low. Coherence ranges from 0 – 1 and is expressed by a coherence-coefficient which is converted into a statistical value and presented as a line on the brain maps. (For the mathematical descriptions and technical aspects of coherence analysis see Rappelsberger 1977, 1988, 1993).

3. Study Design

3.1. Subjects
There were two groups under investigation. A group of English students and a group of non-English (and non-language) students. The two groups of students, who volunteered to participate in the study, consisted of 38 (19 persons each group) right-handed, female students of 24 years of age in the mean (ranging from 20 to 30 years, standard-deviation: 2,5 years; median: 23,6 years) whose mother-tongue was German. Thus, handedness, sex, mother-tongue, field of study, place of study and age - were the controlled variables.

The two groups participating in the study can be described as follows:
Group 1: The English students. The first group was the one of the “experts” for English as a foreign language. The participants were studying or had studied for a degree in English Language and Literature at the University of Vienna. Those who were still studying were at an already advanced level (2. Studienabschnitt). They were assumed to be good language learners with regard to English as a second language, having a profound knowledge of the English language and good comprehension skills, because English is not only the subject but also the medium of their studies. The average amount of time they had spent abroad in an English-speaking country was 10 months.

Group 2: Non-English students. The control group was the “lay-persons”-group. They were students of various disciplines, except language studies. Persons of this group studied medicine, psychology, biology, business and mathematics. They all had basic or moderate knowledge of English because they learned English at school and had to do an English exam to pass their A-levels, but their level of proficiency was intermediate compared to that of the English-students. They certainly lacked particular language comprehension skills which the language students had acquired during the course of their studies. The most important criterion in this group was the condition that the students had not developed their English-skills any further in a decisive way since their school-leaving examinations and that they described themselves as not being especially interested in or talented for English. The mean amount of time spent abroad in an English-speaking country was 5 weeks in this group.
According to the theoretical model described in 1.1., this group functions as the group whose foreign language automatic linguistic competence has not yet been fully internalized because of lack of training and exposure time. A group of even lower proficiency level (absolute beginners) have deliberately not been taken as subjects, because of psycho-experimental problems with the stimulus material. If absolute beginners had been used, they would have understood very little of the presented texts and therefore probably have stopped watching the videos and initiated distracting thought journeys.

3.2. Stimulus Material

The subjects were seated on a comfortable relax-armchair in a small acoustically screened, dimly-lit experimental room where they had to watch / listen to various video sequences of TV / Radio reports, features, discussions or interviews while their EEG was recorded. Nine different video sequences of TV news were presented by a single male speaker (close-up focus) in randomised order and in 3 conditions: as a normal TV scene (visual + acoustic), as a pure acoustic presentation and as a pure visual presentation. Control conditions (base line tasks) were also inserted randomly. The base-line task was looking into a grey flickering picture while trying to think as little as possible. The duration of a typical task as well as control-item was approximately 2 minutes. The whole EEG-recording session took 3 hours in total for each student.

