UNIVERSITÀ DEGLI STUDI DI UDINE

DIPARTIMENTO DI SCIENZE UMANE

DOTTORATO DI RICERCA IN

COMUNICAZIONE MULTIMEDIALE – CICLO XXVI

Tesi sottomessa per il titolo di

Philosophiae Doctor

Features of narrative language in fluent aphasia

DOTTORANDA:
Dott.ssa **Sara Andreetta**

RELATORE:
Dott. **Andrea Marini**

1. Reviewer: Prof. Heather H. Wright

2. Reviewer: Prof.ssa Francesca Marina Bosco

Day of the defense: April, 9th 2014

Head of PhD committee: Prof.ssa **Leopoldina Fortunati**

Abstract

Fluent aphasia is a disorder affecting linguistic processing in persons who suffered a brain damage. It is a syndrome gathering several typologies of aphasia and is less severe than a non-fluent aphasia. Indeed, patients suffering from fluent aphasia experience minor difficulties: normally, they are still able to produce complete and informative sentences. However, they are often affected at semantic level, therefore they face impairments in lexical retrieval. Interestingly, these difficulties affecting the microlinguistic dimension of language, may also lead to impairments at macrolinguistic level. For instance, in a group of patients with anomic aphasia, the lexical impairment was related to a significative higher percentage of global coherence errors with respect to healthy controls (Andreetta et al., 2012).

The aim of the present study is investigating the linguistic skills of a group of individuals with fluent aphasia. The assessment is focused on narrative discourse since evidence showed that spontaneous discourse can provide more information than classical standardized tests for aphasia. In particular, I used a multi-level approach gathering quantitative and functional measures of narrative analysis (Marini et al., 2011). Forty individuals participated in the study. They were divided into two groups: twenty persons with fluent aphasia made up the experimental group, and twenty healthy individuals made up the control group. The group of persons with fluent aphasia produced narratives with a comparable number of words but with a lowered speech rate, a reduced mean length of utterances and a higher percentage of both phonological and semantic errors with respect to healthy controls. Also the percentage of complete sentences was reduced in persons with aphasia. At macrolinguistic level persons with aphasia significantly produced more errors of cohesion and of both local and global coherence. Furthermore, a significative difference was found also for thematic informativeness. A further analysis investigated the grammatical skills and the errors of global coherence committed by persons with aphasia. A bivariate correlational analysis showed a strong correlation between the percentage of words and the percentage of tangential utterances, and between the production of semantic paraphasias and filler utterances. These correlations suggest that semantic processing is related to the macrolinguistic level. Indeed, the first result indicates that the comparable number of words produced by the two groups isn't comparable from the informative point of view; the second result indicates that the difficulty in lexical retrieval influences the production of both semantic errors and lexical fillers. Lexical fillers in particular are a strategy to cope with their difficulty.

Another bivariate correlation analysis was used to observe the clinical implications of the multi-level approach. These analyses were based on the potential interrelations between narrative measures and subtests of the Aachener Aphasie Test. Several measures significantly correlate, indicating that the multi-level approach is a valid instrument for the clinical practice as it provides complete information of the linguistic impairments in persons with aphasia.

This thesis also constitutes the Italian contribution of an international multimedia database for aphasia: AphasiaBank. AphasiaBank is an American project which aims at collecting data about the spontaneous speech in persons with aphasia. Spontaneous speech is elicited through interviews between researchers and persons with aphasia. The project aims at collecting data in several languages. Ten of the persons with aphasia participating in this study were videorecorded during test sessions and transcriptions were also made according to AphasiaBank instructions. Their performance then, will be soon at disposal in the official website of the project (http://talkbank.org/AphasiaBank/).

Index

Preface

This thesis presents an assessment of linguistic skills in a group of persons with fluent aphasics compared to a group of healthy subjects matched for age and education. The aim of the study is to investigate the linguistic abilities in fluent aphasia using an innovative multi-level approach for the narrative assessment. Indeed, evidence showed that standardized tests for aphasia are not sensitive enough for a complete understanding of the impairments, whereas spontaneous speech has gained new interest among researchers and clinicians since it allows to contemporarly assess several aspects of language processing.

The thesis starts with a general introduction about the linguistic processes involved in message producion. Therefore, the organization of the language system and the dynamics of linguistic production are described. The second chapter is a historical and clinical framework of aphasia. Indeed, starting from antiquity, it goes through several centuries and states how was considered aphasia in those different times. At the end it describes the clinical classification for the typologies of aphasia most used today. The third chapter is focused on the role of discourse for the assessment of aphasia. It presents the traditional approaches to discourse analysis and describes then in detail the innovative multi-level approach. The fourth chapter presents the Italian contribution to an international multimedia database for aphasia: AphasiaBank. The fifth chapter is focused on the main study of thesis: the narrative assessment of twenty patients with fluent aphasia compared to twenty healthy subjects. Therefore, materials and methods and results are described. The final section of the fifth chapter presents further analysis indicating the clinical implication of the use of the multi-level approach to the analysis of speech samples produced by persons with aphasia. Finally, the sixth chapter is related to conclusions and future developments.

1

An introduction to the linguistic processes involved in message production

1.1 Introduction

The faculty of language is a specific function of human beings. Indeed, differently from animals' communication systems, human language is characterized by some peculiarities: *duality*, *discreteness*, *recursion*, *structure* and *competence* (Graffi and Scalise, 2003). *Duality* refers to the possibility of human language to generate arbitrary signs from a limited number of meaningless discriminatory units (phonemes). On the contrary, in animal communication every gesture is meaningful and can't be analysed in terms of meaningless discrete elements. *Discreteness* indicates that the sounds used in a language have clear limits among them. It is possible to distinguish words by a single sound (e.g., ***c**at* – ***h**at*), whereas in animal communication signals can be continued and then become more and more specialized. That happens for instance in bees' waggle dance making use of kinesic competence: during this dance, in order to indicate where the food source is, they keep on modifying rhythm and direction making them more precise. *Recursion* implies the possibility to have a finite set of elements that generate a potentially infinite amount of sequences (i.e., syllables, words, sentences). It is particularly important since it seems to be partially in contrast with other components of the human body. Lung capacity, for instance, imposes some limits on the length of sentence production; similarly, working memory poses some limits on the complexity of sentences. This aspect seems to exist just in the human faculty of language: there isn't any analogy in other animal species (Hauser, Chomsky, and Fitch, 2002). *Structure* means that human language is fundamentally dependent on a structure. Indeed, we wouldn't be able to build up a sentence just putting some words next to each other: that would produce a non-sense utterance. Consequently, relationships within words are dependent on a structure. The concept of *competence* is related to that of grammaticality, since it refers to the intuitive sense native speakers have about the correct expressions of their language. Notably, this intuitive sense does not necessarily derive from the normative grammar of languages. Rather, it belongs to a inner intuition of the speaker about his/her language. In fact, a native speaker is able to distinguish between a correct and an incorrect sentence despite his/her knowledge of normative grammar.

Most scholars share this description of language. What is still controversial though, is the faculty of language itself. Today, two main approaches are considered the most influential in linguistic studies: the behaviourist model and the generativist one. The first was influenced by the psychological theory of behaviourism (Watson, 1913). Based on the principles outlined by this theory, the psychologist Burrus Frederic Skinner (1904-1990) published the book “Verbal Behavior” (Skinner, 1957). In this publication, he claimed that language could be considered as a behaviour that may be modified according to the stimuli coming from the outside environment. However, a pair of years later, a young student of Skinner, Noam Chomsky, wrote a review of “Verbal Behavior” in which he criticized most of the assumptions made by Skinner (Chomsky, 1959). According to him, language wasn’t a behaviour depending on external stimuli but it was a cognitive skill. Notably, he considered language as partially innate and partially to acquire. “Verbal Behavior’s” review, together with other publications signed by Chomsky in those years, marked the beginning of another approach in linguistics: the generativist model. The contribution of Chomsky to linguistic theory is still considered a great revolution. Indeed, his ideas symbolize a big change even though some of them are still debated. Yet, one of the major concepts he introduced was the notion of the faculty of language as a complex cognitive system made up by both innate and cultural factors. He used the expressions *competence* and *performance* to draw a difference between what the speaker knows about his/her language from a grammatical and pragmatic point of view (*competence*) and how he/she uses this knowledge (*performance*).

In the last century, psychologists and linguists gathered in the study of language; they focused on the structure of language and the brain and cognitive structures related to its processing, respectively. In this common field two main theories are integrated: *modularity* (e.g., Fodor, 1983) and *connectionism* (e.g., McClelland and Rumelhart, 1981). According to the former, the cognitive system collects an amount of different functions and it is constituted by a central system and by a number of peripheral modules. Modules are independent and the central system integrates upcoming information. According to this theory, language is considered as a module. According to the connectionist theory, the cognitive system elaborates knowledge based on connections between the nodes of a neural network.

On these bases, language is considered nowadays as a complex dynamic cognitive system, which integrates several competences along two main dimensions of processing: the microlinguistic dimension and the macrolinguistic one (Caplan, 1992; Glosser and Deser, 1990). We will outline here the linguistic competences and how they are organized in the two dimensions of processing.

1.2 Organization of the language system

Linguistics considers language as a complex structure that can be analyzed at different levels. For example, phonetics focuses on the phonetic level of analysis: in that it studies the way speakers articulate the linguistic sounds (i.e., phones; Articulatory Phonetics), perceive them (Auditive Phonetics) and the physical characteristics of such sounds (Acoustic Phonetics). In a similar way, Phonology focuses on the phonological level of analysis. This level addresses the need to analyse how speakers cluster different phones in the same phonological category (i.e., phonemes). The following level of analysis (i.e., morphophonology) studies the way phonemes are grouped in syllables. Morphology studies how these syllables are grouped into meaningful units (i.e., morphemes) in order to generate well-formed words. Morphosyntax focuses on the linguistic contexts out of the lexical level that are required by a word (e.g. the object required by a verb). Syntax studies the process of elaborating words into bigger units (e.g., phrases) and the way phrases gather to build sentences. The following level (i.e., Semantics) focuses on the way words and sentences are connected to their direct meanings without taking into account contextual or extralinguistic aspects; it is related just to the linguistic items. The last levels are connected to a between-utterances dimension of language (i.e., macrolinguistic dimension). Indeed, Pragmatics studies the relation between sentences and communicative situations. Therefore, it is also associated to other kinds of knowledge, out of the linguistic ones. Finally, Textual analysis studies the way in which complex communicative structures (i.e., texts) are built. In particular, topics must be organized through measures of coherence and cohesion. Cohesion refers to the ability of establishing relations among contiguous utterances through the use of grammatical and lexical ties (Halliday and Hasan, 1976). Coherence is related to the ability to establish relations among remote utterances.

From a cognitive point of view, each level of analysis assesses different competences (Marini, 2001). These competences are organized along a microlinguistic and macrolinguistic dimension of processing. In particular, the microlinguistic dimension of processing is responsible for intrasentential functions. As such, it includes lexical and syntactic processing: it organizes phonological and graphemical patterns into morphological strings and words, and determines the syntactic context required by each word for the generation of well-formed sentences. This means that this dimension requires phonetic, phonological, morphophonological, morphological, morphosyntactic, syntactic and semantic competences. The macrolinguistic dimension manages between-utterances functions and includes pragmatic and textual competences. Therefore, it involves the ability to determine the contextually appropriate meaning of words and sentences and their connection through the generation of cohesive and coherence ties, in order to integrate linguistic and conceptual information and understand the main topics of a conversation, discourse or a written text (Kintsch, 1994). These two dimensions of processing are deeply interconnected. In particular, it is suggested that cohesion has an important role in this connection, since disrupted cohesion, that may reflect a microlinguistic impairment, such as a difficulty in lexical retrieval, may also impair macrolinguistic organization (Marini et al., 2011).

1.3 Dynamics of linguistic production

Understanding the mechanisms of linguistic production is important for the investigation of language disorders. Indeed, theoretical models allow us to better identify the production stage that has been damaged by a brain lesion.

Several linguistic production models have been hypothesized in the last century. Most of them share the inclusion of at least three stages in the linguistic processing (e.g., Levelt, 1989; Frederiksen et al., 1990; Indefrey and Levelt, 2004): a conceptual phase, a phase of linguistic formulation and a phase of linguistic expression. In the conceptual phase, the speaker generates a mental concept of what he/she is intends to say. Therefore, he/she must retrieve the appropriate concept from long-term memory and complete it with the adequate semantic information, such as participants and setting of the target message.

Moreover, the speaker is required to integrate what he/she is about to say with what has previously been said. In particular, he/she is required to respect the context from a linguistic as well as from an extralinguistic point of view. In fact, he/she is asked to maintain the topic of conversation and adjust it on the basis of the situation, place, people and time in which the communicative act is taking place. Then, in the linguistic formulation phase the speaker needs to convert the concept into a speech plan (Levelt, Roelofs, and Meyer, 1999). Therefore, the intended meaning is matched with the corresponding lexical items that are stored in the mental lexicon. A multi-stage process is required, as the speaker goes through a phase of lexical selection and one of lexical access. The phase of lexical selection, in which the speaker has to select the lexical items corresponding to the intended meanings, goes through an activation/inhibition mechanism. Indeed, each word has its own activation threshold, determined by the frequency of its use. Consequently, the speed of accessing a word is dependent of this threshold: access is easier if it is low and, it is more difficult if it is higher. Activation is also influenced by the co-occurring inhibition of semantically related competitors. By selecting the target word though, the competitors' activation thresholds are raised. When the target word has been activated then, the speaker has access to its morphosyntactic and morphological information and then to its syllabic and phonological form. If the target is a single word, the lexical information is transmitted to the output system where phonemes are programmed and implemented. When the target is a sentence production, then the morphosyntactic information required by the selected word assign thematic roles and generate the phrase to create the sentence. Subsequently, the information of the selected word generates grammatical relations among the phrases in order to produce well-formed syntactic representations (Chomsky, 1995). Now, the speaker can access the syllabic and phonologic representations of the selected words. Finally, the information is sent to the output system where articulatory information corresponding to the selected phonemes are programmed and implemented. This last stage corresponds to the phase of linguistic expression (Marini et al., 2011). Similarly, for the comprehension processing, when the stimulus is heard it is transmitted through brain areas responsible of the codification of sounds. Then, the stimulus goes under a differentiation between a meaningless sound and a phoneme, so that the speaker can recognize it. Subsequently, the phoneme is analysed by the mental lexicon and the speaker can recognize the word and understand the concept (Gazzaniga et al., 2005).

