Consequences of bilingual aphasia.

Examination of bilinguals’ linguistic resources.

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1. Introduction

Just as twins generally get a lot of attention for being special, we tend to envy bilinguals their incorporation of two of the same kind. In general, exceptionality also arouses science, since oddity can reveal mechanisms that would otherwise not be recognized. At the same time physical and mental disorders, for example the loss of speech, are of interest as studies into such diseases help us better understand how the human brain and body works. In this thesis I join two special phenomena together, namely bilingualism and aphasia.

What can we learn from aphasic bilinguals? Inquiries in aphasia, the loss of ability to understand and/or express speech, which is caused by brain damage, can tell us more about the system that we call language. For example, such research already has suggested that this system is made up from several modules that reside in distinct areas in our brain. Bilinguals are of relevance since they exploit this system twice; might it be, for example, that there are two separate languages represented in their brains? Exploring both particular cases in tandem will result in a better understanding of the organization of the brain and hence of the underlying processes of language use.

In the chapters to come I will investigate different approaches towards modeling the language system(s) of bilinguals and what problems arise when a bilingual is hampered by aphasia. The main question that this thesis revolves around is whether bilinguals, in recovering from aphasia, benefit from being bilingual. Intuitively, one would expect that if there is more of something cognitive, in this case language, prior to the instance of brain damage, there will be more left afterwards as is demonstrated for, for example, IQ (Valenzuela & Sachdev, 2005). Is this indeed the case with respect to speech and language pathology? Can capabilities of two different languages simply be summed, anyway? We will need to look into the representation of languages in bilingual brains and we will see that recovery from aphasia to a great extent depends on which moment in life languages are acquired. Different memory systems that will appear to be involved during language use seem to have an effect on the organization in the brain. Also, it will become clear that, because of the various sorts of aphasia tests as well as the heterogeneity of pathology, data are difficult to compare.

The structure of this thesis is as follows. In the next chapter I will formulate some relevant definitions. Further, I will report approaches to model language production from a historical perspective as well as to model the bilingual system. Along such models language pathology and its underlying organization in the brain can be comprehended. Chapter 3 is dedicated to bilingual aphasia. First I look into issues of assessment and recovery of aphasic bilinguals and then I try to compare the neural correlates to the proposed models. Doing so, components in the brain involved with language control emerge. The hypothetical construct ‘cognitive reserve’ in chapter 4 helps us to understand the development and recovery from mental diseases. It may also be of help to understand recovery patterns of bilingual aphasics. After discussing my findings and suggestions for future research in chapter 5, I will conclude with chapter 6.
2. Definitions and models of language

2.1 Definitions: bilingualism, aphasia, and modules

In this thesis human language (henceforth language) is referred to as the implicit linguistic competence or “the grammar”, which is characterized by the components phonology, morphology, syntax, and semantics. Key feature of language is the possibility of recursion, that is, the embedding of clauses within sentences.

To be defined as a bilingual one needs to be fluent speaker of two languages, that is, using these languages in everyday life (Grosjean, 1994). People who are fluent in even more languages are usually called polyglots. I will use these terms arbitrarily, as it is more important to know when such persons become fluent. A major characteristic of human language is how it is acquired, since language acquisition depends heavily on a critical period: to become a native speaker this speaker needs to be exposed to at least one language before his/her second birthday. Some people may be exposed to two, referred to as L1 and L2, (or more) languages from the day they are born (i.e. early bilinguals), others, however, may become a native speaker of one language, referred to as L1, and acquire one, referred to as L2, (or more) later in life for reasons of migration by example. In the literature the age of 5 is usually seen as the boundary between early and late fluency. Both types of polyglots may become aphasic and we will see that we need to be aware of the bilingual patients backgrounds in order to get a grip on their language pathology and potential recovery.

As said in the introduction, aphasia is the loss of ability to understand and/or express speech, which is caused by brain damage. Specifically, the implicit competence is impaired (Paradis, 2004, p.9). This damage can be the result of a focal lesion, dementia or a stroke, typically in the left hemisphere of right handed people. This also holds for the majority (approximately 80%) of left-handers. Mazzocchi & Vignolo (1979) deliver a useful definition of the aphasias as they tested ninety right-handed aphasia patients who were given a standard language battery (they don’t mention which). At the same time, the site and extent of the lesions of these patients were examined by a standard Computedized Tomography (CT) scan. It appears that the results of Mazzocchi & Vignolo (1979) stand the test of time as the categorization in Table 1 on the next page is still practical, despite disagreement among experts about the number of types (Kolb & Whishaw, 2009, p.544). By means of a gross classification there are three categories: fluent, nonfluent, and pure aphasias. Wernicke’s aphasia is sometimes described as ‘sensory’ or ‘receptive’, since it involves mainly disorders in comprehending language, opposing Broca’s aphasia, which is sometimes called ‘expressive’ or ‘productive’, since it involves mainly disorders in articulation and the disability to find words to speak.¹

Since aphasia syndromes involve dissociations, the language system as a whole is understood as modular in the literature. As there are different interpretations of “module”, I prefer the definition of

¹ Neurologists usually associate Broca’s aphasia with “word finding problems”. A fairly ambiguous interpretation, as Wernicke patients, although they may be fluent speakers, use words in contexts one wouldn’t expect: they might find a word, yet it might be wrong. Word finding problems refer to the ability to find a word at all.
Paradis (2004, p.119): “Neurofunctional modules are isolable and computationally autonomous, have a specific purpose, and function as a component of a larger unit.” Within this definition the possibility of selective impairment is captured as well as the notion that the internal structure of a module is independent of those of other modules. Different modules, components of a larger unit, may work together to serve a common goal.

<table>
<thead>
<tr>
<th>Syndrome</th>
<th>Type of speech production</th>
<th>Severity of the defect (score 0-4)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Oral expression</td>
</tr>
<tr>
<td><strong>FLUENT</strong></td>
<td></td>
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</tbody>
</table>
| Wernicke, severe| Fluent speech, without articulatory disorders  
Neologism, anomias, paraphasias | 0-1               | 0-2                             | 0-2        |
| Transcortical  | Fluent speech, without articulatory disorders  
Verbal paraphasias and anomias           | 0-1               | 0-2                             | 3-4        |
| Conduction     | Fluent, sometimes halted, speech  
Phonemic paraphasias and neologisms;         | 0-2               | 3-4                             | 0-2        |
| Anomic         | Fluent speech, without articulatory disorders  
Anomia and occasional verbal paraphasia- | 0-2               | 3-4                             | 3-4        |
| **NONFLUENT**  |                                                                                         |                    |                                 |            |
| Broca, severe  | Laborious articulation  
Speechlessness with recurring utterances | 0-1               | 3-4                             | 0-1        |
| Broca, mild    | Slight, but obvious articulatory disorders  
Phonemic paraphasias with anomia;            | 2-4               | 3-4                             | 2-4        |
| Transcortical motor | Marked tendency to reduction and inertia; without articulatory disorders | 0-1               | 3-4                             | 3-4        |
| Global         | Laborious articulation  
Speechlessness with recurring utterances | 0                 | 0-2                             | 0          |
| **“PURE”**     |                                                                                         |                    |                                 |            |
| Alexia without agraphia | Normal, but poor reading | 4                 | 4                               | 4          |
| Agraphia       | Normal, but poor writing                                                                 | 4                 | 4                               | 4          |
| Word deafness  | Normal, but impaired auditory verbal input                                               | 4                 | 0                               | 0          |