Figure 1. The stimulus material

<table>
<thead>
<tr>
<th>British English:</th>
<th>American English:</th>
<th>Austrian German:</th>
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<tbody>
<tr>
<td>John Cleese</td>
<td>Senator Baker:</td>
<td>Fritz Verzetnisch</td>
</tr>
<tr>
<td>„How to irritate people“</td>
<td>About the Clinton case (visual+acoustic)</td>
<td>About a tax reform (visual+acoustic)</td>
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<td>(visual + acoustic)</td>
<td>(visual+acoustic)</td>
<td>(visual+acoustic)</td>
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<tr>
<td>BBC-Radio-Speaker about South Africa</td>
<td>American Radio Speaker about Bacteria (scient.)</td>
<td>Ö1-Radio speaker about the Vienna Stock Exchange</td>
</tr>
<tr>
<td>(only acoustic)</td>
<td>(only acoustic)</td>
<td>(only acoustic)</td>
</tr>
<tr>
<td>Chris de Burgh</td>
<td>CNN-Speaker</td>
<td>Prof. Johannes Huber</td>
</tr>
<tr>
<td>TV-interview</td>
<td>In front of White House</td>
<td>In „Zur Sache“</td>
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<tr>
<td>(only visual)</td>
<td>(only visual)</td>
<td>(only visual)</td>
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To substantiate the group differences in linguistic abilities and as behavioural measure of validation, after each sequence the students were asked compre-
hension questions. The questions reflected the different proficiency levels of the two groups in understanding the English texts. As expected, the non-English students understood only approximately 50% of the English contributions, whereas the English students understood the texts nearly perfectly. But, strangely enough, when it came to understanding and reporting the German texts, the non-English students also scored slightly worse than their English studying colleagues! This is a marked detail which will be interesting for the interpretation of the EEG results. As examples of the TV reports listened to by the participants, three of the items are provided in the appendix with their subsequent comprehension questions: 1. John Cleese, 2. About South Africa, 3. Chris de Burgh.

3.3. Reasons for choosing the stimulus material

The presentation of language stimuli as multi-modal parts of real spoken speech where the speakers can be seen articulating and gesticulating, was chosen to imitate a natural and frequent communicative situation of every-day life. The most important criterion for presenting the foreign language stimulus material in video form was, that it captures the naturalness of a communicative situation which closely resembles a form of spoken linguistic reality: you sit or stand in front of a person and listen to what he is saying while at the same time you are watching his gestures and facial expressions, observing the whole person with his idiosyncratic movements, voice and looks that accompany the act of speaking – which is, in short, the whole pragmatic act itself. It is precisely this pragmatic aspect, capturing the social meaning of a linguistic output within its situational and contextual embeddedness, which is so scarcely investigated with neuropsychological methods. The intention behind this is to investigate the mental processing of language as it occurs in context, and not language as isolated sentences or words. The cerebral organisation of language on the word- and sentence level has been investigated extensively with PET, fMRI and ERP studies and voices have been raised that more research should be carried out on the processing of coherent language on the discourse-level, where phonetic, grammatical, semantic and pragmatic aspects of language have to be integrated. This could shed new light on the questions concerning the cerebral and neuronal organization of language phenomena. Due to methodological restrictions, ease of implementation, fear of the inability to interpret complex “full language” stimulus material and simply interest in other aspects of language processing, there are large numbers of investigations in the field of cognitive neuroscience which are based on the single-
word-presentation or isolated-sentence-presentation paradigm, but there are hardly any neurolinguistic studies which investigate language in its full context – that is to say – with a stimulus-item that contains components of all levels of linguistic organization (syntax, morphology, semantics, lexicon, phonetics (including word and sentence prosody, and pragmatics). Other brain imaging studies with the focus on bilingualism that make use of such language input - investigating short story processing - are using PET or fMRI as method of analysis (compare Perani 1996, 1998; Dehaene 1997). To date there have only been two EEG studies conducted in this manner, investigating mental interpreting (compare Petsche, 1998).

4. Results

This diagram provides a visual summary and reflects the essence of the main results. For the purpose of this paper the results for the visual items are not discussed. (For details see Reiterer, 2002.):

*Figure 2. Summary of brain activation results for the two groups of subjects*

**NON-Language-Students**

**English - Students**

**HOW TO INTERPRET THESE BRAIN MAPS:**

**Solid lines – Increase in coherence**

The solid lines presented on the brain maps connecting the single electrode positions mean an increase in coherence as compared to a base-line activity (task minus base-line). Coherence is defined as cooperative activity between cortical areas which cooperate during a certain task. Therefore, an increase in coherence means more connected activity and more cooperation during a certain task.
No lines - No coherence
The missing lines indicate no or almost no cooperative activity between two or more brain areas.