2

Aphasia: historical and clinical framework

2.1 Definition of aphasia

The term *aphasia* refers to a communicative disorder triggered by an acquired brain lesion. This is an umbrella term, since it implies several deficits involving one or more aspects of linguistic processing (Goodglass, 1993). Brain damages may result from strokes, traumatic brain injuries or cerebral tumors. Aphasia could have different symptoms, depending on the affected brain region. Indeed, it can compromise oral production or comprehension and/or reading and writing skills. Notably, aphasia is a central linguistic disorder and it differs from peripheral deficits. It is strictly related to the cognitive function of linguistic processing, not to auditory or articulatory impairments (Marini, 2008). In fact, a person suffering from aphasia may experience difficulties in the coordination of tongue and lips movements for the act of speaking but he/she may still be able to coordinate movements for swallowing or even for singing (Goodglass, 1993). However, some patients may suffer from a peripheral disorder together with aphasia. *Apraxia* for instance, is a disorder affecting the coordination of speech movements. Therefore, patients who suffer from apraxia have difficulties in producing sounds related to language but do not go through the same deficits with other typologies of sounds. Brain areas associated with this disorder have been investigated (Dronkers, 1996) and sometimes they can involve areas related to central disorders of linguistic processing.

Traditionally, aphasia has been studied from different points of view: brain areas involved, linguistic levels affected, and possibility of rehabilitation. Since the beginning of aphasia studies, with the contributions of Broca (1861a, b) and Wernicke (1874), scholars understood that there are several typologies of aphasia. In this chapter, I will provide an outline of the major historical contributions to the field of Aphasiology and of the most accepted classifications of aphasic syndromes.

2.2 Early descriptions of speech disorders: from Antiquity to the Middle Ages

The first documentation of a clinical interest about brain lesions resulting in aphasic symptomes comes from ancient Egypt. In the Edwin Smith Papyrus[1], which is considered the first medical document of humanity, we find the first mention of a speechless person. The Papyrus presents an amount of 48 cases. Many of these cases were patients who had suffered head injuries and, two of them in particular (cases number 20 and 22), seemed to have a head injury associated with loss of speech. Interestingly, the author of the papyrus didn't often refer to their status as *speechless* but he defined these patients as being "silent in sadness […] because of something which has entered from outside" (Finger, 1994). Notably, no differentiation was mentioned between central disorders, caused by the head injury, or peripheral disorders, caused by damages in areas outside of the central nervous system (Tesak and Code, 2008). Furthermore, it seems that there weren't hypotheses in Ancient Egypt about connections between brain damages and speech disorders. That was probably also due to the cardiocentric view, which was dominant in Egyptian culture. According to this view, heart was the most important part of the human body, whereas brain didn't gain that central position: it was even discarded in

[1] (http://www.neurosurgery.org/cybermuseum/pre20th/epapyrus.html)

mummification processes. Ancient Egypt culture largely influenced following eras.

As in Ancient Egypt culture, also in Ancient Greece medicine there wasn't a clear distinction between central disorders of linguistic processing and other disorders, such as loss of voice. Indeed, there is quite a rich documentation collected by Hippocrates (460-370 BC): he gathered writings about clinical cases coming from different authors and from different periods. Many of the cases described presented speech and language disorders but, whether disorder regarded speech, voice or language in general wasn't very clear. We can find first mentions of a connection between stroke and speech and language disorders in one of these writings, but no direct cause-effect hypothesis was made and observations were quite vague (Tesak and Code, 2008). Interestingly, in most of Greek writings, terms referring to linguistic disorders have been translated into: *speechless*, *voiceless* or *without articulation* (Benton and Joynt, 1960). There is one exception though, of a man called "learned man of Athens" who, after being hit in the head by a stone, lost his memory for letters and didnt' have other deficits (Goodglass, 1993). However, there wasn't still a clear awareness about the involvement of the brain in linguistic disturbances. Notably, the Greek philosopher Celsus (II century B.C.) believed that the responsible of most speech disorders was the tongue, not the brain.

One of the most influencing theories of ancient medicine was proposed by the Greco-Roman physician Galen (130-200 AD): his ideas on the human brain dominated throughout the Middle Ages. He introduced the *cell theory*, or *ventricle theory*: according to this theory, the human intellectual faculties were located in some “cells” of the brain. He hypothesized that imagination was located in the two lateral ventricles, that were considered the first cell; reason was in the third ventricle, which corresponded to the second cell, and memory was in the fourth ventricle, the third cell. On these basis he also hypothesized a *rete mirabile*, which was a structure located at the base of the brain, important for intellectual functions but where soul also may be located. Later, in the Middle Age, the *cell theory* was still influencing. In particular it was adopted by the fathers of the Christian church: Nemesius, Augustinus and Posidonius (IV and V century AD). According to them, damages at the frontal ventricle could cause deficits in imagination, while damages in the occipital ventricle could impair memory. Symptoms of speech and language disorders were considered a result of a damage to the fourth ventricle: therefore, in the Middle Age aphasia was considered a memory disorder.

2.3 Advances from the Renaissance to the 18th century

During Renaissance there were some important innovations in medicine, mostly in anatomy. The empirical methods used by Leonardo Da Vinci (1452-1519) importantly improved the knowledge of body structures. On these bases, Andrea

Vesalius (1514-1564) published important writings on brain structures, provoking a breakthrough in neuroanatomy studies since he confuted much of Galenian anatomy, in particular the existence of the rete mirabilis. Vesalius described ventricles in detail but he localized memory in the cerebellum. Thomas Willis (1621-1675), a Professor of Medicine who was interested in the functions of the brain as well as in its anatomy, also dismissed the theory of cells. He gave great importance to the cerebral cortex and to the cerebral gyri. The aspect of cortex played an important role also for the future theory of phrenology. There are some important writings on aphasia during the Renaissance time. Antonio Guainerio (? – 1440), for instance, reported two cases of patients who suffered head injuries and exhibited forms of aphasia: one could only say few words, the other one produced paraphasias in naming. He thought that the cause of the impairment might have been the damage of the fourth ventricle. Again, the language disorder was considered as an impairment of memory. In the same period, Baverius de Baveriis (1405?-1480) described cases of paralyses associated with aphasia. He believed that these were due to peripheral disorders: therefore, the role of the brain wasn't still considered (Finger, 1994). An important presentation of aphasia was made by Johannes Schenck von Grafenberg (1530-1598), a German physician who rejected the cell theory. He published a collection of cases observed from the Ancient Greece time until his contemporaries. Among them, there were several cases of speech and language disorders. He was among the firsts to understand that speech could be affected even when tongue or other body parts weren't involved. Some of the cases described in his writings had lost their ability to access words but could still perfectly move tongue and lips. However, von Grafenberg didn't consider the possibility of the existence of a linguistic system partially independent. Rather, he still believed that language deficits were related to an impairment of memory. In the XVII century other authors reported observations of patients suffering from speech impairments. Johann Schmidt (1624- 1690), for instance, reported the case of a patient exhibiting a right-sided paralysis and a severe linguistic deficit, as he committed so many speech errors that he couldn't be understood. A few years later, the German physician Peter Rommel (1643-1708), described the case of a woman who had suffered from a severe non-fluent aphasia. He was surprised by the contrast between the patient's inability to colloquially speak and a preserved capacity to recite her prayers. In spite of this, he called this disorder aphonia, as in the Greek tradition (Tesak and Code, 2008). In the same period also Johannes Jakob Wepfer (1620-1695) described cases of patients who experienced a brain damage and suffered from a linguistic disturbance, but his writings were published just posthumous, in 1727. Wepfer didn't mention a direct relation between brain injuries and speech disorders but, notably, noticed an association between right-sided paralysis and an inability to speak. Moreover, he believed that memory was responsible of the speech disorder.

In the 18th century the Italian pathologist Giovanni Battista Morgagni (1682-1771) published a collection of cases where he demonstrated a great interest for neuroanatomy and outlined the importance of autopsies in order to understand neurological disorders. His work is of great importance because he made a distinction among: loss of voice, utterances made up by meaningless sequences of sounds, and speech disorders due to abnormal features of the tongue. Furthermore, he noticed that loss of speech was often associated with stroke (Finger, 1994). In the same years, a first important theory of aphasia emerged with the work by Johann Augustin Philip Gesner (1738-1801). The German physician wrote a volume on medical observations in which he dedicated a section to the loss of speech. He presented some cases of patients who suffered from different speech disorders. In particular, he described in detail the case of a 73 years old man whose fluent speech teamed with neologisms and nonsense utterances. Also comprehension was affected. The patient was aware of his impairments. Remarkably, Gesner noticed the dissociation between language disorder and other cognitive aspects. Indeed, language was apparently the only system affected in the patient. Gesner understood that the impairment wasn't due to motor dysfunction, so it wasn't a peripheral disorder: in fact, if the problem had been in the tongue, the patient wouldn't have had difficulties also in writing and reading. Therefore, the German physician theorized that language disorders weren't due to an impairment in memory in general but to a specific loss in verbal memory. According to him, his patients had lost the ability to associate images or ideas to their linguistic signs (Goodglass, 1993). In fact, he believed that ideation wasn't affected, whereas the use of inappropriate words or neologism was the result of incorrect associations between thought and words (Finger, 1994). Gesner's model is believed to be the first modern theory of aphasia, as it anticipated the general thought developed in the 19th century (Benton and Joynt, 1960).

2.4 Early 19th century: the birth of Phrenology and its influence on aphasia

Franz Joseph Gall (1764-1828) has been one of the most influent but discussed figures of 19th century's neurology. In the debate between holistic and localizationist theories, his writings produced a strong theoretical framework in support of the localizationist theory. He claimed that the cerebral cortex was composed by distinct functional areas and that skull features were an index of the developments of the different areas. Consequently, the development of a function corresponded to the size of the brain area and this was visible from the skull because the cranium adapted itself to the growth of the brain and its functions. Therefore, it was easy to detect the most developed functions and faculties of a person by observing the shape of his/her cranium. His hypotheses started observing a classmate who seemed to have an exceptional memory for words and large bulging eyes. Therefore, Gall assumed that the faculty of retrieving and reminding words was located in the frontal lobes. The basis of phrenology were established, giving constrain to localizationist theories (Tesak and Code, 2008). Gall used to teach in Vienna but in 1801 his ideas were forbidden by the Holy Roman Emperor, Franz II, because they were considered too materialistic and politically dangerous. Gall then, started travelling across Europe giving lectures about the new-born theory, giving many scholars the opportunity to get in touch with his ideas. In England, for instance, the medical doctor Alexander Hood studied the case of a 48 years old man who had suffered an impairment of expressive language following a stroke. Comparing this case to others he came to the conclusion that the organ of language had three major components: a motor one for the verbal articulation, a linguistic one for the organization of words production and another linguistic one for the comprehension of words (Marini, 2008). Hood's model represents a very pioneering hypothesis for the organization of linguistic processing. What Gall assumed about language, was that two main faculties existed: the faculty of words and the faculty of language. According to him, the faculty of words was subordinated to the faculty of language. The faculty of words contained the words that the faculty of language, innate and independent, used to communicate. Separating these two faculties provided the basis for the later theory of modularity (Tesak and Code, 2008). As previously mentioned, he thought that these faculties were located in the frontal lobes. Gall's theory gained popularity as well as a great opposition. However, he gave a remarkable importance to the cerebral cortex: for the first time it wasn't considered just as a wrapping aimed at preserving deep brain structures but important functions could be located in it.

In France, Gall's theories gave birth to a great debate about localization of functions in the brain. In particular, Jean-Baptiste Bouillaud (1796-1881), a member of the Parisian Société Phrénologique, was against phrenology as a whole but in favour of the localization theory. He published a book in which he presented fifteen case descriptions. From these data emerged a connection between language loss and a lesion in the frontal lobes. Descriptions of symptoms and of lesions were quite vague but he could divide the impairments he studied in two typologies: articulation disorders and language disorders, assuming that language disorders were associated to memory impairments. Moreover, even though he was quite against the phrenological theory, he hypothesized that the language organ was localized in the frontal lobes, where the white matter was responsible for the articulatory production, whereas the grey matter was responsible of the 'memories' of the meaning of the words, that is to say the verbal representations of words. Notably, Bouillaud was probably the first brain scientist to use large samples of subjects for his studies: during his career he collected up to 500 cases. He also used animals for some of his experiments (Finger, 1994). His studies allowed him to confirm Gall's hypothesis about the localization of language in the frontal lobes. He was so convinced of this localization that he even made a bet: he offered 500 francs to anyone who would have showed him a patient with lesions in the frontal lobe without a speech disorder.

At that time, the debate in the scientific community put on one side the phrenology and its localization theory and on the other side the holistic theory. According to the holistic theory, functions in the brain weren't localized in any specific area but the brain workded as a whole. One of the most influential representatives of the holistic approach was Jean-Pierre Marie Flourens (1794-1867). From his studies on animals he concluded that the cerebral cortex coulnd't be divided into specific functional regions but, on the contrary, functions were represented throughout the brain. In particular, one of his most famous experiments involved pigeons (Flourens, 1824). He found that if these birds had lesions in specific areas of their brain, that didn't casuse long-term impairments since, whatever was the site of the lesion, they ended up with the recovery of the lost functions. For this reason he assumed that sensations, perceptions and voluntary actions couldn't be localized in specific areas of the brain. Rather, he assumed that the brain worked in a holistic way. These experiments were also the first basis for the later concept of plasticity in the brain.