Table 1. Definition of aphasic syndromes (Mazzocchi & Vignolo, 1979).
2.2 Working models: in search of levels of representation

Modeling language comprehension and production is closely related to neurological and cognitive findings. Firstly, the first scientists who explored language pathology with respect to brain damage gave rise to investigations of language modeling. Secondly, models, once proposed, are best tested within a (neuro-)cognitive scientific environment. The first scientist who noted the close relationship between language pathology and brain damage was the Frenchman Paul Broca (1824-1880). Broca (1865) reports the postmortem brains of several patients who had had a premorbid speech impairment - they lacked speech production combined with paralysis of the right arms and legs - and found an atrophied area in their brains in the fronto-temporal area of the left hemisphere, suggesting that different regions of the cortex could be specialized for different functions. As these patients seemed to understand language while lacking the ability of articulation during their lives, the Polish-German Carl Wernicke (1848-1905) suggested that if there were a language faculty it should consist of a perceptive and a productive part (Wernicke, 1874). Together with Broca’s findings, it appeared that mainly the left hemisphere is involved in language production and comprehension. Later, this would be referred to as lateralization. Wernicke’s premature language model is further expounded by Geschwind (1970). In figure 1 we see the core of this model and its neural correlates. Typically, we observe the areas of the first explorers.²

![Figure 1. The Wernicke-Geschwind model and its neural traits.](image)

As can be seen in figure 1 several sequences can occur. Visual input which is to a great extend processed in the primary visual cortex is send to the angular gyrus and then to Wernicke’s area which is assumed to contain sound images of words. Comprehension of speech sounds hinges on the primary

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² As soon as Broca presented his research, a big run on dissected brains started, since many people (not only scientists), eager for fame, wanted to link their name to a certain region of the human brain.
auditory cortex which sends information to Wernicke’s area too. The arcuate fasciculus is a big bundle of neural fibers that connect Wernicke’s area to Broca’s area. From here, where motor programs for speaking words are stored, speaking plans are send to the facial area of the primary motor cortex which command the cranial nerves that control the muscles involved in articulation. In this model we discern the perception as well as the production modules that can account for the gross categorization of aphasia. Interestingly, as Wernicke (1874) predicts, this model can also account for conduction aphasia (poor repetition, fair comprehension), in case the arcuate fasciculus is blocked. Not only empirical data by means of descriptions of lesions in relation to behavior support this model. The German Korbinian Brodmann (1868-1918) who studied for nearly his whole career just one dissected brain meticulously, found that different regions in the cortex show differences in the organization, structure and distribution of cortical cells (Brodmann, 1909). Compellingly, areas showed in figure 1 are managed by distinct cortical layers.

A further refinement of the Wernicke-Geschwind model is proposed by Ellis & Young (2004, p.222) based on several experiments they had done over a decade, providing a helpful instrument to categorize mainly reading and writing disabilities. Again, it appears that different functional modules can be isolated within the brain as it is possible that a patient may show isolated disorders. Let us take a look at figure 2.

Figure 2. Proposed model by Ellis & Young (2004). Red figures refer to isolated disorders. Where arrows cross no connection is assumed.
Every grey tinted box in figure 2 represents a module which may be individually impaired. Also, at the level of a connection, indicated by arrows, damage can occur. Ellis & Young (2004, p.221) state that all modules are empirically motivated by evidence of both brain-injured patients and normal subjects. For example, when the speech output lexicon (8) is hampered it is likely to yield anomia, a condition in which a subject is able to understand words but cannot easily find them. This may occur in several types of aphasia (see figure 1). Although impairments do occur below phoneme level, e.g. in Broca’s aphasia, detailed case studies are not available to date (Ellis & Young, 2004, p.140).

The proposed speech model by the Dutch psycholinguist Pim Levelt (1938 - ) could be hold for a more detailed process of the route from the Semantic System to Speech that we observe in the model of Ellis & Young in figure 2. Levelt (1989; 1999) distinguishes several components each of them performing different functions. Grossly, speech is established following a sequence of four levels: a conceptual, a lexical, a phonological, and an articulatory. Like the modules in the model of Ellis & Young, each component within the different levels could be subject of a research program, as Levelt stresses, in order to be tested and evaluated in terms of relevance at all and in terms of neural correlates, by using brain imaging techniques. Let us take a look at Levelt’s model outlined in figure 3.

![Figure 3. Outline Levelt’s speech production model (1999). Processing components are in orange.](image_url)
In figure 3 we discern two main systems. A rhetorical/semantic/syntactic system, which comprises the processing components conceptual preparation and grammatical encoding, should map a concept onto a linear pattern (lemmas, that form a surface structure). Levelt (1999) refers to macroplanning as it comes to ‘what to say’ and to microplanning as it comes to ‘how to say’. A phonological/phonetic system comprises the processing components morpho-phonological encoding (to produce a speech plan), phonetic encoding, and articulation. This system should translate the given pattern into articulatory gestures. According to Levelt, both systems have access to the mental lexicon. He assumes that generating a surface structure is mostly lexically driven. Further, he suggests that a lexical concept first activates a corresponding lemma in the mental lexicon; then, the syntactic features of this lemma become available for further syntactic construction, at the same time, its form code becomes obtainable for the composition of phonological words. By means of a monitoring system, which is assumed to be applicable at two different stages (during internal and overt speech), the component self-perception stands alone. As ‘perceptual loop’ it is assumed to detect articulatory errors prior and after articulation. Further, it should monitor the speech plan as well as the appropriateness of the message to be conveyed. All components are assumed to work in parallel while every procedure is carried out step-by-step.

As said, different levels should be subject to further investigation. As an example of such research we will take a more detailed look at phonological processing and semantic processing within Broca’s area. Without aiming to explicitly synthesize a model such as Levelt (1999), Devlin & Watkins (2007) nevertheless note that within Broca’s area discrete processing components can be made visible using a (relatively new) transcranial magnetic stimulating (TMS) procedure. TMS is a non-invasive technique during which a specific cortical region can be disrupted for a short time, simulating a lesion. Combining TMS with functional magnetic resonance imaging (fMRI) potentially delivers excellent insight in both anatomical and functional connectivity. Devlin & Watkins (2007) review several TMS studies and demonstrate that the anterior region of Broca is implicated in semantic processing whereas the posterior region is implicated in phonological processing, the latter underpinning presumably the phonological/phonetic system as proposed by Levelt (1999). Besides, it seems that Broca’s area is not solely involved in speech production.