Broken Lines - Decrease in coherence
If there is a decrease in coherence or cooperative activity, as compared to the base-line condition (i.e. more cooperative activity in the baseline than in the task), then it is indicated as a broken line on the brain maps. And this third kind of activity is a very special one, because its interpretation is still an unresolved issue as will be explained later in the text.

T3 and T5
are the labels of electrode positions – the T stands for temporal lobe (the lobe above the ear). The temporal lobe is one of the four lobes (the others are: occipital, frontal, parietal) and “houses” the primary acoustic cortex.

4.1. Ad hypothesis 1 (Right / Left Lateralization)
Do the non-language students show more right hemisphere involvement, because they use a more holistic language strategy?

*Figure 3. Intergroup comparison of lateralisation*

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<thead>
<tr>
<th>NON-English-students</th>
<th>English-students</th>
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<tbody>
<tr>
<td><img src="image1" alt="Alpha1" /></td>
<td><img src="image2" alt="Alpha1" /></td>
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<tr>
<td><img src="image3" alt="Alpha1" /></td>
<td><img src="image4" alt="Alpha1" /></td>
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Alpha1: only the Alpha 1 frequency band (8-10 Hz, classical Alpha) was analysed in detail, because it reflected the most pronounced results.

The answer is no! There is no statistically significant difference which regards the use of the right hemisphere alone. Extensive right-hemispheric activity could neither be attested in the predicted group of the non-English-students, nor in the group of the English-students. The focus of activation during the language tasks was in the Left hemisphere in both groups! There was no significant difference between the groups concerning the place of activation. In other words, the right hemisphere was not more involved during the tasks.
than the left hemisphere within the group of the non-English students, as the hypothesis would have predicted. As a result, hypothesis 1 was rejected.

Only the extent of the activation was markedly different between the two groups (see hypothesis 2). The core centers of activation lay in the left hemisphere for both groups with the following refinements:

The English students’ activity was restricted to certain regions of the left temporal lobe (above the ears) where the center for language understanding is located (the so-called Wernicke center; see in figure 2: T3, T5 - most active electrodes - see the small circle on the left side in right brain map in Figure 2. The non-English students’ activity extended almost to an intricate network (see big circle in the left brain map in Figure 2, which involves almost the entire left hemisphere and also some parts of the right. When regarding the right hemisphere alone, no significant group differences come to light.

The right hemisphere is presumably involved in the language tasks as well in both groups, but probably only to a minor extent, so that it plays only a marginal role in these tasks.

Thus, the left / right hemisphere model does not explain the results so adequately as does the second theoretical model of “cortical efficiency”.

4.2. Ad hypothesis 2 (Cortical Efficiency)

Do the experienced English-students adopt a more efficient strategy and therefore have less cortical effort – reflected by less overall brain activity?

Figure 4. Cortical efficiency over all audio and visual tasks

The tentative answer is, yes. Systematic (meaning in all 9 tasks) and statistically significant differences could be obtained for the extent and distribution of the activity patterns and for the coherence increases and decreases (focal versus diffuse activation).
The non-English students had many coherence increases, which sometimes spanned the entire cortex, but in most of the cases the core activity lay in the left hemisphere. (See also the mapping overview below, Figure 6.)

In contrast to that, within the group of the English Students, the following picture emerges: 1. accentuated frontal decreases in coherence (broken lines – see small frontal circle in the right brain-map in Figure 2 and 2. only selectively focused connections over the language areas of the left hemisphere (left-sided circle in right brain-map in Figure 2) could be found, which points to a selective activation of the Wernicke-region, localizable under the electrode positions T3, T5. The Cortical Efficiency hypothesis was accepted.

4.3. Activation of the prefrontal cortex

One of the most marked results of the present study was the difference between the two groups with regard to prefrontal cortex activation. Only the English students showed decrease in coherence over the prefrontal areas.