2.5 The second half of the 19th century: Broca's breakthrough

In the second half of the 19th century the debate was still going on, in particular during the annual meetings of the French Société d'Anthropologie. The position of localizers was held by Ernest Auburtin (1825-1893), who was Bouillaud's son-in-law. Pierre Gratiolet (1815-1865) led the holistic approach. Auburtin was particularly in favor of the theory of language localization. Indeed, during one of the meetings of the French society he presented some thoughts about disorder on the spontaneous speech, gaining the attention of one of the participants, Paul Broca (1824-1880). Aubertin presented the case of a patient who, attempting suicide, shot in his frontal bone, so his anterior lobes were exposed. Aubertin claimed that with the pressure of a large spatula in the anterior lobes the patient couldn't speak anymore; though, once the spatula was quit, the patient could speak again. According to Auburtin, this was of great importance, indicating that, as pressure was directly only in the anterior lobes, any other function was affected by it, giving constrain to a localization model of linguistic functions. Furthermore, he stated that if someone had a frontal lobe damage without speech disorders, it meant that the injury was unilateral. Indeed, to prove that his theory was wrong it would take a bilateral frontal damage without loss of speech. Then, he declared that he would have publicly revoked his views on localization if the brain of an aphasic patient he was studying wouldn't have had a lesion in the frontal lobes in the postmortem autopsy (Finger, 1994). Broca was interested during Auburtin's presentation and invited him to visit one of the patients followed by Broca, Monsieur Leborgne. This patient was also called "Tan" because "tan" was the only sound he could pronounce. Comprehension didn't seem to be affected. Monsieur Leborgne had experienced epilepsy since he was young; then, when he was thirty, a loss of speech occurred. After a few months he was hospitalized because of his communicative problem and remained in the hospital for the rest of his life, twenty-one years. Ten years after the loss of speech he started suffering from a paralysis to his right arm and, after six years, a paralysis affected his leg. Some years later, he was transferred to the surgical ward of the Bicêtre hospital, where Broca worked, because of gangrene in the paralyzed arm (Domanski, 2013). Broca then, got interested in the severe language disorder of this patient and invited Aubertin to visit him. Monsieur Leborgne died six days later. Autopsy showed an important lesion in the left frontal lobe (Fig. 1). Some months later he presented a complete report at the Société d'Anthropologie, claiming that the brain lesion had degenerated but its centre were the second and third frontal gyrus (Tesak and Code, 2008). Consequently, Broca attributed the speech disorder to the lesion of the third frontal gyrus and declared that his findings had supported Aubertin and

Bouillaud's hypotheses on the role of frontal lobes for speech. Therefore, he confirmed the hypotheses of his predecessors but his work gained much more impact than what had been studied so far. Broca signed an important breakthrough on clinical studies. The reason of this great influence could be that, differently from Aubertin and Bouillaud, he went into deep details in describing his case and, above all, he was looking for a precise localization for speech. Aubertin, though, claimed that if some persons had frontal lobes damages without an associated speech disorder, was because a precise localization for language faculty still hadn't been found (Finger, 1994).

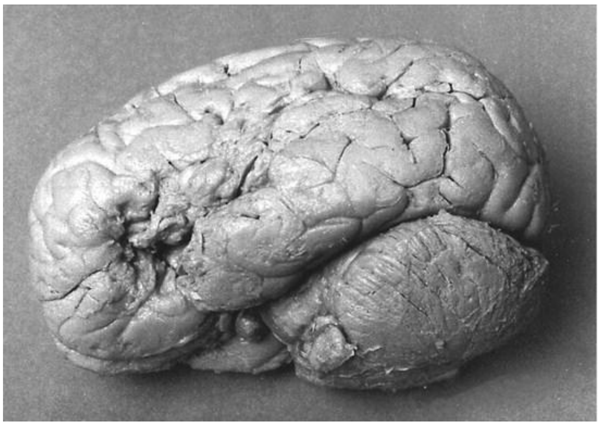


Fig. 1: Lateral view of Monsieur Leborgne's brain. Modified from: Dronkers et al., 2007.

Even if not everyone in the scientific community was convinced by Broca's findings, the localization theory and, in particular, the cortical localization, gained good achievement. Notably, Broca referred to a speech disorder, not a language one. His patient in fact, had precise symptoms just on articulatory processing. Therefore, he provided brain localization just for speech faculty. Afterward, Broca collected other cases of articulatory disorders. His second case in particular was that of Monsieur Lelong, an old man who, after a stroke, could only say three or four simple words and couldn't write anymore. The autopsy revealed that Monsieur Lelong too had a lesion between the second and third inferior frontal gyri of the left hemisphere, but the third was the most severely affected. Consequently, Broca assumed that he had confirmed his previous finding about localization of articulatory speech. In the following years he collected more cases of aphasic patients. All of these cases, except one, had a lesion in the third frontal gyrus of the left hemisphere. Before 1865, Broca remarked that all these lesions were in the left hemisphere but he didn't make any theoretical assumptions on this topic (Goodglass, 1993). About thirty years earlier, the French physician Marc Dax (1771–1837), had examined more than forty cases of aphasia and noticed that they were all associated with a lesion in the left hemisphere. The same language disorders didn't show up if the brain damage was in the right hemisphere. He wrote a paper about his findings in 1836 but he never presented it publicly. Later on, his son Gustave went studying medicine in Paris, where he got in touch with the work published by Broca in 1861. In 1863 he submitted a report on aphasia to the French Academy of Science and to the French Academy of Medicine in which he integrated his father's findings of 1836 with material he collected on his own. He wanted to claim for a left hemisphere lateralization for language. This paper was published only two years later. Six weeks after this publication, another contribution by Broca was published, in which he formulated a theory of language lateralization represented in the left hemisphere. Due to the recently published paper by Dax, a conflict started about the importance of the left hemisphere discovery. Broca, however, was already popular so he is considered the founder of this theory. Later, in 1869, he presented his theory about the different forms of speech disorders. According to him there were four main typologies of difficulty in articulation: 1) *alogia*: reduction of intelligence and ideation; 2) *mechanical alalia*: an inability to control the organs of articulation; 3) *verbal amnesia*: loss of associations between ideas and words; 4) *aphemia*: loss of articulate speech (Tesak and Code, 2008). The latter, *aphemia*, was the syndrome who affected Monsieur Leborgne. The term was soon replaced with *aphasia* by Armand Trousseau (1801-1867). Notably, Broca understood that a language disorder could also affect comprehension. Indeed, he actually identified *verbal amnesia* before Wernicke did. He defined this syndrome as a problem in which patients didn't understand anymore the connections between ideas and words and consequently, they expressed utterances that weren't what they were planning to say. Besides, they didn't understand utterances they were told.

Broca presented his classification at a meeting in England in 1868. The English neurologist John Hughlings Jackson (1835-1911) was present at that meeting. During this conference, several criticisms were addressed to Broca. Some of them included the presentation of cases that disconfirmed Broca's theory of localization. Jackson, who was later considered the first strong opponent of the localization theory, argued that it was possible to make a distinction between an intellectual and an emotional aspect of speech. Indeed, he observed a case in which a man wasn't able to retrieve lexical items but, if provoked, he could perfectly swear. According to Jackson, language didn't regard just words and utterances considered in isolation but, conversely, he thought that the act of speaking was an act of making propositions. He proposed then, the idea of *propositionality* of language. This idea suggested that there was a *propositional* and a *non-propositional* speech. The latter is the speech produced automatically: swearing, counting or prayers are included in *non-propositional* speech. Monsieur Leborgne for instance, produced the *non-propositional* "tan-tan" sequence. Propositional speech is different because it doesn't include automatisms but ideas are expressed through new referential utterances. As regards emotional and intellectual speech, then, Jackson believed that *non-propositional* speech was the emotional one, whereas the *propositional* speech was produced under conscious control. Jackson noticed that several aphasic patients, like Monsieur Leborgne, could produce non-propositional speech even though they hardly uttered spontaneous discourse. In summary, Jackson argued that aphasia didn't have to be considered isolated from other cognitive disorders. Broca partially agreed with this assumption but he also specified that sometimes brain damage could be bigger than the area he found, so in those cases cognitive disorder could be larger than the only speech deficit. Jackson, though, believed that even when the lesion was limited to Broca's area, damage could be widespread (Tesak and Code, 2008). On these bases, Jackson was considered an opponent of the localization theory, mostly because he didn't consider language as a proper faculty on its own, so it couldn't be located in a precise area. Actually, he claimed that locating the damage that destroyed speech was quite different than locating speech. He agreed that Broca's area had a crucial role for speech but he assumed that even other brain areas were involved in speech. The right hemisphere for instance was responsible for the *non-propositional* speech. In addition, comprehension was, according to him, located in the undamaged right hemisphere. For this reason, patients who only produced automatisms also understand well.

2.6 The second half of the 19th century: Wernicke's influencing model

After Jackson's hypotheses, another English physiologist gave a new impact in aphasia studies. Henry Charlton Bastian (1837-1915) was a localizationist who mainly contributed to the understanding of comprehension disorders in aphasic patients. In fact, he was one of the firsts who noticed aphasic disorders in comprehension. Actually, even though he isolated comprehension disorder as a deficit on its own, he didn't locate it into a precise area. He anticipated Wernicke's findings of some years later, although Wernicke also attributed the deficit to a specific area. Also the Austrian anatomist Theodor Hermann von Meynert (1833-1892) had published, a few years earlier, a report on a patient suffering from a comprehension deficit and a non-sense linguistic production. Autopsy showed a lesion in posterior insula and in the posterior aspect of the superior temporal gyrus. Meynert assumed that, possibly, in that area of the left hemisphere, comprehension could have been located (Marini, 2008).

Some years later, one of Meynert's students, Karl Wernicke (1848-1905), presented the cases of two patients who had difficulties in the comprehension of language. Differently from Monsieur Leborgne, they had a fluent speech but they just produced sounds, words and non-sense utterances. Also the prosodic tone was correct but full with phonological errors. Above all, they had difficulties in understanding what they were told. Autopsy in one of the patients showed a lesion in the posterior region of the superior temporal gyrus, next to the primary auditory area, called now Wernicke's area[2]. The author couldn't make an autopsy also in the second patient but he hypothesized that a lesion in

[2] Notably, Wernicke counted convolutions starting from the middle of the brain towards the anterior: therefore, what he consider the first frontal convolution was actually the third according to Broca's method (Finger, 1994).

the area would provoke a disorder in understanding speech and an inability to use words properly. Wernicke's contribution has been very influential because he created the first model of language processing in the brain. According to him, Broca's area was responsible of the programs for the coordination of muscles of speech since it was next to the cortical region of the brain that controlled the muscles of speech; similarly, since Wernicke's area was next to the cortical region that received auditory stimuli, then this area was responsible for the comprehension of stimuli (Geshwind, 1972). In his model, words were considered two types of memory images: movement images and sound images. Movement or motor images corresponded to the Broca's area store, whereas sound or sensory images were stored in the Wernicke's area. Furthermore, he assumed that these areas were connected by association fibres:

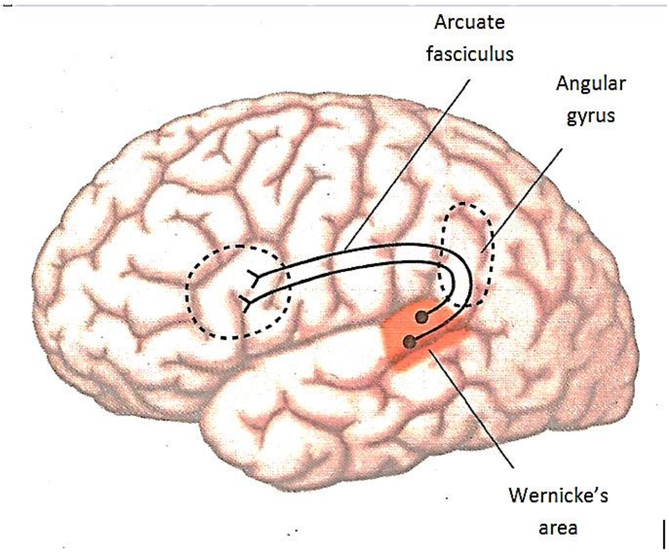


Fig. 2: Wernicke's model of language. Modified from: Gazzaniga et al. (2005).

Recently, new techniques revealed interesting findings about the arcuate fasciculus. Indeed, thanks to diffusion tensor imaging tractography[3], Catani et al. (2005) detailed its different components. In particular, they discovered three different types of connections (Fig. 3): 1) a medial segment, which connects the frontal and temporal lobes and corresponds to the classical hypothesis (represented in red in Fig. 3); 2) a posterior segment, connecting the temporal and parietal lobes (represented in yellow in Fig. 3); and 3) an anterior segment, which connects the frontal and parietal lobes (represented in green in Fig. 3) (Catani et al., 2005).

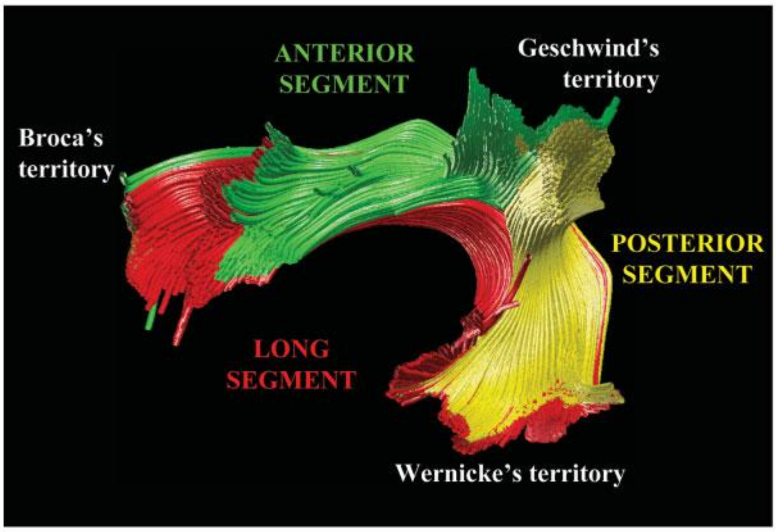


Fig. 3: Tractography reconstruction of the arcuate fasciculus. Taken from: Catani et al., 2005.

[3] Diffusion tensor imaging tractography combines the directional dependence of water molecules in white matter along myelinated tracts (i.e., anisotropy) with the directional dependence of the hindrance water diffusion, obtaining an esteem of the fiber orientation. Then, fiber orientations are put together in order to obtain continuous trajectories.

According to Wernicke, a lesion in the arcuate fasciculus was responsible of a *conduction aphasia*. Indeed, on the bases of his model, Wernicke thought that there could be different types of aphasia which depended on which was the disruption of the pathway between the areas. In fact, he assumed that during speech we take acoustic memory information in the sensory language centre and then transmit this information to Broca's area, where information about speech movements to produce these words is stored. The disorder he noticed in his firsts patients was the consequence of a disruption of the location of sound images. He called this syndrome *sensory aphasia* since just the memory images of the sensory language centre were lost, not the concepts themselves. Differently, if the brain damage was located in the Broca's area, then a *motor aphasia* would be the result, as motor images were affected. He then hypothesized other typologies of aphasia. For instance, if the disruption was located in arcuate fasciculus, then the result was a *conduction aphasia*: production and comprehension were quite preserved but repetition was damaged because the lesion was not in one specific language centre but in pathway which transmitted information from one to another.

As already mentioned, Wernicke's work has been of great influence. Indeed, he definitely endorsed the concept of localizationism and from that moment a lot of studies emerged, which tried to localize several cognitive functions. His model definitely put aside holistic theories; localizationism was accepted by almost everyone in the scientific community. Furthermore, Wernicke gave constrain to Broca’s findings about the dominance of the left hemisphere for language. In this sense, quite a prejudice was born about the left hemisphere: from this moment scholars started to think that since language was located in the left hemisphere, and language was the faculty distinguishing human beings from animal, then the left hemisphere must be the most important, whereas the right hemisphere lost its importance.