2.3 Bilingual models

Based on the blueprint proposed by Levelt (1989) which is similar to figure 3 de Bot (1992) has tried to account for a bilingual model, although the empirical support at that time is meager. Yet, he sums up relevant requirements which such a bilingual model should meet. It should be able to provide an explanation for:

- code-switching: to what extend are languages subserved by separate systems and controlled;
- cross-linguistic influences: these should be incorporated if applicable;
- the production system: should not decelerate in bilinguals;
• language acquisition: biased language preference should have consequences for the organization of the model;
• multilingualism: typological differences between languages should not cause problems, although there are interactions.

As main conclusions de Bot (1992) draws that macroplanning is language independent while the procedure microplanning is language specific (conventions that are practice in Levelt (1999)). In addition, once the preverbal message is ready, a language specific formulator\(^3\) is assumed to be activated to formulate a speech plan just as in figure 3, during which a single lexicon, containing all lemmas of all languages, should be employed; one lemma can be linked to different languages depending on the formulator. The components phonetic encoding and articulation are assumed to be language independent. De Bot (1992) is not very specific in accounting for the monitor system.

Relevance for the above mentioned requirements is justified as they turn up in other studies in bilingualism as well. While concentrating on language control Green (1998), for example, proposes an inhibitory control model (IC model) which should be able to account for the regulation of the lexico-semantic system of bilinguals. The IC model could well be integrated within a Levelt-like framework since at least it makes use the idea of word selection at lemma level. However, Green (1998) assumes lemmas to bear a language tag. Let us see what the proposal looks like in figure 4.

**Figure 4. The IC model (Green, 1998).**

Similar to Levelt (1999), in the IC model a language independent conceptualizer stemming from long-term memory - i.e. the knowledge of the internal and external world - prepares conceptual representations (c.f. macroplanning). This is driven by a goal to respond to by using language. A supervi-

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\(^3\) In Levelt (1989) a formulator consists of the components grammatical encoding and morho-phonological encoding. Although the model has slightly changed in terms of ‘systems’, processing components remain the same in Levelt (1999).
sory attentional system (SAS) is assumed to work with components of the language system simultaneously. These components are the lexico-semantic system and language task schemas (these are for example translation schemas or word production schemas). These schemas select the right outputs from the lexico-semantic system by inhibiting the non-target language after items of both the target and non-target language are being activated. Hence, the lexico-semantic system is understood as language independent; different languages should be seen as subsets of the language system as a whole.

Regulation by activation finds its origin in the research of Michel Paradis (1936 - ). By means of an overview of 25 years of bilingualism research Paradis (2001) evaluates how his theory gradually developed from a psycholinguistic construct, in which nonlinguistic cognitive store was assumed to be separated from the two language stores of bilingual speakers, into a neurofunctional proposal. The latter theory is based on the Subsystem Hypothesis: the language system is assumed to be a neurofunctional module - of which different languages are subsets - that, reminiscent of Levelt (1999), receives inputs from the cognitive systems yielding outputs to articulatory systems (speech and signs). Paradis (2001) assumes that this process is sequential or parallel, making his theory applicable for both ‘serialists’, such as Levelt (1999) as well as for connectionists, who proclaim that the brain (and hence cognition) could be seen as a massive interactive network in which many processes take place simultaneously. A core component of the neurofunctional proposal is the Activation Threshold Hypothesis which holds that an item can only be activated if ‘a sufficient amount of positive impulses have reached it’ (Paradis, 2001), just as neuronal communication works. This rather domain independent component could account for pathology in the sense that aging may disrupt activation levels causing word finding problems whereas different sorts of aphasia could be understood by means of erasure of (parts of) the language system.

![Figure 5. Schematic representation of the neurolinguistic theory of bilingualism by Paradis (2001; 2004).](image-url)
Paradis (2001) stresses that within any neurolinguistic theory pragmatics, a module that he assumes to reside mainly in the right hemisphere, should be taken into account. Further, he notes the distinction between implicit and explicit knowledge, referred to as *competence* and *knowledge* respectively, both subserved by different mechanisms in the brain. The Subsystem Hypothesis only applies to implicit linguistic competence (Paradis, 2004, p.222). Paradis (2004, p.233) defines *knowledge* as learned while *competence* can be acquired. Yet, as Paradis (2004, p.11) notes, both types of systems will become available in normal language acquisition and might be selectively affected by pathology. Support is given by Aglioti & Fabbro (1993) who noted bilingual aphasics who recovered a later learned L2, which is assumed to rest on *knowledge* mainly, over their native L1, which is assumed to be rather determined by *competence*. In addition, Alzheimer’s disease patients would probably lose a later learned L2 first as declarative memory is first affected (Hyltenstam & Stroud, 1993; Obler, 1999).

Apart from the neurofunctional modules of production (and perception4), pragmatics, implicit linguistic competence and metalinguistic knowledge Paradis (2001) considers the factor *motivation*, which is subserved by the dopaminergic system, a major factor in language acquisition and aphasia. In total he pictures his theory as in figure 5 (p.11), which shows clearly distinct language modules. In fact, as a whole, it depicts:

- the production/perception part of the cognitive system;
- subsets of the implicit linguistic competence system, namely phonology, morphosyntax, and syntax and semantics;
- a metalinguistic system resembling a monitor system as proposed by Levelt (1989; 1999);
- a pragmatic system that integrates linguistic and paralinguistic elements with context;
- a motivational module which is the onset of every utterance.

Note, further, that in this representation L1 and L2 are evenly divided, picturing a situation which might only be practice when the two languages are acquired from birth. In addition, after evaluating experience in second language teaching, neuroimaging studies and language pathology, Paradis (2009, p.187) concludes that there can not be an interface between metalinguistic competence and implicit linguistic competence. He assumes that, firstly, both mechanisms are different in nature, secondly, one does not function as input for the other, and, lastly, one can not be not rendered into the other.

Although there are differences of emphasis in the models outlined above, Levelt (1989; 1999) and De Bot (1992) being strictly serial and detailed in the production process, Green (1998) emphasizing the language control and switch elements, and Paradis (2001) taking pragmatics and other cognitive modules into account while assuming separate systems for different languages, they all form a useful guideline along which we can evaluate bilingual aphasia. As we will see, we will be able to develop a more refined theory of the neural substrates of human language.

Apart from the presented models a group of scientists have tried to account for bilingual models from a connectionist perspective. Kroll & Tokowicz (2005), for example, evaluate some of these stud-

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4 Paradis (2004, p.226) takes a part of the cognitive system involved in production and perception as a whole.
ies in the light of the lexical representation of different languages. Suffice it to say that although the connectionist approach differs in essence from a serial model of Levelt (1989; 1999) as connectionists assume a massive interactive network contrasting separate components, it appears that connectionists need to account for different levels of representation such as a conceptual, a lexical, a phonological, too (Kroll & Tokowicz, 2005). In the end both groups of scientists might be looking for the same language processing areas in the brain albeit under different conventions concerning the flow of neural information. Understanding of perceptual inputs as well as the production processes that underly behavior of animals (and hence humans) involves integration of several processes in the brain. Although much of this is still unknown, it might be that within a mass network constellation several subsets of processing modules work serially.
3. **Bilingual aphasia**

3.1 **Diagnosis and assessment**

Test batteries that are used to assess monolingual aphasia come in two types: lengthy and in-depth test batteries that are to be administered by special trained clinicians, and short screening tests that can be administered by neurologists who are prompted with acute patients. The lengthy tests typically comprise many subtests which fit in either of three main categories (Kolb & Whishaw, 2009, p.550):

- auditory and visual comprehension;
- oral and written expression, including tests of repetition, reading, naming, and fluency;
- conversational speech.