The decreases in coherence (less cooperation during task than during baseline – the broken lines in the brain maps) don’t mean „less activity“, but could either mean 1) more focused activity in yet smaller areas of the frontal cortex (isolated activity in many small regions, because no stable connections between areas have yet been established) or 2) a shift of the activity towards more subcortical structures (deeper) brain structures.

4.4. No difference between the languages

As far as one can detect from visual inspection of the mapping data alone, there is no notable difference between the items presented in British English, American English or even German, although the German items - paradoxically enough - show even more pronounced coherence increases, a result and at the same time question, which remains unresolved, at least by this study.
Figure 5. Overall intergroup comparison
For each language, the two language items with audible speech input were averaged

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<td>NON-Engl.-Students</td>
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5. Discussion

The frontal cortex is now known to be a very important wiring place for a wide range of cognitive demands, amongst which working memory plays the most prominent role. But a wide range of other aspects of cognition have also been attributed to the frontal cortex. Data from human neuroimaging and monkey electrophysiology are used to provide information on how the prefrontal cortex is functionally specialized. The data show that the prefrontal cortex is activated by increasing demands in a wide variety of cognitive domains, including perception, response selection, working memory, problem solving, executive control, verbal episodic memory, auditory discrimination, semantic processing of words and focused attention, amongst others (Duncan, 2001). In summary one can say that many current views of prefrontal function reflect that its tasks are in the first place specific cognitive control functions and secondly, maintenance and organization of working memory.

Related to the above mentioned control functions is, set switching and inhibition of inappropriate behaviour. An interesting and for this study highly relevant finding is the prefrontal function of strategy selection.

That the frontal cortex plays a major role in the processing of tasks where general human intelligence is needed, or even that the frontal cortex is the seat of human intelligence, is a longstanding view, that has often been discussed (see also Haier, 1992) and currently again is a hotly debated issue (Neubauer et al., in press).

If the English students show more activity in the prefrontal cortex, does that mean that they have better access to their working memory, attention, strategy control, or even to their faculty of intelligence?

According to interpretation 1) (see 4.3.) the extensive decrease in coherence over the frontal cortex in the group of the English students could stem
from a very specific involvement of the prefrontal areas. If this is true, it would mean that the group of English students did something with their forebrain that the others, the non-language students, did not. This something, could mean that they activated their prefrontal areas in a very specific way, which could reflect a higher involvement of the prefrontal cortex, to achieve the following goals: a better use of 1) working memory, of 2) verbal episodic memory, 3) selective attention, 4) executive control mechanisms, 5) semantic processing of words, 6) auditory discrimination, and 7) selection of the right strategy. It could mean that the English students have developed better strategies of understanding or decomposing language, because they have a better command of their working memory, attentional and control mechanisms, semantic processing of words and the other above mentioned mechanisms. Alternatively, they might possess a more intelligent strategy to tackle the language tasks, which in turn is an achievement of their efficient use and selective employment of the prefrontal areas, due to intensive practice, better knowledge of language structures or simply a more automatized skill in listening comprehension. In the non-English students instead, these prefrontal areas are not involved in this way, because their focus is not set so much on attention, memory and control-related demands, for their primary task is to cope with the text as a whole – not trying or not even knowing how to elicit and remember the fine-structure of the message that is presented to them (i.e. single difficult words or sentence structures).

**If the English students show more coherence decrease over the prefrontal areas, does that mean they have more subcortical activity and thus access to highly automatized language skills?**

According to the interpretation that a decrease in coherence means more activation in subcortical regions of the brain, higher activation in prefrontal areas could stem from subcortical structures like the thalamus, which results in the focal activation of prefrontal areas, still measurable by the EEG on the scalp.