Wernicke’s classifications of aphasias constituted the root for a model elaborated then by the German anatomist Ludwig Lichtheim (1845-1928) (Fig. 4). Observing Wernicke’s schema, Lichtheim elaborated an anatomical-functional model, which was intended to complete some points missed by Wernicke. In particular, he agreed with Wernicke about a centre for motor images and one for sensory images connected by the arcuate fasciculus and he claimed that there should be also a centre to store concepts. Therefore, language was organized in the brain through three main centres: 1) the Wernicke’s area, in which permanent information about auditory images of words are stored; 2) the Broca’s area, in which motor images of words are stored; 3) a store for concepts (Gazzaniga et al., 2005). Notably, he didn’t locate the concepts store in a precise area. According to this model, language is comprehended thanks to the information arriving to the acoustic nerve and then transmitted to Wernicke’s area; here sounds are compared to the stored acoustic images so that the speaker is able to recognize the sounds as a word. In the following step, the word is transmitted to the concept centre where the word can be understood. If the speaker is about to produce language, then the information is transmitted from the concept store to the Broca's area, in order to furnish him the correct information about motor movements to activate; differently, if the information is a word to repeat, there could be two pathways: the first merely corresponds to the one used to produce speech, the second though, supposes that a word can be repeated even if it is not understood, than the transmission to Broca's area wouldn't be necessary. Finally, Lichtheim assumed that there was also a centre responsible for reading ability and one for writing (Marini, 2008).

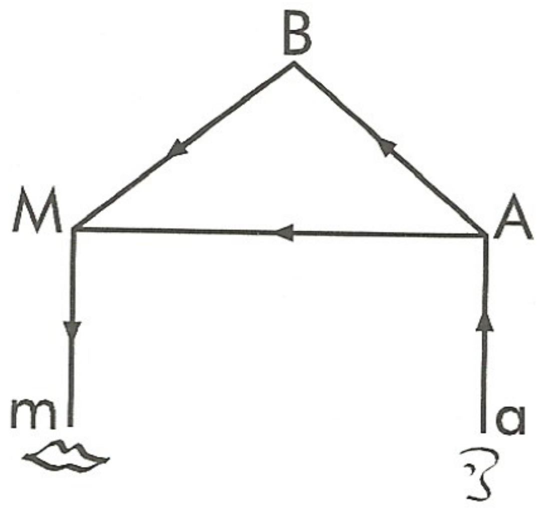


Fig. 4: Lichtheim's model of language. a = auditory input; A = centre of auditory words; M = centre of motor words; m = motor output; B = centre of concepts. Modified from: De Bleser (2001).

Even though it has some critical points, Lichtheim's model was considered the most complete schema on aphasia and its syndromes until the second half of the XX century. Localizationism was the ongoing theoretical framework and several scholars tried to localize in specific brain areas other cognitive skills. Among them, the Swiss Jules Joseph Déjérine (1849-1917), hypothesized a centre for reading and writing abilities after practicing autopsies on two patients who suffered from "*word blindness*". In particular, he assumed that these disorders were the consequence of a lesion in the angular gyrus of the parietal lobe in the left hemisphere, where visual word images were stored.

Among the critics of Wernicke-Lichtheim model we find Sigmund Freud (1856-1939), who tried to elaborate his own classification of aphasic syndromes. According to him, the Wernicke-Lichtheim model wasn't accurate. In particular, he thought that it didn't make sense to divide brain into centres and pathways; therefore also the division in the syndromes studied so far lost any sense. Conversely, he believed that linguistic aspects weren't simply represented in specific areas but in larger networks. For instance, the area responsible for the comprehension of language wasn't just the auditory area found by Wernicke but a network involving regions responsible for visual, motor, tactile and auditory functions. For this reason, he considered aphasia as a unique complex disorder that differs in severity. In particular, if lesions damaged the centre of the language network, then the most severe aphasic syndromes would have resulted.

2.7 The XXth century: from Pierre Marie's remarkable findings to Wernicke-Geschwind model

At the beginning of the XXth century, Pierre Marie (1853-1940), an intern in Broca's department, wrote an article in which he declared that, after having examined damaged brains of aphasic patients, he found that some of them presented a lesion in Broca's area without suffering from Broca's aphasia and *viceversa*. Hence, he adopted a new vision on aphasia: he thought that the main feature to consider in aphasia was the comprehension deficit. In particular, the first temporal convolution and/or the white matter beneath were affected in every form of aphasia. According to Marie, Broca's aphasia was the result of a brain damage affecting both the first temporal convolution and a region including the insula, the claustrum, the external and internal capsule and the caudate and lentricular nuclei (Tesak and Code, 2008). Consequently, he believed that Broca's aphasia resulted from a damage much more spread than what the French author had detected. Notably, he didn't define this disorder as aphasia, because he thought that only one type of aphasia existed: a sensory aphasia as a result of a damage in Wernicke's area. This area, though, was more extended than the one delineated by Wernicke. These observations marked the beginning of critics towards localizationism.

In the second half of the XXth century one of the most influential approaches against localizationism was that developed by Kurt Goldstein (1878-1965). He studied with Wernicke but soon matured his own approach, known as *organismic aphasiology*. He mostly disagreed with his teacher because he retained that Wernicke's approach was too simplistic. Indeed, according to Goldstein words weren't just associations between sound and motor images but gave a great importance to the idea of concept. Furthermore, he criticized the method used by Wernicke: according to Goldstein, observing single cases couldn't be a valuable methodology to classify aphasic syndromes. In this sense he appreciated the work done by Hughlings Jackson, who refused the deficit-oriented approach used by localizationists (Tesak and Code, 2008). Soon, critics about the methodologies used by Broca and Wernicke grew up in the scientific community. Theories of the localizationist models were based on the observation of patients. Often, they were single-cases, not representative groups and methodologies used were not accurate. Henry Head (1861-1940), an English neurologist, argued that localizationist models were too simplistic and they didn't consider many details of the clinical framework of patients.

In the second half of the XXth century new techniques for brain study were developed. One of the most influential has been the technique of cortical stimulation, developed in Canada by the neurosurgeon Wilder Penfield (1891-1976). He stimulated exposed brain areas with electrodes of patients who were undergoing surgery for epilepsy in order to detect which areas corresponded to specific functions. Reactions elicited through the stimulations were written down in small pieces of paper put in the corresponded areas and, at the end of the experiment, the exposed cortex was photographed. In 1959, thanks to an experiment involving a Naming task, Penfield identified some areas which were involved in linguistic processing: the inferior frontal lobe and the temporal-parietal region of the left hemisphere and the left supplementary motor area. In particular, if the patient was stimulated in the inferior frontal lobe, his speech teamed with phonological fillers and sometimes the patient even came to a speech arrest. Notably, this area corresponded to a bigger region than the one described by Broca. From their experiment they also noticed that, if partially or totally removed, Broca's area provoked an aphasia that could be recovered in some time. These findings definitely confirmed that there were brain areas in which language production and comprehension were located even though they weren't exactly what localizationist physicians found. Furthermore, these experiments established that there were some functions, such as naming, that weren't elicited or arrested by a single stimulation: therefore, they involved different brain areas. For this reason, a review for localizationism was necessary (Marini, 2008).

The Russian psychologist and physician Alexander Romanovich Luria (1902-1977) was the first to propose a complete brain model for linguistic processing. He refused both localizationist and holistic theories and considered mental functions as part of a complex functional system. In particular, he believed that language was the main organizer of the human mind since it allowed human beings to organize their thoughts and intentions through it (Denes and Pizzamiglio, 1996). He described six aphasic syndromes*: dynamic aphasia, efferent motor aphasia, afferent motor aphasia, sensory aphasia, acoustic amnestic aphasia, semantic aphasia*. Differently from Wernicke-Lichtheim model, Luria's classification took into account individual processes of language. Consequently, he believed that aphasic syndromes could be connected at different linguistic levels. He also provided strategies for rehabilitation on the bases that brain was conceptualized as an interactive system and his linguistic model was flexible and dynamic. Actually, Luria's impact had a great influence for rehabilitation: his contribution helped clinicians to reintroduce a localisationist view but with a dynamic and multidimensional perspective (Tesak and Code, 2008).

Contemporary to Luria, an American anatomist reviewed Wernicke's classification of aphasia syndromes and developed a model which is nowadays internationally known as *Wernicke-Geschwind model* (Fig. 5). Norman Geschwind (1926-1984) got in touch with Wernicke's papers almost a century after their publication. In particular, he studied and implemented the Wernicke-Lichtheim model. Indeed, he strongly supported his localizationist predecessors's ideas and he is in charge of a return to language localization theory for aphasia classification. He was the founder of the neo-connectionism.

Differently from his predecessors, he didn't base his hypotheses on the observation of single cases; instead he accurately studied cerebral structures of human beings and compared them to those of other superior mammals. His main finding concerned the discovery of a structure owned just by human beings: the inferior parietal lobe of the left hemisphere, including the angular gyrus (Broadmann's area 39) and the supramarginal gyrus (BA 40). This area was absent in other mammals. Geschwind assumed that it was particular important for linguistic processing because it was located at the junction of important associative areas: auditory associative cortex, somesthetic associative cortex, and visual auditory cortex. Therefore, the angular gyrus and the supramarginal gyrus were essential to connect these areas with other centres involved in linguistic processing. Indeed, he hypothesized a linguistic model based on these interactions. According to this model, during language comprehension the auditory sensorial system receives information and then transmits them to the auditory associative cortex; these are subsequently transmitted to Wernicke's area, where the phonological information gains access to words representations and this allows to phonologically and conceptually understand them; subsequently, they are transmitted to Broca's area through the arcuate fasciculus; in Broca's area they eventually receive the grammatical information and the utterance structure. Similarly, in the production phase, concepts are activated in Wernicke's area where they also receive phonological information and then, through the arcuate fasciculus they are transmitted to Broca's area to receive the information for motor actions involved in articulation (Gazzaniga et al., 2005). Notably, based on Lichtheim's theory of a concept centre, Geschwind found a specific location for it in Wernicke's area. His linguistic model, allowed Geschwind to develop an accurate classification for aphasia syndromes. Indeed, in 1971 he implemented Lichtheim's classification by adding three syndromes: *anomic aphasia*, *global aphasia* and *isolation of the speech area*.

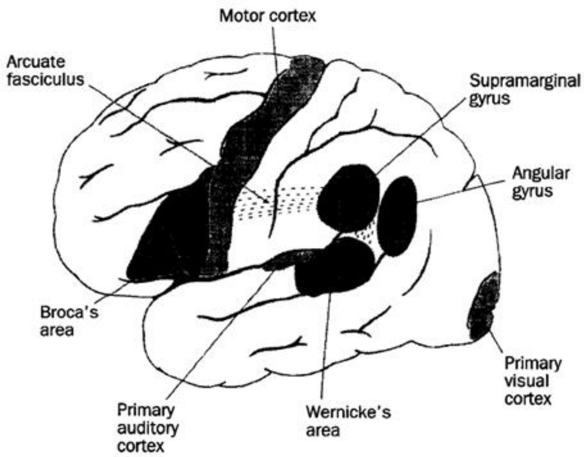


Fig. 5: The Wernicke-Geschwind model. Taken from Tesak and Code (2008).

Interestingly, Geschwind established the main difference in aphasia between fluent and non-fluent syndromes, even though this idea had been originally proposed by Wernicke. We will outline here the classification of aphasic syndromes nowadays used in neurolinguistics distinguishing two main groups: fluent and non-fluent syndromes. Also syndromes delineated by Geschwind are included.

2.8 Contemporary classification of aphasic syndromes

As mentioned, we will outline here the classification of aphasic syndromes which is the most used today both in theoretical research and in clinical practice. It is based on the Wernicke-Geschwind model. Actually, this model has been partially overcome. Indeed, the research of a complete classification, which also integrates new findings coming from neuroimaging techniques, is still in progress. In particular, the Wernicke-Geschwind model presents some weak points: for instance, it provides a classification based on the site of brain lesions but, often, a lesion does not involve just a specific site. Furthermore, it doesn’t provide any information about the functional condition of a patient’s brain before the lesion. Similarly, it doesn’t take into account a possible reorganization of the brain after the lesion. In addition, it is related to a simplistic vision of language: indeed, several aspects of language have acquired importance just in the last decades. For instance, as described in the historical framework, right hemisphere was excluded from having a role in language processing, whereas nowadays evidence showed that it is responsible of crucial competences (Marini and Nocentini, 2003). Moreover, great importance was attributed to the cerebral cortex, whereas subcortical structures weren’t considered at all as having a role in language. Differently, there is now evidence of aphasic syndromes resulting from subcortical lesions. In general, it is now well-known that language is a complex system. From the neurological point of view, neuroimaging techniques contribute to give evidence to the associationist approach (Catani et al., 2012). Indeed, in the history of linguistic studies, we find two main contrasting theories that I described in this chapter: localizationism and holism. According to the first, functions were located in specific sites, therefore the consequence of a lesion corresponded to the loss of the function for that specific site. According to holism, brains area were deeply interconnected through homogeneously distributed association fibres, meaning that a lesion in a specific area provoked deficits in every cognitive skill. Though, according to the associationist approach, brain is organized through distributed networks around cortical epicentres. This theory was originally developed by Meynert and Wernicke and then reformulated by Geschwind. Recently though, it has gained interesting evidence from functional imaging and diffusion magnetic resonance tractography. According to associationism, epicentres have a remarkable role in cognitive functions. In fact, large-scale networks host higher cognitive functions, such as language. The nodes of networks can be divided into epicentres, responsible of integration, feedbacks, connections and several important tasks. Therefore, a lesion can provoke functional loss for the specific damaged area as well as partially affecting the interconnected regions (Fig. 6).