On the one hand, recovery strongly depends on the diagnosis, since a rehabilitation program should address the specific individual disorders. On the other hand, recovery benefits from a quick start of the rehabilitation, since patients are most prone to restore their language capabilities in the first 3 months after initial deficits occur (Kolb & Whishaw, 2009, p.731). Further, although they are based on one of the standard test batteries, they may vary between countries as a consequence of cultural differences (Spreen & Risser, p.220), making it problematic to compare scores cross-linguistically let alone to assess bilingual aphasics.

In an attempt to design a test battery for bilingual aphasics, Paradis & Libben (1987) developed the Bilingual Aphasia Test (BAT), which also contains three parts:

- evaluation of the patient’s multilingual history (50 items);
- systematic and comparable assessment of language disorders in each language known by the subject (472 items in each known language);
- assessment of translation abilities and interference detection in each language (58 items in each known language).

Characteristically, the person who administers may not judge, as the answers given by the patient, after they are written down, are quantified by means of a computerized program. Above that, special care is given in transposing the test in order to make it operational for different languages. Part B and C are not just translated, as stimuli need to reflect the underlying functional analysis. For example, the English items “mat, cat, bat, hat” presented with a picture are rendered into the Friulian “cjoč, čoc, poc, tøc” meaning “drunk, log, chicory, piece”, when items need to differ only with respect to the initial phoneme (Fabbro, 2001a).

Paradis & Libben (1987) and later Paradis (2004) could be hold not only as guides for adapting the BAT to different languages but also as a methodological blueprint. The authors stress, for example, the importance of assessing one language on one day, while premorbid code-switching habits of the patient should be investigated by means of a heteroanamnesis. Some code-switching might be common within certain environments. Therefore, if a patient mixes and/or switches pathologically between L1 and L2, this patient, when testing L1, should be assessed by a person who is fluent in that
particular language (L1) only, to prevent misinterpretations. Testing translational capabilities, however, ask for testers who are fluent in the languages involved.

Fabbro (2001a) puts forward that clinical assessment of aphasia in general should take three different phases into account:

- acute phase: generally lasting 4 weeks post-onset;
- lesion phase: generally lasting for several weeks up to 4-5 months post-onset;
- late phase: beginning approximately a few months after onset and continuing for the rest of the patient’s life.

During the acute phase a bilingual patient may be either temporarily mute while comprehending both languages (if two were fluently used premorbid), or show severe word finding problems, while demonstrating pathology in switching as well as mixing of their languages (Fabbro, 2001a). Sometimes a patient may recover spontaneously. Problems may arise in the translation of L1 to L2 and vice versa: patients may have lost their translation ability, may translate spontaneously or translate paradoxically. Paradis et al. (1982) report on two bilingual aphasics with the latter disorder. Patients who suffer from this disorder are able to translate into a language they cannot use spontaneously but cannot translate into the language that they can use spontaneously. In addition, the patients described by Paradis et al. (1982) displayed alternate antagonism, which is a condition in which a person is able to spontaneously speak one of the languages on one day but unable to do so the other day, instead, the situation is the other way around, while comprehension of both languages is relatively preserved. Finally, a patient may exhibit a severe impairment of the language acquired during childhood, with complete preservation of a later learned language or vice versa. This condition is known as selective aphasia (Fabbro, 2001a).

Evaluating brain-behavior relationships are best done in the lesion phase, during which the disorders appear to be more stable. In this phase it is possible to classify the assessed patients along the definitions of table 1. Although it should be possible to diagnose differential aphasia theoretically, that is, a patient could exhibit Broca’s aphasia in L1 and Wernicke’s in L2, it is still not reported (Fabbro, 2001a).

Fabbro (2001a) notes that in the late phase different types of recovery become more and more apparent. In addition to the above mentioned antagonistic and selective types we discern the following recovery types. When both languages are recovered simultaneously, we speak of parallel recovery; when one language is restored before the other(s), we refer to successive recovery; when one language is recovered better than the other, the recovery is differential; when inappropriate mixing occurs, we refer to the term blended (Ansaldo et al., 2008). In the next paragraph we will take a more in depth look into bilingual aphasia recovery.
3.2 Factors in recovery from bilingual aphasia

From research in monolingual aphasia it is known that the type of aphasia determines the prospect of recovery. In figure 6 we see the main classified types and their prospect of recovery.

![Figure 6. Severity and recovery of main types of aphasia, first measured 3 months post onset (from Kolb & Whishaw, 2009, p.731).](image)

In figure 6 we clearly see that patients suffering from conduction or transcortical aphasia have best prospects, while global aphasics have worst. Curiously, Wernicke aphasics, since they are often not aware of their impairment, might be considered less severe if one would include a measure of ‘disorder awareness’ in the aphasia quotient. Broca patients, then, would be even worse off.

Fabbro (2001a) cites some studies which suggest that either linguistic functions may be taken over by the contralateral hemisphere or by unaffected areas near to the lesion site in overcoming monolingual and bilingual aphasia. Further, he notes that “improvement in communication skills may probably depend on the application of explicit compensatory strategies”. A rehabilitation program designed for such strategies comprises either cognitive-linguistic therapies that concentrate on the explicit knowledge of the language’s phonology, syntax, and semantics, contrasting communicative therapies that are merely designed to teach the patients to use the residues of the communicational possibilities. While there is discussion in the literature which therapy design is most effective, Visch-Brink (2006) suggests that if a cognitive linguistic therapy is carried out in the acute phase of monolingual aphasics, better results in recovery are apparent in later phases, presumably because of neural plasticity that is recognized in the acute phase. The question remains whether this holds too in the case of bilingual aphasics. Further research is necessary.

Green (2005) assumes that Hebbian learning is the most important mechanism for any restitution of function within the brain. Hebbian learning holds that “two neurons or neuronal groups or circuits
can reconnect if they are activated at the same time” (Green, 2005). Well-connected networks are thus assumed to be able to overcome small lesions, whereas less well-connected networks are not as the latter may require very specific input to get activated at all. Since Hebbian learning may account for the restoration of function surrounding the lesion site, neural plasticity refers to the creation of patterns of connectivity in neighboring neural networks. Green (2005) assumes that both Hebbian learning and neural plasticity play a role in recovery and that they may shed light on the different recovery patterns as described in section 3.1. For example, when the recovery is *differential*, the network of one language might recover better due to Hebbian learning (Green, 2005). Meinzer et al. (2007) report a case of differential recovery of a German-French aphasic patient who showed a relation between language training and growth of neural activation. The authors suggest that the progressive use of just one language supports enhancement of the subserving network, possibly by Hebbian learning, whereas the network of the other language is not and therefore fails to recover properly.