Crosson et al. (Crosson & Nadeau 1998) investigated the role of subcortical structures in linguistic processes and concluded that the thalamus plays a direct supportive role in language processing by being a selective engagement mechanism that increases the efficiency of structures needed to process language in such a way that appropriate lexical choices are more reliably differentiated from semantically related but inaccurate alternatives – thus being a control mechanism. In an fMRI study investigating lexical-semantic working memory, they found areas of increased activation, which were the thalamus
and the caudate nucleus (Crosson & Nadeau 1997, 1998). PET studies have also been used to study thalamic activity in cognitive tasks requiring attention (Buchsbaum, 1990). These studies indicate that the thalamus plays a significant role in language and an important supporting role in cognitive processes.

A further point that can be made in connection with subcortical language processing, is that of automaticity and skill learning. It is known that the more automatic and subconscious a process is, the more it is processed in deeper structures of the brain (like breathing is mainly a domain of the arousal system that is located in the midbrain, or brain stem; basic functions of posture and movements, also movements related to speaking, are a function of the cerebellum that is also part of the brain stem). If the more experienced language students show more subcortical activity than the inexperienced language learners, this could mean that they process language in a different and more automatic way, a way that uses the subconscious and so-called “low route” in the brain. As Fabbro (2001) summarizes:

When a second language is learned formally and mainly used at school, it apparently tends to be more widely represented in the cerebral cortex than the first language, whereas if it is acquired informally, as usually happens with the first language, it is more likely to involve subcortical structures (basal ganglia and cerebellum).

These are amongst the most important structures that contribute to any practised skill learning where motor control and movement plays a role, also if it is partly a cognitive skill, like, language and speech. The cerebellum still has a number of yet poorly understood functions, but is known to be involved in the regulation of movement. Patients with damage to the cerebellum can still move, but the movements become more erratic and less controlled. The cerebellum is also involved in the ‘automatic response’ that is experienced when a new skill has been learnt. For example, when learning to play a piece on the piano, at first the cerebral cortex is required to control the fingers, but upon learning, the cerebellum takes over. There is also growing evidence that the cerebellum (together with motor cortex) participates in imagined, mental movement and silent speech. Based on their PET studies, Petersen et al. (1989) suggest that the cerebellum is indicative of fundamental processes in automatic speech. Also Bellugi et al. (1990) have suggested a role for the cerebellum in automatic speech. People with lesions of the left frontal lobe but preserved cerebellum may suffer loss of propositional speech, yet retain relative amounts of other utterances, like nursery rhymes, songs, the alphabet or multiplication tables. Other evidence comes from genetic disorders. Children with William’s syndrome have an atrophic cerebrum, but preserved cerebellum, and are conspicuous for their precocious “cocktail conversation”
– socially responsive, fluent, correct in language content and appropriate to context, it is nevertheless peculiarly devoid of propositional content.

On the background of this neuroscientific (both patholinguistic and experimental neurolinguistic) evidence, second language acquisition could be seen as skill acquisition which is, when automatized by practice, gradually more subserved by deeper brain areas with the effect of more automatic and effortless access to skill knowledge resulting in profound “native-speaker-like” proficiency.

6. Conclusion

Studying a second language could finally result in a better understanding of the first language as well and make you a better listener to language in general. The linguistic refinement one acquires by intensive foreign language study makes one a better listener to one’s mother tongue – as a kind of feedback on the first language!

An interesting finding of this study was that both groups showed the same differences in brain activity - also when processing the German videos. The differences in the brain maps between the two groups were very similar for all nine stimulus items. Each group showed a stable and distinct pattern of activity regardless of the language of input, whether it was British English, American English or German.

There were no indications for distinct places of processing for the different languages (foreign and native) as predicted by the storage hypothesis (Paradis, 1995). All three languages/varieties of the investigation yielded similar results in terms of the place of processing. The distinctions within the study lay more in the differences between the groups in terms of strategies, but not in “storage” differences for different languages.