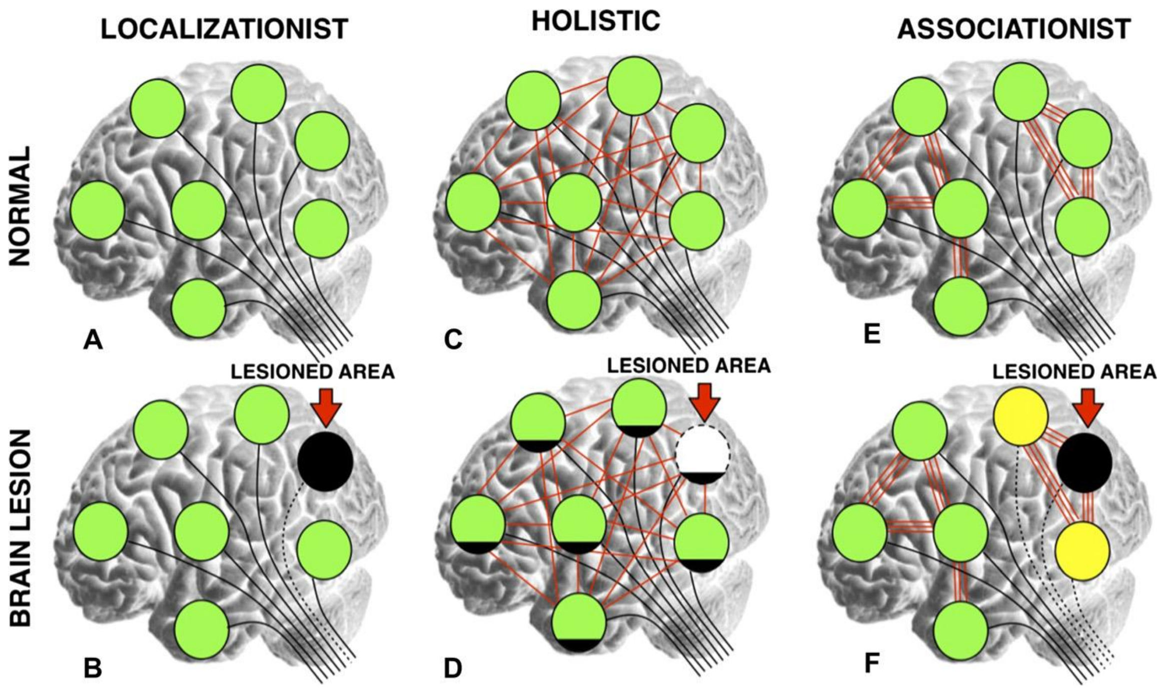


Fig. 6: Brain organization according to different approaches. Taken from: Catani et al., 2012.

The first one is the distinction between cortical and sub-cortical aphasias: cortical syndromes are the consequence of a damage in the cortex, whereas sub-cortical aphasias result from a lesion in sub-cortical structures. The second distinction is between fluent and non-fluent aphasia: this pattern only is valuable for cortical aphasias. Indeed, it is possible to classify cortical aphasias on the base of the brain damage localization as well as from some linguistic patterns: spontaneous speech, comprehension and verbal repetition. The best methodology to assess patient's fluency is to involve him/her in a conversation: spontaneous speech allows the researcher to observe several aspects of linguistic processing (Basso, 2005).

We will first describe fluent and non-fluent cortical aphasias. At the end of the chapter we will briefly go through a general description of subcortical aphasias.

2.8.1 Fluent syndromes

Wernicke's aphasia: patients who suffered from Wernicke's aphasia talk fluently but they experience a severe disruption in the ability to match words to their meanings (Dronkers and Larsen, 2001). Therefore, even if the quantity of words produced by these patients may be comparable to that of healthy subjects, persons with Wernicke's aphasia aren't informative at all. Their performance may be characterized by phonological errors and, often, they express neologisms or jargon. Writing skills are also altered. Prosody isn't affected. Comprehension though, is severely affected. Repetition goes under moderate to severe difficulties. Rarely Wernicke's aphasia is associated with hemiparesis, but often patients present a visual field deficit, in particular blindness in right visual hemifield. Moreover, patients with Wernicke's aphasia often express anosognosia, so they're not conscious of their disturbance.

Localization of brain damage causing Wernicke's aphasia is quite controversial. Most of studies indicate the area of the medial cerebral artery; in particular the posterior region of the first temporal gyrus, Wernicke's area (Basso, 2005). However, it has been suggested that the damage limited to the Wernicke's area causes a temporary aphasia, while the cause of the most serious impairments is due to the brain tissue swelling. Indeed, when swelling reduces, then the comprehension gets better (Gazzaniga et al., 2005). Some authors claimed that, when patients perform a lot of neologistic jargon, then the lesion is localized towards the operculum and the temporal lobe; when auditory comprehension is better than writing comprehension, then it seems that lesion just partially involves the superior temporal gyrus and affects to the parietal lobe, in particular in the angular gyrus. Conversely, when auditory comprehension is worse, thane le4sion is generally limited to the temporal lobe (Denes and Pizzamiglio, 1996).

Transcortical sensory aphasia: spontaneous speech of patients suffering from Transcortical sensory aphasia is full with verbal and semantic paraphasias. Comprehension is seriously impaired. There are also deficits in naming, reading and writing. Repetition is preserved for words and frequently also for long and complex sentences. They have difficulties in Naming tasks, suggesting a deficit in lexical-semantic associations. It is suggested this syndrome hardly ever is chronicle: most of times it turns into a mild anomic aphasia (Dronkers and Larsen, 2001).

Transcortical sensory aphasia may be the consequence of a generalized cerebral atrophy or may be due to a specific lesion (Denes and Pizzamiglio, 1996). The brain lesion is generally localized in the border region of areas bedewed by the medium cerebral artery and posterior cerebral artery (Basso, 2005).

Conduction aphasia: it was Wernicke who first hypothesized this syndrome, associating it with a lesion in the arcuate fasciculus. Patients suffering from Conduction aphasia talk fluently but their speech is full with phonemic paraphasias, anomias and conduits d'approches. Severe repetition impairment is the main characteristic of this syndrome. Comprehension is quite well preserved. Reading and writing skills may also be impaired. These patients are conscious of the errors they're making but aren't able to correct them.

According to Wernicke and Geschwind, lesion provoking Conduction aphasia is localized in the arcuate fasciculus. Further studies associated this syndrome to a lesion in the suprasylvian region, mainly in the supramarginal gyrus extending often to the white matter of the arcuate fasciculus (Denes and Pizzamiglio, 1996). Some authors however, found an involvement of other regions: auditory cortex, insula, superior temporal gyrus. In particular, superior temporal gyrus seems to be involved in the repetition impairment. Indeed, it is suggested that lesions in the superior temporal gyrus caused difficulties in echoic memory, responsible of the phonological store (Baddeley, 1986; Dronkers and Larsen, 2001).

Anomic aphasia: it is the least severe form of aphasia. It is characterized by a fluent speech and good comprehension and repetition. Persons who suffer anomic aphasia have difficulties in lexical retrieval, so they can't find the target words for their discourse. Therefore the speech is often interrupted by anomias, sometimes by *conduites d'approches*. It is reported that higher frequency words area easier to retrieve than those which have lower frequency. Moreover, some patients better denominate action than names (Basso, 2005). As anomia is basically present in every form of aphasia, it is difficult to correctly localize the brain damage. However, anomic deficits may often be associated with temporal lesions, excluding Wernicke's area (Denes and Pizzamiglio, 1996).

2.8.2 Non-fluent syndromes

Broca's aphasia: Typically, the speech of persons with Broca's aphasia is defined as telegraphic. In the worst of cases the subject can just produce some syllables, as was for Monsieur Leborgne. Some persons can produce very short sentences or sentences in which function words are missing. Indeed, their speech contains primarily content words: someone reports that agrammatism is a necessary symptom to diagnose Broca's aphasia (Basso, 2005). Verbs are often produced in the infinite of past participle form or in the third singular person of the simple present. For this reason, comprehension is preserved only when it is limited to single words and short sentences but it is seriously impaired when there are complex grammatical structures. In particular, if a person suffering from Broca's aphasia is required to understand the meaning of a sentence by the grammatical structure (e.g. the passive form of the verb), then comprehension is compromised. Broca's aphasics still have grammatical knowledge but they have difficulties in processing the grammatical aspects of language (Gazzaniga et al., 2005). It is very hard and frustrating for them to go from one phoneme to another in the production of words. They are conscious of their difficulty, and that could make everything even more frustrating. The phrase length is very short. Repetition is poor. Reading and writing as well have a range of impairment. Commonly, Broca's area is associated with right hemiparesis and, sometimes with oral apraxia or dysarthria.

The classical localization of Broca's aphasia lesion is in the region of Broca's area. However, as previously mentioned, Pierre Marie claimed that the language disorder couldn't be limited to the lesion of this area. Further reviews of literature found out that a "complete" Broca's syndrome is the consequence of a lesion of a region involving Broca's area but extending towards the precentral gyrus, insula, the underneath white matter and sometimes to the basal nuclei and temporal pole. Indeed, a lesion limited to the Broca's area often produces transient disorders (Denes and Pizzamiglio, 1996).

Transcortical motor aphasia: patients suffering from Transcortical motor aphasia perform a speech similar to Broca's aphasics. Their spontaneous speech is reduced and agrammatic. In the acute phase of the syndrome they can even be mute. Their Naming ability is preserved and comprehension is spared as well. Repetition is also preserved; sometimes they can successfully repeat even long sentences (Dronkers and Larsen, 2001).

Tipically, the lesion provoking this syndrome is localized in the anterior, superior lobe. In particular, it is suggested that prefrontal dorsolateral area and supplementary motor area are involved. When also the supplementary motor area is affected, then also a mild dysarthria and motor deficits may be the consequence (Basso, 2005). Since lesions don't alter areas directly entailed in language, in most of cases this syndrome resolves into an anomic aphasia (Dronkers and Larsen, 2001).

Global aphasia: it is the most severe aphasic syndrome. Global aphasia is reported to have the lowest recovery rate among all syndromes (Kent, 2004). The speech of persons suffering global aphasia is almost absent. They are severely impaired in expressive abilities: they produce stereotypes, speech automatisms, sometimes unrecognizable forms. Comprehension as well is severely impaired but it seems to be the only aspect that can get better (Basso, 2005). It is suggested that there are isolated areas where comprehension is relatively preserved, such as specific word categories, famous personal and geographical names and also personally relevant information are of better comprehension (Kent, 2004).

Lesion provoking global aphasia is usually much extended in the left hemisphere: it may involve prerolandic and postrolandic areas, including Broca's and Wernicke's areas. It may also extend to the basal ganglia, internal capsule and thalamus. Often, it is due to a large medium cerebral artery infarction (Dronkers and Larsen, 2001).

Transcortical mixed aphasia: this syndrome corresponds to what Geschwind called *isolation of the speech area*. Besides a non-fluent speech, these patients also suffer disturbances in comprehension and reading and writing abilities. Naming as well may be compromised. Repetition is quite well preserved.

Tipically, lesion provoking a Transcortical mixed aphasia is localized in regions next to perisylvian areas, not affecting them directly. However, sometimes the same symptoms may result from lesions in the anterior thalamic regions (Marini, 2008).

2.8.3 Subcortical aphasias

Aphasias resulting from subcortical lesions have been studied just from the XXI century thanks to the neuroimaging techniques (Basso, 2005). Previous methodologies in fact, didn't allow researchers and clinicians detecting these brain damages. Subcortical lesions provoking aphasia generally include structures such as thalamus, basal ganglia and the cerebellum. These structures are involved in many cognitive functions; however it is not clear whether a subcortical damage provoke aphasia because these structures are specifically responsible of some functions of the linguistic processing or if they are an important connection among cerebral regions involved in language (Marini, 2008). For this reason, connections between lesions and typology of aphasia are still not completely clear. Moreover, there are many cases of subcortical damages without linguistic consequences (Basso, 2005). It is then difficult to distinguish between different subcortical aphasias; however, it is possible to outline the main consequences of lesion of thalamus, basal ganglia and cerebellum.

Damage to the thalamus may provoke a linguistic disorder similar to transcortical aphasia. Indeed, spontaneous speech is reduced and full with verbal paraphasias. Comprehension impaired, whereas repetition is quite well preserved (Denes and Pizzamiglio, 1996).

Lesion to the basal ganglia may provoke a quite large range of syndromes. Basal ganglia in fact, are involved in many important functions. Severe diseases such as Parkinson, originate from a lack of dopamine-generating cells in the basal ganglia. Patients suffering from Parkinson disease or from other syndromes originating from basal ganglia may also experience disorders in some aspects of linguistic processing (Marini, 2008). A damage in basal ganglia may sometimes provoke a typical aphasic syndrome: in some cases these patients presented a case history similar to Broca's aphasia. In other cases though, they presented atypical symptoms (Denes and Pizzamiglio, 1996).

Cases of lesions to the cerebellum showed that these patients may have consequences in the verbal working memory, fluency or verb production. However, it seems that these lesions don't provoke a real aphasic syndrome but they cause some cognitive disorders that involve aspects of linguistic processing (Marini,2008).

3

Traditional and innovative methodologies for the assessment of aphasia: the role of discourse analysis.

3.1 The role of discourse in the assessment of aphasia

In the past three decades accumulating evidence suggested that classical standardized tests may have important limits for the assessment of language impairments. Indeed, there is evidence that data coming from the evaluation of phonological, lexical and grammatical skills, are of a great importance but an accurate assessment must also include measures of pragmatics, discourse and conversational abilities (Andreetta and Marini, in press; Marini et al., 2011). For instance, Larfeuil and Le Dorze (1997) analysed language recovery in 17 persons with aphasia by administering a traditional battery of linguistic assessment and a picture description task. All patients were tested at 17 weeks post-onset and after receiving a language therapy for 6 weeks. Results showed that standardized tests didn't show any improvement but, interestingly, patients demonstrated benefits of language stimulation: they performed better communicative effectiveness by, for instance, using more open-class words per time unit in connected speech. In another study (Marini et al., 2007) linguistic skills of three patients with non-fluent aphasia were analysed. Discourse of these patients was characterized by having a reduced information content as well as poor morpho-syntactic organization. These patients experienced two different language therapies: the first was made up by stimulus-response exercises, aimed at producing well-formed sentences (Helm Elicited Language Programme for Syntax Stimulation – HELPSS; Helm-Estabrooks et al, 1981); the second was based on a functional approach aimed at increasing informativeness in storytelling (Promoting Aphasics' Communicative Effectiveness treatment – PACE; Davis and Wilcox, 1985). During assessment patients were asked to describe two cartoon stories and two single pictures. After treatments, standardized aphasia tests such as Aachener Aphasie Test (AAT, Italian version; Luzzatti, et al., 1991) just showed minimal changes. However, informativeness had increased and this was confirmed also by naïve judges.