Any rehabilitation program for polyglot aphasics, following Fabbro (2001a), is confronted with several questions:

- Should only one language known by the patient be treated or all?
- If only one language is treated what should be the criteria?
- Does rehabilitation of one language have beneficial effects on untreated languages?
- Do potentially beneficial effects only occur between structurally related languages?

As research in this area is relatively young and different test batteries are used, little is known about pre- and post-rehabilitation assessment of bilingual language disorders. Currently, only one language is treated. On the one hand treatment of every extra language entails extra session time, on the other hand patients often show mixing or switching problems. It would be confusing for them and a waste of time (Fabbro 2001a). Further, poor availability of bilingual speech-language services may just leave not many choices (Ansaldo et al., 2008).

Other factors that are connected with the questions raised above and that play a role in recovery are age and method of acquisition, proficiency, motivation and neurobiological effects (Ansaldo et al., 2008). As suggested by Paradis (2004, p.11) a later learned language is stored differently: deficits of the explicit memory systems yield to disorders in a later learned language, whereas implicitly acquired languages may be relatively in tact. Early bilinguals, however, who acquired their languages within a critical period and thus are assumed to share the same implicit memory system might show generalization to L2 if efficient therapy is carried out in L1. Ansaldo et al. (2008) further insist on taking proficiency into account as therapy in the most used language pre-morbid should have the best rehabilitation results (if they are stored equally). The authors specify motivation as important since recovery heavily depends on the participation of the patient, who may value his languages differently in terms of social and emotional status. Sometimes the choice of the language might be best left to the patient and his family (Paradis, 2004, p.90). At last, Ansaldo et al. 2008 note that neurobiological issues should be considered by means of an evaluation of the site of the lesion using imaging techniques.
Interestingly, in an attempt to address questions raised above, Edmonds & Kiran (2006) demonstrate that treatment of the non-dominant language in a Spanish-English speaking aphasic may be “more beneficial in facilitating crosslinguistic generalization” (that is, lexical access which is implicit competence seems to benefit) than treatment of the premorbid dominant language. In this study late bilingual aphasic patients were trained in naming cognates and words with at least 50% phonetic similarity. However, while this conclusion is counterintuitive as we would expect crosslinguistic generalizations only in early bilinguals, it should be seen as preliminary and be subject of further research as there were only three participants.

Green (2005) points to the fact that individuals differ greatly in their ability to recover. Lesions at a given site may give rise to different recovery patterns, presumably because patients differ in effectively employing repair strategies. In addition, Green (2005) signals evidence of the influence of age, premorbid IQ, education, and the integrity of the frontal lobes and concludes that “neuropsychological assessments that focus only on language tasks may fail to detect dimensions critical to recovery”. Indeed, several studies stipulate the close relation between neuropsychology and recovery of language pathology. Factors as feedback (Fillingham et al., 2005) executive functioning (Fillingham et al., 2005; Lambon Ralph et al., 2010) as well as attention and visuo-spatial memory (Lambon Ralph et al., 2010) might be predictors of the rehabilitation of word finding problems. Measures of nonverbal memory seem to predict the effectiveness of cognitive-linguistic therapies correctly (Goldenberg et al., 1994). In chapter 4 we will take a more in depth look into the relation between language and cognition.

3.3 Bilingual brain structures: evaluating models

Ever since Broca’s discovery that language processing might reside in distinct areas in the brain, left hemispheric ‘linguistic’ dominance is widely acknowledged. With the development of brain imaging techniques such as Positron Emission Tomography (PET) and fMRI it has become clear that this indeed holds true for a vast majority of the population, whereas the right hemisphere seems rather to contribute to pragmatic integration (Fabbro, 2001b). With the emergence of new techniques earlier proposed models are challenged. Dronkers et al. (2000), for example, propose a modified Wernicke-Geschwind model (cf. figure 1), after evaluating results from monolingual aphasia imaging studies. They suggest, for example, that Broca’s area should be understood as a working memory unit, resembling a part of implicit knowledge in terms of Paradis (2001; 2004), and that the inability to speak (apraxia) may be due to a lesion in the insula which is an evolutionary older part of the cortex.

Support for the neurofunctional modularity as proposed by Paradis (2001; 2004) and described in section 2.3, is given by evidence of the recovery patterns during the different phases we have considered in section 3.1. Yet, Paradis (2004, p.128) cautions that neurofunctional modularity does not necessarily entail localization in gross anatomical brain regions. Some modules may be subserved by different regions that constitute a circuit. Executive control is put forward as an example (Paradis
In addition, within the same cortical area, it may be that distinct neural networks independently subserve different languages: two languages may be represented as subsystems as part of a larger general language system. However, with today’s techniques it might be impossible to make this discrimination visible since it requires a meticulous spatial resolution (Paradis 2004, p.127). In all, Paradis (2004, p.159) is very skeptical about neuroimaging studies in terms of their design (do researchers record what they intend to record?) and the above mentioned problems. As a consequence, different studies may have contradictory outcomes (Paradis 2004, p.161).

With this skepticism in mind, Abutalebi et al. (2005) analyze several imaging studies that have been carried out with bilingual subjects. They cite a consequence of early bilingual acquisition that is noted by Perani et al. (1998). In this study the researchers compared highly proficient English-Italian bilinguals to highly proficient early Spanish-Catalan bilinguals in order to evaluate the importance of age of acquisition. After PET-scans were taken during a story comprehension task, the experimenters saw more complete overlap in processing regions if bilingual subjects had high proficiency in languages that are structurally related. Age of acquisition is described as less important. Concentrating on Broca’s area and using fMRI, Kim et al. (1997) show that within this region two distinct processing areas can be discerned if two languages are acquired/learned at different stages in life. In early bilinguals, however, the processing areas are not distinct while showing almost complete overlap. Interestingly, this difference could not be determined in Wernicke’s area. This might support the idea of a shared mental lexicon as proposed by Levelt (1999). Or, in a broader sense, this area might be part of a shared conceptual system, which is prominent in the neurolinguistic theory of Paradis (2001; 2004).

In accordance with Perani et al. (1998), Abutalebi et al. (2005) conclude that proficiency should be seen as the most significant factor. Other factors that may influence the organization of the brain are the age of L2 acquisition and the usage and/or exposure to languages. The fact that exposure should be understood separate from proficiency might be of help in the rehabilitation of bilingual aphasia when deciding which language to choose for rehabilitation. Yet, future research is needed to collect more evidence as, for example, in some studies (e.g. Kim et al., 1997) it is not clear what underlying factor can account for the image that is found (Abutalebi et al., 2005). Overall, the researchers agree that the higher the proficiency of a speaker the less activation is recognized during language comprehension, suggesting that high proficiency yields relatively effortless processing.

Thus, the more automatized the language, the smaller the neural substrate. Consequently, as Paradis (2004, p.105) asserts, such areas are more vulnerable to lesions.