The last aspect, strategy selection, which is also attributed to the functions of the prefrontal cortex is especially interesting in the context of these results, because the advanced language students certainly use a different strategy, which enables them to understand and process the language stimuli more efficiently. The behavioural results (comprehension questions) also consolidated the differences in understanding between the two groups. Roughly speaking, the English students were 2 times better in understanding the English and American video sequences than the other students, but they could also reproduce the German texts slightly better, although German is the mother-tongue of all students and there should not have been any differences in comprehension and memorizing.
In the context of this study the term “linguistic or language processing strategy” is seen against the background of neurobiological theories of learning, memory and language processing. Unfortunately there has not yet been developed a unifying neurobiological theory that brings all aspects of human learning and cognitive behaviour under one theoretical concept, because the field is so-to-say “under construction”. The neurobiological perspective, which views learning and cognition as adaptations of motor and brain systems, contrasts with the more passive view of learning as purely mental activity maintained in psychology and cognitive science so far, although within cognitive and behavioural neuroscience, comprising neuropsychology and neurobiology and large parts of cognitive science, the understanding of cognition (comprising learning strategies) is more and more directed towards an integrated view of learning as an integrative process of brain, mind and body that consists of aspects of implicit, subconscious, emotional, procedural and automatic as well as explicit, conscious, mental, declarative and cognitively controlled features, which cannot easily be taken apart, because their functioning depends on their very interrelatedness. (see also Schumann, 1994, 1992).

Thus, language decoding strategies are cognitive, neuronal representations of behaviours, thoughts, actions and consequences of action that guide behaviour toward a goal (e.g. understanding a text). For the purposes of this discussion, strategies may be broadly defined as neuronal and cognitive operations or procedures performed by a language learner to achieve the goal of comprehension. Comprehension strategies may be both: conscious and controlled, and, unconscious and automatic, and they serve to direct the various components of the listening process towards an efficient understanding of a given text.

Considering these results, one conclusion could be that it was not only the foreign language comprehension ability that has been measured, but more likely, the strategy selected to firstly understand and secondly memorize “text” in general. If it had only been foreign language comprehension there should have been no differences between the groups for the German texts and the two groups should have understood the German texts to the same degree. This might be an indication that it was not only comprehension as such, which was measured, but a special language processing and memorizing strategy which was adopted by the English language students - because of their “fine-tuned” linguistic training - to listen to, differentiate, understand and reproduce the texts efficiently. It is this “fine-grained” training in a foreign language and linguistics, which may have influenced and shaped their
language uptake capacity in such a way that their attention was focused on a detailed but quick and efficient decomposition of the text they were presented with. This different strategy may also have a “neuronal correlate” and therefore be traceable by electro-physiological means of investigation – like in this case by EEG-coherence analysis.

Thus, strategy selection or better automatic listening comprehension skills are most likely the factors that brought about the group-differences in the activation of the prefrontal cortex.
Figure 6. Summary of results & overview: the 9 tasks and corresponding brain maps:

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Brain Map</th>
<th>Left</th>
<th>Right</th>
<th>Annotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>British English acoustic only</td>
<td>Brit. Engl. acoustic only</td>
<td></td>
<td></td>
<td>South Africa</td>
</tr>
<tr>
<td>British English visually only</td>
<td>Brit. Engl. visually only (mimicry)</td>
<td></td>
<td></td>
<td>Chris de Búsch</td>
</tr>
<tr>
<td>American English visual + acoustic</td>
<td>Am. Engl. TV= ac. + vi.</td>
<td></td>
<td></td>
<td>Senator Baker</td>
</tr>
<tr>
<td>American English acoustic only</td>
<td>Am. Engl. ac. only</td>
<td></td>
<td></td>
<td>Baeßria</td>
</tr>
<tr>
<td>American English visually only</td>
<td>Am. Engl. vi. only</td>
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<td></td>
<td>CNN</td>
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<tr>
<td>Austrian German visual + acoustic</td>
<td>Austrian German TV= ac. + vi.</td>
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<td>Verzetmitsch</td>
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<tr>
<td>Austrian German acoustic only</td>
<td>Austrian German ac. only</td>
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<td>Prof. Huber</td>
</tr>
</tbody>
</table>
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Appendix