Consequently, due to increasing evidence, there's a new and growing interest in the way language is processed in daily communicative interactions. Then, many methodologies to analyze discourse have been developed. First, it is important to define what exactly is discourse[4] (Prins and Bastiaanse, 2004). Aphasiologists may use the term to refer to different speech elicitations. In an attempt to give a definition, Prins and Bastiaanse (2004) made a distinction between *semi-spontaneous speech* and *spontaneous speech*. The first is elicited through pictures, retelling of a fairy tale or by a role-playing, whereas the "real" spontaneous speech is obtained by a conversation between the patient and someone who is familiar with him/her or by an interview with open questions in which the patient is given the opportunity to talk as much as possible without interruptions while the examiner maintains an informal conversational mood. Discourse may present some differences depending on the methodology through which it has been elicited. For instance, structured tasks may not be considered as providing "real" spontaneous speech. However, there are some advantages in using specific stimuli: for instance, it may be easier to extract grammatically analyzable utterances (Easterbrook et al., 1982). Also, in structured tasks it is possible to check other patterns of language, such as the thematic selection (see further). Another advantage of the structured tasks is the possibility to administer the same stimuli to many subjects and, consequently, provide the opportunity to design studies in which clinical population is compared to healthy subjects. Finally, it is possible to make predictions about the expected

[4] In the whole dissertation we will consider as synonyms the following expression: discourse, spontaneous speech, narrative discourse.

narrations, such as the expected speech rate, the expected grammatically complexity and so on (Marini et al., 2011a).

Discourse analysis allows clinicians and researchers making specific questions about patient's speech: what meanings speaker is still able to convey, which are the lexical and grammatical resources he/she uses to convey these meanings and how much grammatical and lexical resources are affected by the language disorder (Armstrong, 2000). Discourse analysis is important for both clinical and theoretical purposes. Indeed, it provides important information for treatment as it detects patients' everyday difficulties in talking. Moreover, from a theoretical point of view it is of particular interest because it is just in discourse that all linguistic levels interact (Prins and Bastiaanse, 2004).

3.2 Traditional approaches to discourse analysis in persons with aphasia

In most studies focusing on discourse analyses two approaches have been adopted: a functional approach or a structural approach. Based on these approaches, also the definition of discourse from a linguistic point of view is different. Also from a linguistic point of view there are different definitions for discourse (Armstrong, 2000). These differences also establish the methodologies in which discourse is investigated and analyzed. According to the structuralist approach discourse is a unit of language above the sentence (Grimes, 1975). In particular, it is considered the product of the interaction among different levels of processing. Most of the aphasiological research comes from the use of this approach. According to the structuralist approach discourse is analyzed in terms of quantity, therefore measuring the patient's skills in the different linguistic levels: phonological, lexical, grammatical. Therefore these analyses are focused on the microlinguistic level. Using this approach, clinicians and researchers can detect measures such as % word retrieval, % substantive verbs and so on. As regards lexical skills for instance, discourse analysis allows to have more information than a classical naming task. Furthermore, from a discourse analysis is possible to identify relations between microlinguistic and macrolinguistic impairments, such as a lexical deficit that affects global coherence (Andreetta et al., 2012).

From a functional point of view though, discourse is considered as language in use, so it's seen as a semantic unit (Halliday, 1985); therefore, from a functional perspective a text could be a conversation or even a road signal, its length is not important. The functional approach is focused on macrolinguistic level, as it aims at investigating the patients' ability to convey relevant information and the way they are organized within the text. One of the most important measures analyzed by the functional approach is *informativeness*. In a study by Yorkston and Beukelman (1980) authors identified informativeness through the *Content Units*' count. They defined a *Content Unit* as a relevant piece of information that has been mentioned by at least 1 of the 78 healthy individuals who had joined the study. Approximately ten years later, Nicholas and Brookshire (1993) introduced the *Correct Information Unit* count. According to the authors, *Correct Information Units* were those words which were relevant, accurate and informative with respect to the eliciting stimuli.

Methodology introduced by Nicholas and Brookshire (1993) actually used both functional and quantitative measures and it demonstrated to have high diagnostic sensitivity. In their study, patients were persons with mild aphasia and their methodology detected their ability to generate speech samples with the same structural principles employed by healthy controls. These findings gave constrain to previous studies in which patients with mild aphasia showed to have preservation of discourse structure but reduction of information (Ulatowska, Freedman-Stern, Doyel, Macaluso-Haynes, and North, 1983).

A contribution by Sherratt (2007) outlined the importance of multi-level approaches for discourse analysis. In fact, even if spontaneous speech analysis became commonplace, still most methodologies focused on discrete linguistic levels. As we mentioned, just a few of them integrated functional and structural measures (Nicholas and Brookshire, 1993), detecting some aspects of the linguistic production of an aphasic speaker that a standardized test wouldn’t detect. Indeed, according to Sherratt (2007), a multi-level approach can help clinicians and researchers to have a more realistic perspective on language processing than the analysis of individual aspects as well as provide them information about possible impairments at a more conceptual level. Finally, also correlations among measures are useful to identify measure and subjective concepts that would be difficult to define, such as the relevance to a specific topic.

We will outline here a multi-level approach used to analyze narrative discourse in persons with linguistic or cognitive disorders.

3.3 A multi-level approach to the analysis of narrative language in aphasia

The present method for the assessment of spontaneous speech in persons with linguistic disorders integrates functional and structural approaches (Marini et al., 2011a). Therefore, it may help clinicians to better understand the exact nature of the patients’ linguistic impairments and, consequently, find innovative, specific and efficient rehabilitative protocols. Moreover, from a linguistic point of view it can help detecting the way specific microlinguistic difficulties might affect macrolinguistic ones (Andreetta et al., 2012).

As we already mentioned, speech samples elicited from specific tasks may not be considered as real spontaneous but, in structured elicitations, it may be easier to detect specific patterns of language. An important factor to consider is the length of the samples; there is evidence that samples ranging from 300 to 400 words report great test-retest reliability scores (Nicholas and Brookshire, 1993). In our experience, samples of this extension can be obtained by administering the following pictures: two single pictures and two cartoon stories (see Appendix A). The two single pictures we have routinely used are the *Cookie Theft* (Goodglass and Kaplan, 1972), and the *Picnic* (Kertesz, 1982). The two cartoon stories are the *Flower pot* (Huber and Gleber, 1982) and the *Quarrel* (Nicholas and Brookshire, 1993). Cartoon stories are made up by six pictures each presented on the same page in the correct order.

During the administration of the stimuli each subject is asked to produce a description of the situation in each of the four stimuli. They are told that that there isn't a good or a bad way to describe images but, importantly, that they should avoid using ambiguous words without clear referents, such as "that", "this" when they are referring to a specific person and/or object. For this reason, the administrator must tell the patient that he is not familiar with the story and he/she must not share the image with the participant. Consequently, stimuli are administered using a laptop facing the participant. In order to avoid poor performance due to short-term memory limitations, picture must remain visible to the participant until the description is over. Samples are audio-recorded and then transcribed verbatim including phonological fillers, pauses, false starts and extraneous utterances. The duration of each sample is also calculated.

The linguistic analysis focuses on four aspects of linguistic processing: productivity, lexical and grammatical processing, narrative organization and informativeness. We will describe here in four separate sections measures for each aspect.

3.3.1 Analysis of productivity

Productivity measures consist in the count of units and words and in computing speech rate and Mean Length of Utterance (MLU). A *unit* is any verbalization, despite its linguistic or contextual correctness or appropriateness. Therefore, in the unit count also non-words such as neologisms, phonological paraphasias, false starts or syllable repetitions are included. Differently, the *word* count includes only phonologically well-formed verbalizations; therefore phonological fillers or phonological errors are excluded. The number of words is used obtain a measure of *speech rate* in terms of words per minute. For each sample also the total number of *utterances* is calculated. Several criteria have been proposed to obtain a correct segmentation of speech samples into utterances (e.g. Shewan, 1988). It is hardly difficult to adopt just one criterion. Therefore, the present method refers to a set of parameters that has gained high inter-rater reliability scores. Indeed, they integrate acoustic, semantic, grammatical and phonological criteria. According to the *acoustic criterion* boundaries of an utterance are delimited by pauses that can be easily identified. Paused may be either empty or full. A empty pause is characterized by silence of some seconds, whereas a fully pause can be a non-lexical emission, such as “ehm”. For instance, in the sequence: “it is a … [silent pause of 4 seconds] dog”, there is an clearly perceivable empty pause. Therefore we can segment the sequence into two utterances (divided by /): “it is a … / dog/”. The same segmentation would occur if, instead of silence, there was a non-lexical emission or a filler, such as, “let me see”. For instance: “it is a.. let me see.. a dog”. In this case we can segment the sequence into three utterances: “it is a / let me see/ a dog”. According to the *semantic criterion* an utterance is formed by a conceptually homogeneous, like a proposition. A proposition is a semantic unit made up by the main predicate with its arguments and predicates correctly associated with it (Olness et al., 2010). Let’s consider, for instance, the following sequence: “A woman is doing the washing up. Children are trying to get the cookies”. We can clearly distinguish two utterances as the second one (“children are trying to get the cookies”) introduces a new proposition. Similarly, if the first utterance isn’t complete and the second one constitutes a reformulation, we still segment the sequence into two utterances, e.g.: “the woman is cleaning the / she is doing the washing up”. According to the *grammatical criterion*, utterances must be segmented when there is a grammatically well-formed sentence, eventually also including subordinate clauses. For instance, “The man is walking on the sidewalk with a dog that looks very nice/", constitutes a single utterance even if the sequence is long and with a subordinate clause. Coordinate sentences though, are divided into two utterances, such as: "/ The man is walking on the sidewalk / and a dog is following him /". According to the *phonological criterion,* when a word is abruptly interrupted then the utterance is considered interrupted as well. For instance, when there is a false start as in: "/ and she is ca- / stroking his dog/" we identify two utterances. The last measure of productivity, MLU, is calculated by dividing the total number of words by the number of utterances.

3.3.2 Analysis of lexical and grammatical processing

Lexical processing is related to the speaker's ability to select semantically appropriate words and to access adequate phonological, morphological and morphosyntactic information relative to the target words. The ability to select these words is calculated through a percentage of *semantic* and *verbal paraphasias* (Haravon et al., 1994). Therefore, the number or paraphasias is divided by the number of informative words and then this value is multiplied per 100. The ability to adequately access morphological and morphosyntactic information is calculated in terms of *paragrammatic errors*. There are two types of *paragrammatic errors*: *substitutions of bound morphemes,* and *substitutions of function words*. We can calculate the percentage of substitutions of bound morphemes by dividing them by the number of phonologically well-formed words and then multiplying this value by 100. Differently, the percentage of *substitutions of function words* is calculated by dividing them by the total number of function words and then multiplying this value by 100. The ability to select adequate phonological information is calculated in terms of *phonological errors*. Phonological errors are false starts, phonological and phonetic paraphasias and neologisms. This was derived by dividing the total number of phonological errors by the number of units and then multiplying this value by 100.

Grammatical processing is analyzed in terms of percentage of complete sentences and percentage of omissions of morphosyntactic information. A sentence is considered complete when all the arguments required by a word (e.g. a verb) are correctly inserted in its body without any omission of morphosyntactic information or substitution of free or bound morphemes. An omission of morphosyntactic information occurs when the argument structure of a word in a sequence is not complete. For instance, the following sequence: "/the man is hit by the soldier/" is considered correct because both agent (the soldier) and patient (the man) are correctly inserted in the body of the sentence. Differently, the following sequence: "/the man is hit by.." isn't a complete sentence because a grammatical information (the agent) is missing. In this case therefore, an omission of morphosyntactic information is scored. The percentage of complete sentences is calculated by dividing the total number of grammatically correct sentences by the number of utterances and then multiplying this value by 100 (Saffran et al.,1989; Thompson et al., 1996). The percentage of omission of morphosyntactic information is calculated dividing the number of omissions of morphosyntactic information by the number of words and then multiplying this value by 100.

3.3.3 Analysis of narrative organization

Narrative organization measures are related to the macrolinguistic level of processing. Indeed, it is analyzed in terms of production of errors of cohesion and both local and global coherence. Cohesion reflects the structural connectivity among contiguous utterances. Hence, cohesive errors include misuse of cohesive ties, such as anaphoric pronouns, errors in number and gender agreement between pronouns or nouns phrases across utterances, misuse of either cohesive function words or semantically related content words and abrupt interruption of utterances. An abrupt interruption of the utterance, defined as *aposiopesis* (Haravon et al., 1994) is scored just a cohesive error if the following utterance competes the previously introduced information. Otherwise, a *topic switch* would occur (see further). Some cohesive errors may be linked to microlinguistic processes. Indeed, in cases as the following sequence: "/the man is staring at… / the man is watching the dog/", a self-repair reflects the complex relationship between micro- and macrolinguistic errors. In the first utterance there is an omission of morphosyntactic information, scored then at the microlinguistic level. This omission though, also influences the macrolinguistic organization of discourse, as the abrupt interruption of the first utterance, where an aposiopesis is scored, obliges the speaker to reformulate the sentence in the subsequent utterance or to omit pieces of information that may be important for the comprehension of the story. In this example the second utterance completes the flow of thoughts introduced in the first one, then any local coherence error is scored (see below). A percentage of cohesive errors is calculated by dividing the number of cohesive errors by the number of utterances and multiplying this value by 100. Local coherence is related to the extent to which each utterance is conceptually related to the previous one. Therefore, local coherence errors are scored when referents are ambiguous or when they are omitted. Also, as mentioned above, local coherence errors include cases of *topic switch*. A topic switch occurs when an utterance is abruptly interrupted and, after the aposiopesis, the following utterance does not complete the current thought but new information is introduced. Let's consider, for instance, the following sequence: "/he's trying to… / these two girls are watching the dog", where the first utterance remains incomplete and the second introduces new information. Missing referents errors are scored whenever a referent of a pronoun or the implicit subject of a verb are not clear or even incorrect. For instance, in the following sequence: "/ Qui stanno litigando furiosamente / Poi dice /" (in English: "/ Here they are quarrelling furiously / Then [implicit pronoun] says /"), there is a missing referent in the second utterance because it's not clear to whom the verb "dice" ("says") is referring to. The percentage of local coherence is calculated by dividing the number of local coherence errors by the number of utterances and multiplying this value by 100. Global coherence is related to the ability to semantically relate remote utterances within the narration. Global coherence errors include: production of tangential utterances, conceptually incongruent with the story, propositional repetitions or fillers (Christiansen, 1995). An utterance is considered tangential when there is a derailment in the flow of discourse with respect to the information already provided in the previous utterance. For example, in the following sentence: / It is a picnic / I like picnics / I have made several picnics in my life /, the second and the third utterance are tangential, as they provide irrelevant information. Differently, an utterance is considered conceptually incongruent when it includes ideas not directly addressed by the stimulus. For instance, in the following sequence, where the *Cookie Theft* was administered: / the children are trying to get the cookies / the TV is out /, the second utterance is incongruent because in the picture there is no TV. A propositional repetition occurs when the speaker repeats information that he/she had already provided without adding any other. A filler utterance occurs when the speaker produces an utterance that is not providing any additional information, as in: / the man and the woman are eating / my God, and now? / ah, yes, I get it /, where the last two utterances are considered fillers. A percentage of global coherence is calculated by dividing the number of global coherence errors by the number of utterances and multiplying this value by 100.