In a meta-analysis of experimental and imaging laterality studies, Hull & Vaid (2005) suggest among other things that early bilinguals show bilateral activation during language tasks yielding more symmetrical neural correlates during language processes. Also, balanced language processing is reported in some late bilinguals, causing the authors to argue for the effects of proficiency and age of exposure. For example, less left hemisphere activation was recorded in late bilinguals during tasks in which syntactic violations were evaluated. Event related potential (ERP) components such as the early LAN (late anterior negativity) and the relatively later P600 were more left-lateralized in mono-
linguals (Hull & Vaid, 2005). However, Paradis (2004, p.98) doubts that the implicit language system is situated differently in bilinguals. He further claims that to date laterality studies refer to various subgroups of bilinguals making it impossible to pose generalizations. He agrees, however, that right hemisphere activation has to do with the integration of pragmatics which he assumes to rely more on declarative memory. Later learned L2 seems to depend more on this memory system (Paradis, 2004, p.183).

The earlier mentioned patterns of recovery have led Green (1998) to conclude that “speaking a language spontaneously and translating a language are functionally distinct activities”. Therefore, Green (1998) suggests, a translation may be managed by a functional control circuit containing Language Task Schemas (see figure 4). Referring to alternate antagonism, on one day a translation schema of L1 into L2 may not dominate the opposite translation schema of L2 into L1 (Green, 1998).

The fact that pathological mixing might be independent of language mechanisms is also proposed by Fabbro et al. (2000). This study describes a patient who suffered from a lesion to the anterior cingulate cortex and to the frontal lobe, regions not particularly known as ‘language areas’. Yet, this patient showed pathological switching while no other linguistic impairment was apparent.

Green & Price (2001) suggest how parallel, selective, and antagonistic recovery could be understood with the help of neuro-imaging studies. For example, since monolingual aphasics show peri-lesion activation, they pose the interesting question of whether such activation is relatively greater in case of parallel recovery in bilingual aphasics. If so, rehabilitation could focus on the residual capacity. Still, more research is needed to establish this. Later, Green (2005) proposes to theoretically distinguish a linguistic system from a control system to account for the different types of recovery, which is further expounded in Abutalebi & Green (2007) which reviews 28 studies. Let us first take figure 7 (on the following page) into consideration.
In figure 7 we distinguish three cortical areas, namely the prefrontal cortex, the anterior cingulate cortex, and the inferior parietal lobule. In addition to these cortical structures a subcortical area, the basal ganglia, known for its control function in bodily (motor) movements, is concerned to be a fourth separable neural system. Although the areas are depicted in the left hemisphere, they are assumed to be apparent in both hemispheres. Abutalebi & Green (2007) argue that the distinct devices mainly play a part in (bilingual) word production, namely in the selection and sequencing of lexical items. The integration of these four components should be understood as cognitive control. Along with the characteristics mentioned in the boxes in figure 7, the prefrontal cortex is involved in selection of (or switching to) the intended language, while inhibiting the irrelevant language. The anterior cingulate cortex is at work during translating and should reflect the SAS as proposed in Green (1998); the inferior parietal lobe keeps track of the linguistic context (cf. the pragmatic system proposed by Paradis (2001; 2004)); the basal ganglia control motor movements (articulation) and play a role in language selection.

Abutalebi & Green (2007) conclude from the different imaging and aphasic studies that:
- there is a common neural network subserving L1 and L2;
- as seen above, both cortical and subcortical areas are involved in language control and lexical selection;
- at both cortical and subcortical sites there is competition to control output of L1 vs. L2;
- inhibition is a key mechanism in language control and lexical selection.
In the light of these conclusions recovery patterns should be better understood (Green & Abutalebi, 2008; Green et al., 2010): damage to neural networks subserving control might be the underlying cause of, for example, pathological switching, parallel, or selective recovery. In this proposal language control is seen as a distinct system (as a part of a general control system) apart from the language system. As a working model the IC proposed by Green (1998) still holds (figure 4), since recovery patterns can be explained along inhibition. Selective recovery can be caused by permanent inhibition, sequential recovery by temporary inhibition, antagonistic recovery by alternating inhibition, differential recovery by greater inhibition in one language, and blending by loss of inhibition (Lorenzen & Murray, 2008). In successive recovery “one language is inhibited until it is eventually disinhibited, while the other remains available” (Paradis, 2004, p.114). As lexical items are assumed to be part of a distinctive language subsystem, however, lexical representations do not need to be specified by a special language tag as proposed by Green (1998): bilinguals should be able to selectively deactivate an entire subsystem or parts of it (Paradis, 2009, p.166). Thus, different languages should rather be seen as subsystems of the language system as a whole than as subsets. A language independent articulatory module and monitor system (as part of control) as presented by Levelt (1989; 1999) could still be applicable.

In view of Paradis (2009, p.163) a component of the control system is conscious. This involves attention and general executive functions, subserved by the prefrontal cortex and the anterior cingulate (see figure 7). Unconscious control is implicated by the perisylvian cortex (which among other areas comprises the inferior parietal lobule), basal ganglia, and cerebellum. All in all, the neural correlates of language control seem to be scattered throughout the brain.
4. Cognitive reserve

4.1 Language and cognition

Let us first consider the following statements:

- Any aspect of cognition appears to be, at least in principle, accessible to language (Hauser et al. 2002).
- Cognition could be hypothesized in terms of clusters of modules (Paradis, 2004, p.144).
- Cognitive skills, such as language, pragmatics, and musical ability, are suberved by neurofunctional modules, each of which containing several subsystems (Paradis, 2004, p.127).
- Metalinguistic knowledge requires more cognitive capacity than implicit competence (Paradis, 2004, p. 50).
- Even aspects of emotion or cognition not readily verbalized may be influenced by linguistically based thought processes (Hauser et al. 2002).

In an attempt to set a guideline along which the evolution of language might be evaluated by different scientific disciplines, Hauser et al. (2002) propose to distinguish two language faculties. A language faculty in the broad sense (FLB) is assumed to include a subset in the form of a faculty in the narrow sense (FLN). The latter should only contain recursion and hence being uniquely human; humans are able to embed sentences within other sentences, a feature not (yet) seen among other animals. FLB is assumed to provide the computational mechanisms for recursion, that is, to generate infinite sentences using a finite set of segments. Also, it should include a sensory-motor system to let us speak (or gesture) and a conceptional-intentional system in order to prepare our thoughts to be conveyed. In other words, FLB should comprise a wide variety of perceptual and cognitive mechanisms.

Ignoring the details concerning the evolutionary aspects of the proposal for the moment, it is interesting to note the analogy with the neurolinguistic theory of bilingualism as proposed by Paradis (2004). Implicit competence might be understood as a subset of general knowledge, just as FLN is of FLB. Procedural memory could be subserving the recursive feature, whereas declarative memory should rather be involved with the conceptional-intentional system roughly. Note, however, that a sensory-motor system can be controlled either by automatisms (procedural) or by conscious actions. FLN should therefore be assumed to account for all procedural aspects of language.\(^5\) Paradis (2004, p.14) points out that the distinction between two memory systems may explain why it is possible to

\(^5\) In this sense the proposal of Hauser et al. (2002) meets to some extent to the critique of Pinker & Jackendoff (2004) who assert that there is more to language that makes it special than the recursion-only claim. By example, they bring forward that uniqueness is also seen in speech perception and production.
let chimpanzees learn an impressive amount of words while they lack acquisition of syntax, implying that this acquisition is uniquely human in nature.