1. Tapescript JOHN CLEESE: How to irritate people
   (British English: „TV“ = acoustic + visual presentation)

Extract 1

We’re going to take a look at how to irritate people - at life.
We can’t of course hope to be comprehensive. So just look on this as a refresher course; a
few hints on how to help people to become more neurotic. Now, if you want to irritate
people purely for pleasure, one fundamental rule must be observed. Never push them too
far.

If you don’t go too far they will explode into anger, shouting, stamping, becoming
abusive and so forth, which releases all the tensions and frustrations which we have care-
fully built up. And we don’t want to do that, do we?

With a little skill and tact we can keep those very same tensions bottled up inside them
for weeks, months, who knows? Eventually you may induce a nervous break-down or,
better still, actual damage to the brain cells. So, to avoid this explosion of anger, whatever
you are doing to irritate someone, should seem to be unintentional. And the great masters
of this art are parents.

Extract 2

You see it isn’t inefficiency itself that is so irritating. It’s the refusal to admit inefficiency.
Mr. Graham Chapman recently had trouble with his telephone. He explained to the tele-
phone supervisor that over a period of six weeks his telephone had been out of order about
four days in each week, despite at least five visits from the telephone engineers.

She explained that the trouble was, quote, "There are too many people on this island!
"Presumably the plans for an improved telephone service include deportation of selected
subscribers - or even this, " Hi, I’ve come to improve the telephone service!"

We get the same sort of treatment from banks. The bankmanager himself irritates peo-
ple by writing to them immediately they owe the bank forward. I advise you if you’ve had
this trouble in the past, but are now in credit, to write to your own bankmanager pointing
out that he owes you money and would he please drop in and have a word with you about
it. The banks themselves they’re all in business of making money, so when they get hold of
yours they make it as difficult as possible for you to get any of it back. For this end they
open just after you arrive at work and close two hours before you leave. And should you
sacrifice your lunch-hour to join the angry queue in the street outside, don’t blame the sin-
gle cashier on duty for the slowness of the service. After all, the cleverer cashiers are out at
lunch!

In this way banking hours have been carefully tailored to the needs of two classes of
persons: the unemployed and bankrobbers.
Actually, the increase in the number of bankrobbers in Britain is not as horrifying as it sounds. It is now known that over 70% of them are only frustrated customers trying to get at their money. Yes, banks are maddeningly greedy!

But, to some of the more eccentric professions money isn’t everything. We all know what actors are after.

- End -

Ad 1: Comprehension questions
1) What is the aim of this course John Cleese speaks about in the beginning?
2) Which were the difficulties Mr. Graham Chapman had with his telephone?
   (describe the scene).
3) What could solve or improve the English telephone problem?
4) Explain the scene where the man is shooting with a gun!
5) How exactly do the British banks manage to irritate people?
6) Which two groups of people are the British bank opening hours tailored on?
7) What is the cause for the enormous increase of the number of bankrobbers in Britain?

Additional Questions
1) According to your personal impression, how do You feel You have understood the text?
   best 12345 worst
2) Did You like the speaker or not? How much sympathy did You feel for him?
   best 12345 worst
3) How interesting was this video-sequence for Your personal taste? most 12345 least
4) How demanding was the task for You? (in terms of concentration)
   not very 12345 very much
5) How much attention did you pay to the sequence? (attentiveness, alertness)
   not much 12345 very much