3.3.4 Analysis of Informativeness

Informativeness of samples is calculated through two main measures: the production of appropriate lexical information and the identification of the thematic units contained in the language sample.

Appropriate lexical information units (LIUs) are those content and function words that are phonologically well-formed and also appropriate from a grammatical and pragmatic point of view. Therefore, words that are consider semantic or verbal paraphasias, lexical fillers, lexical repetitions, paragrammatic errors, words without clear referents, or words included in tangential or conceptually incongruent utterances must be excluded from the LIU's count. For this first measure, the percentage of lexical informativeness is calculated by dividing the number of LIUs by the number of words and multiplying this value by 100. Moreover, an index of informative speech rate can be calculated (LIUs/minute), providing additional information about the informative efficiency of the speaker. These measures approximately correspond to the functional measures proposed by Nicholas and Brookshire (1993), who in the CIU analysis method evaluated discourse efficiency with respect to the time required to produce the narrative (Words per minute=Ws/m' and Correct Information Units per minute=CIUs/m') and extension of the sample (% CIUs = percentage of Words in the sample that are Correct Information Units).

Secondarily, informativeness can be measured through the identification of the thematic units contained in the language sample. A thematic unit is considered a main idea or a detail in the story. Each picture had a series of concepts that provide the backbone of the plots: thematic units were identified with a methodology described in Marini et al. (2005a). Consequently, it is possible to measure how many thematic units the participant produced with respect to all ideas that are expected to be elicited by each stimulus. The percentage of thematic selection is calculated by dividing the number of thematic units produced in each story by the total number of all potential thematic units for that story and then multiplying this value by 100. This value is considered an index of the amount of conceptual and informational content that the speaker is able to derive from the stimulus (e.g. Marini et al., 2005b).

3.4 Application of the multi-level approach: behavioural and anatomo-functional data

The multi-level approach just described has proven useful in the assessment of language deficits in several clinical populations. For instance, it has been applied to assess the linguistic performance of persons with right hemisphere damage (RHD) (Marini et al., 2005a). In this study the narrative performance of persons with RHD was compared to that of persons with left hemisphere damage without aphasia and to a group of healthy control participants. Each participant was administered a story description task. In particular, the experiment included three conditions: in the first participants were asked to retell previously read story; in the second they had to describe what was going on in a set of cartoon picture stories; in the third condition they had to arrange a set of pictures to reconstruct a well-formed story. Results showed that in the first condition all groups performed quite well on both within- and between-sentence measures. However, in the second and third condition the performance of persons with RHD was poorer than that of the other groups in terms of information content and coherent aspects of narrative production. These findings give constrain to the hypothesis that persons with RHD have deficits in deriving the mental model of a story from visual information. However, it is important taking into account that there could be different portions of the right hemisphere contributing to narrative production. Therefore, in another experiment Marini et al. (2012a) compared narrative performances of persons with RHD with those produced by a group of healthy controls. Both groups scored within normal range on tests assessing their level of global cognitive impairment, logical visuospatial reasoning, general linguistic skills, and the potential presence of hemineglect. Results confirmed the hypotheses that persons with RHD produced descriptions with normal levels of microlinguistic processing but their percentage of tangential errors and conceptually incongruent utterances were higher than that of healthy controls. Therefore, their levels of informativeness were lowered. Interestingly, further analyses revealed that these deficits were most evident in persons with anterior lesions to the right hemisphere. These findings lend indirect support to the hypothesis of a major involvement of frontal right hemispheric areas to the process of organization of information in a narrative discourse.

Further evidence about the usefulness of a multi-level approach for the assessment of linguistic disorders come from an experiment of persons who, even if not aphasic, show impaired linguistic and/or narrative abilities. Marini et al. (2011b) analyzed the features of narrative discourse impairment in a group of non aphasic adults with severe traumatic brain injury (TBI) in the phase of neurological stability. Their performances were compared to those of a group of healthy controls. Results showed that the group of participants with TBI were not impaired at lexical and grammatical level. However, their narratives had many errors of cohesion and coherence due to the frequent interruption of ongoing utterances, derailments and extraneous utterances that made their discourse vague and ambiguous. Notably, they produced a normal amount of expected concepts but these information were not correctly organized at micro- and macrolinguistic levels. A Principal Component Analysis showed that a single factor accounted for the production of global coherence errors, and the reduction of both propositional density at the utterance level and proportion of words that conveyed information. For this reason the authors hypothesized that the linguistic impairments observed in participants with TBI might reflect a deficit at the interface between cognitive and linguistic processing rather than a specific linguistic disturbance. In a further study Carlomagno et al. (2011) examined the relationship between standardized measures of informativeness (i.e., Correct Information Unit analysis) and language processing errors at the macrolinguistic level by comparing the performance of a group of non-aphasic TBI adults with that of a group of healthy control participants on a narrative discourse task. Also in this case participants with TBI did not produce more microlinguistic errors than healthy controls and information content was not different. However, their production of errors of cohesion, local coherence and global coherence was significantly greater. Consequently, the high percentage of macrolinguistic errors predicted reduced levels of information efficiency.

The multi-level approach was also applied for the linguistic assessment of a clinical population who often suffer from linguistic disorders: persons with schizophrenia. Generally, schizophrenic patients show linguistic deficits at the microlinguistic level. However, deficits become more pervasive and severe at the macrolinguistic level when patients need to organize what they want to communicate at the pragmatic-communicative level and generate appropriate mental models. Nevertheless, their difficulties are not easy to detect and quantify. Marini et al. (2008b) studied the narrative skills of a group of individuals with schizophrenia in the phase of illness stability. Narratives were elicited using a single-picture and two cartoon stories as stimuli. Also, a modified version of the Mental Deterioration Battery (Carlesimo et al., 1996) was used to assess selective cognitive performances. Results showed that these patients produced a relatively high amount of semantic and morphological errors whose occurrence was determined by the production of macrolinguistic errors such as tangential utterances. Moreover, macrolinguistic deficits were predicted by the patients' impaired performance on tests assessing sustained attention and executive functions. Therefore, the multi-level approach allowed authors to determine the exact nature of the patients' semantic and morphological errors and to infer the potential interconnections between executive functions, discourse planning and processes of lexical selection and access. A remarkable study (Spalletta et al., 2010) investigated anatomical correlates of schizophrenic patients by examining the characteristics of narrative processing and correlating the linguistic scores obtained with cortical and subcortical gray matter volumes. The authors found that the production of lexical information units (LIUs) significantly correlated with volume changes in the dorsal aspect of the left inferior frontal gyrus (lIFG). In particular then, this study provided correlational evidence on the association between brain volume change in the lIFG and the ability to retrieve appropriate words in patients with mental disorders. Therefore, it suggested that that this part of the lIFG may play a major role in a wider network for the controlled selection of contextually adequate words from the mental lexicon. On the basis of these findings, Marini and Urgesi (2012b) tried to explore the crucial role played by the lIFG in semantic processing and lexical retrieval in a discourse production task. Authors performed and experiment with an off-line repetitive TMS protocol targeting at the area found correlated with the production of LIUs in the study by Spalletta et al. Namely, the authors applied rTMS over a dorsal aspect in the anterior lIFG and right IFG (rIFG) at the border between the pars opercularis and the pars triangularis (BA 44/BA 45) and tested the effects of the stimulation on the narrative abilities of healthy individuals. Results clearly showed that rTMS over the dorsal portion of the anterior left, but not right, inferior frontal gyrus reduces the levels of lexical informativeness and global coherence of narratives produced by healthy individuals. Interestingly, levels of productivity and microlinguistic processing were unaffected by the stimulation. These findings suggested that the dorsal aspect of the anterior left inferior frontal gyrus is an epicentre of a wider neural network subserving the selection of contextually appropriate semantic representations. This experiment has been very important for both theoretical and clinical implications. Indeed, further experiments grounded on its findings to develop useful rehabilitative strategies (Marangolo et al., 2013)

In conclusion, the multi-level approach demonstrated its efficacy in literature for three main reasons: 1) it allows clinicians to simultaneously evaluate different aspects of linguistic functioning; 2) it provides an insight on the interactions between macro- and microlinguistic competence; 3) it captures symptoms that may not be identified by traditional batteries of tests focusing only on microlinguistic skills. Furthermore, this procedure has potential to contribute to our understanding of the neural underpinning of important aspects of human communication.

3.5 Implications for informativeness

As described in § 3.3.4, informativeness is related to two measures: appropriate lexical information and identification of thematic units. In the studies just outlined, results showed that in some cases informative level was impaired despite other abilities that weren't affected. Interestingly, the study by Spalletta et al. (2010) found an important correlation between a measure of informativeness and volume changes in the left frontal cortex. Specifically, areas involved were an anterior cluster located in the prefrontal cortex and a more posterior one, located anteriorly to the primary motor cortex. These observations lead to the experiment by Marini and Urgesi (2012b), which aimed at investigating in the role of the lIFG in semantic processing and lexical retrieval. The study confirmed the role of this area in the ability to adequately retrieve words from the mental lexicon related to a specific context. Recently, some experiments attempted to transfer these issues on clinical and rehabilitative programs. In particular, the goal was to find new strategies for rehabilitation in aphasic patients. Marangolo et al. (2014) investigated the combined effect of transcranial direct current stimulation (tDCS) with an intensive Conversational therapy treatment. Linguistic performances of twelve aphasic participants were compared to those of twenty healthy controls. All participants were administered six short videoclips reproducing everyday life situations. Three of them were used during the treatment to elicit spontaneous speech in aphasic patients whereas the three remaining were showed to them just before and after the therapy. All six videoclips were showed to the control group before the experiment and they were asked to describe them accurately. Subsequently, persons with aphasia were stimulated with the tDCS under two conditions: a stimulation over the Broca’s area and a stimulation over the

Wernicke’s area. Also a sham condition was included. Stimulations were performed during Conversational therapy. However, the tDCS stimulation lasted twenty minutes, whereas the Conversational therapy lasted two hours. At the beginning and at the end of the speech therapy participants were asked to describe the videoclips. Then, one month after the experiment, participants were shown again videoclips used in the treatment and asked to describe them. Results showed that: 1) participants improved informative speech in terms of production of more C-units after Broca’s stimulation; 2) informativeness also changed in terms of production of verbs and relative increase of sentences produced; 3) notably, changes persisted also after one month. These findings suggest that Broca’s area and the adjacent left inferior frontal cortex play an important role for informativeness in spontaneous speech. Similarly, another study investigated the role of lIFG in the important feature of using cohesive markers in discourse (Marangolo et al., 2013). Also in this case patients were administered videoclips representing everyday life scenes and two picture descriptions. Three videoclips were used during tDCS treatment to elicit discourse, whereas the remaining tasks were shown to patients just before and after the therapy. tDCS was used in the left hemisphere both in the frontal and temporal areas. A sham condition also was included. Each treatment was performed for ten consecutive days. Results showed improvements in the use of cohesive markers just after frontal stimulation, giving constrain to previous findings about the remarkable role of lIFG in the production of informative speech.

4

AphasiaBank. An international multimedia database for the study of discourse in aphasia: the Italian contribution

4.1 Introduction

As outlined in § 3.1, discourse is a very important feature for the analysis of linguistic production in aphasic patients. Recently, many clinicians and researchers got interested in narrative analysis for the assessment of the linguistic disorders since evidence showed that standardized tests failed to show important aspects of language.

For the analysis of discourse, researchers work with transcribed language. Usually conversation is audio-recorded and then transcribed verbatim. In order to collect a large corpus of data and putting it at disposal of world spread researchers, a group of American aphasiologists developed *AphasiaBank* database (MacWhinney et al., 2011). AphasiaBank is a multimedia database where interviews between aphasic patients and researchers are collected. Notably, interviews are video-recorded. Video recording is a valuable instrument for conversations with persons suffering from linguistic disturbances, since it allows researchers to implement analysis with the observation of face or gestural expressions. Gestures indeed, may compensate some verbal deficits (Fex and Mansson, 1998). There is evidence for the relevance of gestures in some clinical populations. In particular, some studies outlined the relationships between speech and gestures even in terms of gesture impairments. For instance, a study by Glosser et al. (1998) on patients with Alzheimer disease revealed that, besides a reduced information content in their speech, they also performed impairments in gestures. Recently, a study explored patterns of conversational gestures comparing a group of patients with Alzheimer disease with a group of fluent aphasics and a group of healthy controls. One of the main findings revealed that the group of fluent aphasics and two persons suffering from Alzheimer disease performed a higher rate of gestures with respect to healthy controls. Gestures appeared especially during the production of paraphasic expressions or when the subjects weren’t able to identify a concept. Also other patterns were found, suggesting that gestures are an important feature to evaluate when working with people with communicative disorders (Carlomagno et al., 2005).

Furthermore, videorecording is important because sometimes it can be difficult to detect sounds expressed by patients, especially if they also suffer from apraxia; therefore, video can help the researcher to better detect specific sounds. AphasiaBank has been developes on the model of the Child Language Data Exchange System (CHILDES), a database for language acquisition (MacWhinney, 2000). Data collection for AphasiaBank started in 2007 and by February 2011 the database counted 145 persons with aphasia and more than 120 healthy controls. They were all English speakers, since the research started in the United States. One of the goals of the project was to collect data in other languages; we then decided to participate in the project and contribute with Italian data. The remarkable property of AphasiaBank is that its data are available for free in its website[5]. In particular, everyone can access to programs, manuals and other resources, whereas the access to transcripts and video is restricted to AphasiaBank members. Indeed, the main goal of AphasiaBank is sharing data regarding aphasia with researchers and clinicians all over the world.