Altogether, it appears that studies with different aims and perspectives suggest that language and cognition seem to interact. Particularly the metalinguistic part of the language system seems to be interwoven with cognition. This could imply that aphasic (i.e. when implicit knowledge is damaged (Paradis, 2004, p.9) patients who relied relatively more on metalinguistic knowledge premorbid, might have an advantage in that they might fall back on some sort of cognitive reserve.

4.2 Cognitive reserve

Brain lesions of the same magnitude may lead to different levels of cognitive impairment among individuals. Stern (2002), therefore, proposed the concept of cognitive reserve (CR). This active model assumes that the brain is able to actively face up to pathologies such as Alzheimer’s disease contrasting passive models which are merely based on brain size and neuron count. However, Stern (2002) explains that the two models are not mutually exclusive and that a combination might best describe the concept of reserve in the end. Within the active model he distinguishes at least two types of reserve, namely cognitive reserve and compensation, but in a later version of his theory this is slightly changed: in Stern (2009) CR is based on neural reserve and neural compensation, the first referring to an individual’s network efficiency, the latter to networks that function as substitute.

One of the predictions of the CR hypothesis is that elderly people with higher cognitive ability will have lower risk of developing dementia than adults with lower cognitive ability for the reason that the brain of the first group should be assumed to be better coping with the loss of neurons, while the amount of loss is at least the same as in the other group. More CR should be seen as a better ability to adapt by “differential recruitment of brain networks”. These networks could be either more efficient by means of neural reserve, or be networks employed by means of compensation. In any case, inter-individual differences should be apparent. (Stern, 2009). As we have seen in section 2.3 a later learned L2 will be more vulnerable to Alzheimer’s disease as it is assumed to be relying more on declarative memory. In line with Stern (2009) we could predict that elderly with higher cognitive ability will have lower risk of loosing a later learned L2.

CR should be assessed using information about patients’ socioeconomic status, education levels, former occupations, that is, the complexity of these, and premorbid IQ levels, just as is suggested during the assessment of aphasia. Further, details about mentally stimulating leisure activities could be important, implying that CR can increase later in life (Stern, 2002). From a biological point of view Whalley et al. (2004) note that despite the diversity of the assumed factors underlying CR, they all serve a common goal, namely healthier lifestyles, yielding healthier brains, provoking probably neuroplasticity which in turn subserves higher mental activities. We could expect that greater neuroplasticity might support recovery in the acute phase of aphasia. Still, the details of the neurobiology remain to be investigated.
To my knowledge, the first systematic analysis of factors that may underpin CR is done by Valenzuela & Sachdev (2005). They collected epidemiological studies that reported relevant effects of education, occupation, premorbid IQ, and mentally stimulating leisure activities on the development of dementia. While correcting each factor for every other factor, they found in twenty-two papers a significant protective effects of education in 10 out of 15 studies, of occupational attainment in 9 out of 12 studies, and of engagement in leisure activities in 4 out of 4 studies. 2 out of 2 papers showed a protective effect of premorbid IQ. Overall, the investigators found that the factor ‘leisure activities’ was most robust and that dementia risk was 46% lower in high-reserve individuals. Bilingualism is not as yet investigated as a possible significant factor of CR.

4.3 Cognitive aspects of bilingualism

As noted in section 3.3 early bilinguals tend to have a more bilateral language organization (Hull & Vaid, 2005). In the light of this fact it is interesting to take a study of Catani et al. (2007) into account. Without commenting on bilingual brain structures, these researchers found that verbal recall (typically a metalinguistic task according to Paradis (2004)) benefits from symmetric patterns of connections. People that employ a bilateral organization are supposedly better in learning words as they process semantic association more easily. Catani et al. (2007) suggest that anatomical predictors such as laterality might be of help in aphasia recovery research since, for example, we could predict that relative symmetrical patients should show less word finding problems. Also, hypotheses concerning early bilinguals could be tested. For example, we could investigate to what extent bilateral language organization influences cognition.

Under the assumption that linguistic and nonlinguistic knowledge converge on some domain-general system, Bialystok (2005) examines nonverbal cognitive consequences of becoming bilingual in childhood (early bilinguals). Concentrating on three areas, namely (i) concepts of quantity and arithmetic ability, (ii) hierarchical classification in a task switch paradigm, and (iii) theory of mind, she concludes that bilinguals do not show an overall advantage in these three areas. However, at least one consequence of bilingualism for cognitive development seems that bilinguals tend to score better on the control of attention and inhibition tasks during their childhood as well as later in life. Characteristically, these functions are managed by the prefrontal cortex of which structures are highly associated with intelligence. Still, as Bialystok (2005) warns, since no relevant studies exist, the conclusion that bilingualism correlates with higher intelligence is extremely premature. Notable, however, is that language control as proposed by Green (2005) might have beneficial effects on control and attention tasks in general. In other words, an often used subsystem might improve the larger system to which it belongs.

Paradis (2004, p.195) cites some studies that have reported other findings with respect to bilingual brains. Some suggest that cognitive plasticity and flexibility may explain why bilinguals are superior on metalinguistic tasks, verbal intelligence tests, divergent thinking tasks, concept formation, and general reasoning tests. Also, bilinguals tend to perform relatively better in the discovery of underly-
ing rules in problem solving as well as on tests of (both verbal and nonverbal) creativity and flexibility. In general bilinguals are assumed to have a reserve of cognitive cues, signs, meanings, and relationships that they can use.

Normal aging bilinguals might benefit from a relatively higher level of education (Juncos-Rabadan, 1994), although in this study it did not become clear whether it can compensate for age related deterioration. Nevertheless, as already pointed out in section 3.2, age, premorbid IQ, education, and the integrity of the frontal lobes are variables in the prognosis of recovery from aphasia. These variables may account for the fact that individuals show differences in recovery. Green (2005) notes that “A lesion at a given site and extent may yield different effects (e.g., parallel recovery versus differential recovery) because of more effective repair process in one individual compared to the other”. He doesn’t refer to CR but his comment is totally in accord with this hypothetical construct. If IQ and education are factors, Paradis (2009, p.116) concludes, it has to do with the declarative memory system which subserves metalinguistic knowledge. Typically, this memory system might be employed as a means of “explicit compensatory strategies” (Fabbro, 2001a). Levels of IQ and education have shown in the study of Paradis (2009) to be relevant for learning a language rather than acquiring one and they might be factors in recovery patterns. In addition, as the neurolinguistic model proposed by Paradis (2001; 2004) predicts, when Alzheimer’s disease is diagnosed, declarative memory will be affected causing loss of a later learned language (see section 2.3). Contrastingly, procedural memory affects for the most part the native languages. As a consequence, patients with Parkinson or Huntington disease will rather show deficits in these languages (Paradis, 2009, p.175). Pursuing this line of reasoning, we could predict that such patients would profit relatively less from a cognitive reserve if there is any at all.
5. The bilingual brain: language reserve?