2. Tapescript: South Africa
   (British English: acoustic presentation only)

BBC – Radio Report
South Africa looks pretty much as it did a decade ago. The whites still have the wealth, the blacks still suffer the poverty. Nowhere is this more evident than in Cape Town. The magnificent contours of Table Mountain that so enthral the tourists mean something else to those who live in its shadow. It is a great granite barrier dividing black from white, continuing privilege from desperate grinding hopelessness. The white people still live on the sunlit north side where the mountain slopes down to the sea in gentle pleasing gradients.
On the other side on the dry and barren plains of the interior the blacks and coloured still live in the isolation and poverty that apartheid designed for them. When Nelson Mandela bears out a public life and hands the leadership of the country over to his deputy Thabo Mbeki later this year, there will be less talk of reconciliation and much more of black empowerment. When I lived in South Africa during the Mandela-years the talk was all of rainbows and the miracles that so inspired the whole world. Is the miracle safe in Thabo Mbeki’s hands? It is the question that frightens so many whites.

Look, leave Nelson Mandela out of this“, the satirist Peter Deragase has one of his characters say. “Nelson Mandela is all that stands between us Whites and the refugee-camps“. The line is supposed to raise a laugh but it seldom does among his predominantly white audiences. It is too close to home for them. It reawakens the paranoia that fuelled apartheid, the fear that the menacing, appalling, dark and frightening continent to the north will get them in the end. It is what the Afrikaaners used to call: “the swarche war – the black danger“. And it is still part of the white South African mind set. In Cape Town “Hrute Kerk“ – a group of worshippers in the dutch-reformed church, the church that once provided scriptural justification for white supremacy and which has this year for the first time publicly apologized for apartheid, describing it as a sin, are struggling to come to terms with the new reality. They are trying desperately not to be afraid.

I would feel a lot safer“, one woman told me, “if you could show me a single black government anywhere in Africa that has been successful“.

There are many reasons why South Africa is not like the rest of the continent and many reasons to believe that it will not follow the same dismal path that led so much of the continent to ruin. The task of the new generation is to rescue the miracle from the twin threats of deepening poverty and violent crime. It is terrifying to live in South Africa.

Those who can leave are doing so in ever growing numbers. They are taking the skills the country needs with them. It is painfully evident to most employers that skilled jobs vacated by educated whites heading overseas cannot be filled by blacks because of the skills-gap bequeathed by apartheid, a system in which black people were deliberately undereducated. It is almost impossible to say so without being denounced as racist.

**Ad 2: Comprehension questions**

1) What is the situation in Cape Town? How do the Blacks and the Whites live?
2) Who is Thabo Mbeki?
3) What are the Whites afraid of?
4) *Hrute Kerk - a group of worshippers in the Dutch-reformed Church*: What did they confess or admit this year for the first time?
5) Does the speaker say that South Africa is similar and comparable to the rest of the African states?
6) Why is it terrifying to live in South Africa?
7) What does the speaker say about the job situation in South Africa?
Ad 2: Additional questions

1) According to your personal impression, how do You feel You have understood the text?
   best 12345 worst

2) Did You like the speaker or not? How much sympathy did You feel for him?
   best 12345 worst

3) How interesting was this video-sequence for Your personal taste?
   most 12345 least

4) How demanding was the task for You? (in terms of concentration)
   not very 12345 very much

5) How much attention did you pay to the sequence? (attentiveness, alertness)
   not much 12345 very much

3. TV-Interview: Chris de Burgh
   (British English, visual presentation only)

Questions on the visual item

1) What did you concentrate on during the presentation of this item? What caught your special attention?

2) What did you think of during this sequence?

3) What could the speaker have said according to your judgement of lip-reading?

4) Do you think that he had a rather clear pronunciation or not?
   yes 12345 no

5) According to your personal impression, how do You feel You have understood the text?
   best 12345 worst

6) Did You like the speaker or not? How much sympathy did You feel for him?
   very much 12345 none at all

7) How interesting was this video-sequence for Your personal taste?
   most 12345 least

8) How demanding was the task for You? (in terms of concentration)
   not very 12345 very much

9) How much attention did you pay to the sequence? (attentiveness, alertness)
   not much 12345 very much