In the previous sections we have seen that bilingualism may have consequences for the organization of the individual brain. A clear distinction can be made between early and late bilinguals and hence different predictions can be made for each type of bilingual. Both types as well as monolinguals, however, develop automatized brain areas when acquiring fluency. The more automatized an area the smaller the activation that can be measured by an imaging technique (Paradis, 2004, p.105). We could pose the unfortunate prediction that the most automatized language should be the most vulnerable to a certain lesion as a small area is an easy target. In addition, early bilinguals, contrasting late bilinguals, tend to show almost complete overlap in the processing areas of the Broca region (Kim et al. 1997). In this respect late bilinguals might theoretically have an advantage as they should be able to employ the unaffected language system if a lesion in Broca’s region impairs only one of the distinct processing units. Such cases might account for a form of selective recovery. Although incidences of this type of recovery have been reported in the literature, it is to my knowledge to date explained in terms of inhibition. It might be worth, however, to thoroughly evaluate selective recovery using brain imaging techniques in order to explore the prediction made above.

While early bilinguals will show relatively more automatized processing regions, it seems that these areas are organized more symmetrically (Hull & Vaid, 2005). As noted in section 3.3 this conclusion is under debate since Paradis (2004, p.116) claims that the difference between monolinguals and bilinguals rather depends on the application of metalinguistic knowledge. This knowledge, he assumes, is not part of the implicit language module. Cortical symmetry could then be accounted for by a relatively increased implementation of the declarative memory system. Presumably, this could have beneficial effects on verbal recall (Catani et al., 1997). Especially late bilinguals should have an advantage. Concerning the recovery of aphasia predictions of rehabilitation results could be made. We should, however, keep in mind that aphasia only affects (parts of) the implicit language system (Paradis, 2004, p.9) and it is still unclear to what extent late bilingual aphasic patients really benefit from their declarative memory processes. Firstly, research in this area is relatively young, and secondly, clinicians use different test batteries which makes it difficult to compare patient groups. Heterogeneity of the aphasic syndromes might well have to do with the diversity of assessment procedures.

If we could establish a significant role of the declarative memory system in the recovery of bilingual aphasia it seems reasonable that this system may profit from a relatively higher CR. As cognitive-linguistic therapies when given during the acute phase might help in the recovery of monolingual aphasics (Visch-Brink, 2006) it seems that metalinguistic knowledge is a factor in the restoration of the implicit competence. As noted too in section 3.2, although their conclusion is underpinned by insufficient data, Kiran & Edmonds (2006) might indicate that declarative memory processes (supporting the non-dominant language mostly) may endorse procedural memory processes in late bilingual patients. Future research is required as both cited studies used different training methods as well as dissimilar types of assessment.
Finally, I would like to point to the monitor system of the speech production model as proposed by Levelt. It could be interesting to investigate to what extent this system fits in the proposed cognitive control system of Abutalebi & Green (2007). One question of interest is, for example, to what extent is monitoring a conscious process, that is, which parts should be considered to be subserved by (in Paradis’ terms) declarative memory (conscious) and which by implicit competence (unconscious)? Specifically, to what extent is verbal monitoring underpinned by cortical, subcortical and cerebellar motor control processes? Evidence of the relation between cortical areas and verbal monitoring is reported by Ganushchak & Schiller (2006). They suggest that the Error-Related Negativity (ERN) they recorded during verbal self-monitoring tasks under time pressure in monolinguals corresponds with other performance action monitoring: under time pressure the amplitude decreases. During verbal self-monitoring the amplitude is typically found in the anterior cingulate cortex (see figure 7) and the neighboring medial frontal cortex (cf. prefrontal cortex in figure 7). This might indicate, as the researchers put forward in accord with Abutalebi & Green (2007), that the processing of verbal monitoring is a subsystem of a general explicit control system. Presumably, the participants were forced to employ their control system consciously. But could there be an implicit or unconscious aspect of verbal monitoring? It might therefore be interesting to investigate the role of the basal ganglia and the cerebellum in relation to Levelt’s monitoring component.

In a follow up study, Ganushchak & Schiller (2009) report unexpected higher ERN scores in German-Dutch bilinguals during verbal self-monitoring tasks under time pressure. As for the monolingual control groups as reported in the previous study, the participants made more errors under time pressure. However, as the ERN normally decreases during pressure tasks the bilinguals showed higher ERN scores. The researchers suggest that participants were presumably disturbed by their dominant language. I would like to add, considering the findings of this thesis, that this could well be explained in terms of the neurolinguistic theory of bilingualism (Paradis, 2004): it might be that the participants were making use of their metalinguistic knowledge on which they rely most in using the second language, causing more activity in the cingulate cortex and medial frontal cortex. This might consequently explain the higher amplitude. Even, it could be possible that surrounding cortical areas that are more proximal and hence easier to tap by EEG assist in a time pressure control task in late bilinguals. We could predict that early bilinguals should not produce increased ERN scores. Additional research is needed to corroborate this. Further, we could test the hypothesis that late bilingual aphasics perform better on verbal self-monitoring tasks under time pressure in their non-dominant languages. If they do, then we could speak of reserve albeit in the form of control.
6. Conclusion

In this thesis I inquired two special phenomena, namely aphasia and bilingualism, and the consequences when these phenomena occur simultaneously. The main question to examine was whether bilinguals might have a language reserve to fall back on. First, I looked into approaches to model language production from a historical perspective as well as to model the bilingual system as language pathology and its underlying organization in the brain can be comprehended along such models. Then, after investigating the assessment and recovery patterns of aphasic bilinguals I compared some of the neural correlates of the proposed models. Especially components of cognitive control, of which language control seems to be a subsystem, emerged. Utilizing the hypothesis that language use is underpinned by two distinct memory systems, aphasia seems to affect only the implicit component. Within this system it is assumed that every ‘grammar’ of all languages acquired by its user is comprised. With respect to Broca’s area it seems that early bilinguals show almost completely overlap of phonologic and semantic processes, whereas late bilinguals tend to develop two distinct areas. More research is needed to establish whether this division in late bilinguals could be seen as a form of language reserve. If so, then brain imaging may help to decide which language should be treated.

The second memory system, subserved by declarative memory processes, seems important for late bilinguals. Although every speaker, either monolingual or polyglot, employs this system, late bilinguals seem to rely more on this system than early bilinguals do. In addition, the relatively more symmetrical language organization in the brains of early bilinguals might be caused by declarative procedures too. The assumed subset of a general cognitive control system, language control seems to heavily depend on declarative memory processes and hence might be of influence on patterns of recovery. Moreover, this memory system might benefit from ‘cognitive reserve’, a hypothetical construct - initially proposed to account for the development and recovery from mental diseases - that may also be of help to understand recovery patterns of bilingual aphasics. It is hypothesized that late bilinguals might have a reserve in the form of language control, which might be an advantage. However, future research is required to corroborate this.
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