[5] http://talkbank.org/AphasiaBank/

4.2 Elicitation of the speech samples

Conversations for AphasiaBank are elicited through a standard protocol allowing the production of four different types of discourse: personal narratives, picture descriptions, story telling, and procedural discourse. Each session begins with the production of personal narratives. First, the examiner asks the patient what he/she thinks about his/her language. Often, patients who suffer from a linguistic disorder complain a lot about it, therefore talking about this topic may be very familiar to them. Conversation follows asking the patient about his/her stroke and the recovery and about an important event of their lives. For picture descriptions elicitation subjects are shown three black and white drawings: two cartoon stories and a single image. The first cartoon story is a four-paneled picture in which a child playing with a soccer ball breaks a window; the second is a six-paneled picture of a child refusing an umbrella his mother offered him and gets caught in the rain; the single image is a picture of a cut stuck in a tree while other scenes is happening around it (Nicholas and Brookshire, 1993). For each stimulus participants are asked to look at the pictures and tell a story with a beginning, middle, and end (Wright and Capilouto, 2009). For the story telling participants are asked to tell the story of Cinderella. First, they are shown a picture book of Cinderella where text words are covered. They are told to look through the pictures to help them remembering the story. Then, the book is taken away and they are asked to tell as much of the story as they can. For procedural discourse American speaking participants are asked to describe how they would make a peanut butter and jelly sandwich. For the Italian version this task has been adapted to a quite similar butter and marmalade sandwich (see further).

In some cases participants have difficulties in starting to speak: to come them over AphasiaBank provides a list of prompts the examiner can use to help participants. If participant still isn’t able to reply a troubleshooting script with additional prompting and simplified questions is available. However, while participant is talking, the examiner should be as silent as possible.

AphasiaBank protocol also includes a standardized test, the Verb Naming Test (Thompson, in preparation) and a non-standardized repetition test. For the Italian adaptation see further.

4.3 Working with CHAT and CLAN

Video recordings are transcribed with the CHAT format and analysed with the software analysis program CLAN (MacWhinney, 2000). “CHAT” stands for “Codes for the Human Analysis of Transcripts”. It is designed to produce standardized transcriptions of face-to-face conversations and it can be used with several populations, both clinical and healthy. It has been largely used with children and, with the development of AphasiaBank, it has been applied to persons with aphasia. Standardization of transcription is very useful in order to share data about language in the scientific community. However, it may be challenging finding a methodology to share this data of spontaneous speech, because a uniform approach to transcribe and analyse discourse doesn't exist. CHAT is an attempt to create homogeneity among different systems. Noteworthy, our research group applies the methodology described in § 3.3 for the study we will describe in chapter IV. Indeed, we are familiar with the multi-level approach and it has gained interesting findings in literature (see § 3.4). Though, wishing to contribute to AphasiaBank with Italian data, we use CHAT and CLAN to transcribe and analyse language elicited with AphasiaBank protocol. These data are now under the revision of the principal investigators of the project and will be soon at disposal on the official website.

We will outline here the main characteristics of CHAT transcription (for further examples see Appendix B).

a) a standard format must be written at the beginning of every transcription:

@Begin

@Languages: *ita*

@Participants: *SUB10 Participant*

@ID: *ita|M|SUB10*|||||Participant

@G: *nido*

Italics indicate forms that must be changed in every transcription. Therefore, the researcher will change the language (*ita* in this case stands for *Italian*); the name or the code used to identify the subject (e.g. *SUB10*); a letter to identify the principal investigator (e.g. *M*); and the title of the stimulus (e.g. *nido*).

b) In the corpus of transcription every line starts with a ***** and three letters to code the participant**.** Each lined codes just one utterance. Therefore, for a participant we call “sub 10” every utterance must be written in a new line starting with: ***S10.** After the three-letter code comes a colon (|) and then a tab.

c) The transcription of what was said by the participant may begin with the % symbol if there is any commentary regarding what was said.

d) In the text of transcription errors can be inserted in < > and tag using the adequate coding in [ ]. For instance, if the participant produces a lexical filler such as “I don’t know”, then this sentence will be written as follows: <I don’t know> [fil].

e) The very last line of the transcription must be an “@End” line.

Once the transcription is ultimated, the researcher can run the CLAN program. "CLAN" stands for "Computerized Language Analysis". It is specifically designed to work with CHAT format. CLAN provides a window in which CHAT transcriptions must be written. A command then, will allow the computation of the total number of words and errors. CLAN includes some supports for analysis based on automatic morphosyntactic coding. Most of them have been developed just in English whereas one, the MOR program, may be used also in other languages. Indeed, MOR taggers have also been developed in Spanish, German, French, Italian, Japanese, Cantonese, and Mandarin. However, some versions, like the Italian one, are still not complete. For this reason, a personal control by the researcher is necessary.

4.4 Italian contribution to AphasiaBank

We will outline here the main procedures for the data collected with Italian participants. Ten Italian speaking adults were included in the study. They all suffered from fluent aphasia following a stroke. All participants were in the phase on neurological stability and had been exposed to several months of rehabilitation. All participants released their written informed consent to participate to the study after all procedures had been fully explained. Approval for the study had previously been obtained from the AphasiaBank ethic committee.

Before AphasiaBank session, participants were administered the Aachener Aphasie Test (Luzzatti, et al., 1991) (described in chapter IV) in order to diagnose the aphasic syndrome. Subsequently, important correlations between this test and narrative measures have been found (§ 4.4). The first session of AAT, concerning conversation, hasn't been administered since AphasiaBank protocol already provided data for conversation analysis.

For AphasiaBank protocol interview has been translated into Italian, stimuli images have been downloaded from AphasiaBank website and a copy of the paperback with Cinderella story has been sent from the American laboratory of AphasiaBank in order to get comparable data on this task. Finally, for the procedural discourse, Italian participants were asked how they would make a butter and marmalade sandwich.

After the interview the Verb Naming Test had been administered after it has been translated into Italian. The non-standardized repetition test however, wasn't administered because it was particularly difficult to adapt. Indeed, it is a test based on length and frequency of English words and it is quite complicated finding comparable words sharing length and frequency also in another language. Furthermore, a repetition task was already provided by the AAT, including repetition of sounds, words and sentences.

At the end three more pictures were administered to Italian participants: Picnic (Kertesz, 1982), the Flower Pot (Huber and Gleber, 1982) and the Quarrel (Nicholas and Brookshire, 1993). As described in § 3.3, participants were asked to describe the situation in each of the three stimuli. They were told that there wasn't a correct way to describe them and that they should avoid using ambiguous words. The description of these three stories underwent linguistic analysis. In particular, these data were gathered with narrative performances of ten more fluent aphasic patients and compared to healthy controls. Procedures of this study are explained in chapter 5.

5

Study: Narrative Assessment in patients with Fluent Aphasia

5.1 Introduction

Fluent aphasia gathers a variety of syndromes sharing the main characteristic of a fluent speech. In many cases comprehension is impaired but, as in the case of anomic aphasia, lexical retrieval can be the only deficit experienced by patients. In order to detect which are the main difficulties for a fluent aphasic person, involving him/her in a spontaneous speech task is the methodology that can better provide information to clinicians and researchers. Indeed, especially for the least severe forms of aphasia, it can be difficult to detect macrolinguistic impairments. For instance, despite their lexical impairment, persons with anomic aphasia have been usually described as having fluent speech and using grammar and syntax appropriately (Dronkers and Larsen, 2001). Standardized tests, however, don't provide any information about additional problems with these forms of aphasia, such as impairments affecting discourse processing. Indeed, as described in chapter 3, discourse production relies on both micro- and macrolinguistic features. In order to generate well-structured and informative narratives it is necessary establishing accurate cohesive and coherent links among the utterances as well as integrating the sentential meanings with a linguistic and extralinguistic context. Consequently, for a complete assessment of fluent aphasia it is important to assess not only lexical and grammatical processing skills, but also the ability to generate adequate cohesive and coherent links among subsequent utterances. Only few studies directly assessed the macrolinguistic skills of persons with aphasia. A group of persons with anomic aphasia, for instance, was investigated by Huber (1990) who suggested that these patients had a potential difficulty in the identification and/or organization of conceptual information at the macrolinguistic level. A remarkable contribution was signed by Christiansen (1995) who analyzed the coherence skills in a group of mild to moderate fluent aphasic persons compared to a group of 20 healthy controls. Persons with aphasia constituted three subgroups: five of them suffered from anomic aphasia, five were affected by Wernicke's aphasia and five were patients with conduction aphasia. All participants were asked to describe a cartoon picture. Linguistic analysis focused on the propositional content of the narratives produced by each participant and on the occurrence of coherence violations in speech samples. Results showed that the subgroups of anomic and conduction participants produced the same amount of propositions as healthy controls whereas participants with Wernicke aphasia produced significantly more propositions than the other participants. Coherence violations were calculated in terms of: 1) percentage of essential propositions missing from the participants' narratives; 2) repetitions of propositions; 3) percentage of irrelevant or illogical propositions. Results showed that only the subgroup of anomic participants significantly missed essential propositions with respect to healthy controls. However, their score of information gaps was even higher than that of the other two aphasic subgroups. Repetitions of propositions were significantly more than healthy controls in both conduction and Wernicke's groups. As for the production of irrelevant propositions, both conduction and Wernicke's participants produced significantly more irrelevant propositions than healthy controls whereas participants with anomic aphasia did not differ significantly from the other groups. Overall, these data support the hypothesis that persons with fluent aphasia may experience also problems in dealing with specific aspects of macrolinguistic processing. However, it is not clear yet whether these problems must be interpreted as a sign of a macrolinguistic impairment per se or are the epiphenomenon of microlinguistic deficits. Indeed, in anomic aphasia it can reflect a strategy to cope with the lexical impairment:

whenever the patient can't retrieve the target word, he/she simply skips to a new argument producing a novel proposition. Coelho and Flewellyn (2003) described the case of a 55 years old man with anomic aphasia. The authors analyzed his story narratives over a period of twelve months. Results showed that this patient had moderately impaired macrolinguistic skills that did not seem to improve over time: no significant improvement was found in his ability to link utterances by means of local and global coherence ties.

In an attempt to better understand the interrelations between micro- and macrolinguistic skills in fluent aphasia, I present here data regarding both micro- and macrolinguistic skills in a group of twenty individuals with fluent aphasia. Indeed, this study aims at investigating these skills applying a multi-level approach, which allows the researcher to take into account both micro- and macrolinguistic aspects of message production, as described in § 3.3 (Marini et al.,2011).

5.2 Materials and Methods

5.2.1 Subjects

Forty Italian-speaking adults were included in the study. They formed two groups: twenty persons with fluent aphasia made up the experimental group; twenty healthy participants formed the control group. All aphasic participants were in the phase of neurological stability and had been exposed to several months of rehabilitation. The two groups were matched for age and level of formal education (cfr. Table 1). The categorization into fluent aphasia was based on their original diagnoses when they were hospitalized. Furthermore, for this study they were administered the Aachener Aphasie Test (AAT, Luzzatti, Willems, and DeBleser, 1991). The AAT provides percentages for a classification into more specific diagnoses. These data have been taken into account and compared to narrative measures. Performances at AAT subtests presented a high variability within the group of persons with aphasia due to the different levels of aphasia severity. For instance, on the Naming subtest the lowest score performed by a subject is 24/120, the highest 118/120. Similarly, in the Repetition subtest the lowest score performed is 16/150, the highest 143/150. However, ranges were adequante to run a repeated measures ANOVA (§ 5.2.3).

Criteria for admission in the control group included normal range performance on Raven’s progressive matrices (Raven, 1938) and normal performance on a series of neuropsychological tests assessing memory, attention, executive functions and visuo-spatial processing. None of the participants had a previous history of psychiatric illness or learning disabilities. All participants released their written informed consent to participate to the study after all procedures had been fully explained.

Table 1. Demographic characteristics of the groups of aphasic and healthy control participants.

Group	Number of subjects	Age		Years of Education
		Range	*Mean; SD*	*Mean; SD*
Fluent aphasia	20	28-76	57.6; 12.78	11.85; 4.72
Control	20	33-77	57.3; 12.73	12.45; 4.23

5.2.2 Materials

Participants were asked to produce three narratives elicited by administering three pictures: a single picture, Picnic (Kertesz, 1982), and two cartoon stories, the Flower Pot (Huber and Gleber, 1982) and the Quarrel (Nicholas and Brookshire, 1993). Participants described the situation in each of the three stimuli after the examiner had explained all the instructions. The picture or cartoon story remained visible until the subject had finished his/her description. Storytellings produced by the healthy control participants and by a group of ten fluent aphasics were audio-recorded, whereas descriptions produced by the remaining group of ten fluent aphasics was video-recorded according to the AphasiaBank instructions provided earlier (see chapter 4). Each storytelling was subsequently transcribed verbatim, including phonological fillers, pauses, false starts and extraneous utterances. Transcriptions then underwent quantitative, in-depth linguistic and textual analysis focusing on four main aspects of linguistic processing: productivity, lexical and grammatical processing, narrative organization and informativeness (see chapter 3 for details of the analysis).

The scoring procedure was performed independently by two raters and then compared. An example of the narrative analysis is provided in Appendix B. Acceptable interrater reliability was defined as Cohen's $k>0.80$. The residual differences were resolved through discussion.

5.2.3 Statistical analyses

The narrative performance of the two groups of participants was analyzed performing a repeated measures ANOVA with two groups of subjects: fluent aphasics and healthy controls. Groups was the independent variable, whereas the following were the dependent variables: words, speech rate, Mean Length of

Utterances, % phonological errors, % semantic paraphasias, % substitutions of bound morphemes, % complete sentences, % cohesion errors, % local coherence errors, % global coherence errors, % lexical informativeness, % thematic informativeness, % details to main themes. The level of statistical significance was set at $p < 0.004$ after Bonferroni correction for multiple comparisons. Story*group interaction will be reported only when significant.

5.3 Results

The results will be presented in five separate sections: microlinguistic analysis, macrolinguistic analysis, analysis of informativeness, grammatical measures and global coherence measures.

5.3.1 Microlinguistic analysis

The mean values for each group on each microlinguistic measure are reported in Table 2. The two groups produced narratives with a comparable number of words [$F(1; 38) = .931$; $p = .341$; $\eta p^2 = .024$]. However, the group of fluent aphasics talked with a significantly lower speech rate [$F(1; 38) = 51.318$; $p < 0.0001$; $\eta p^2 = .575$] as well as a significantly lower Mean Length of Utterances [$F(1; 38) = 35.553$; $p < 0.0001$; $\eta p^2 = .483$]. There was also a significant interaction story*group for MLU (Wilk's Lambda = .015) (Fig. 7). Moreover, persons with aphasia produced more phonological errors [$F(1; 38) = 18.301$; $p < 0.0001$; $\eta p^2 = .325$] and more semantic errors [$F(1; 38) =$ $p < 0.0001$; $\eta p^2 = .393$]. Interestingly, they didn't differ from the healthy controls in the substitutions of bound morphemes [$F(1; 38) = 5.382$; $p = 0.26$; $\eta p^2 = .124$]. The percentage of complete sentences produced by fluent aphasics was significantly inferior than controls [$F(1; 38) = 101.266$; $p < 0.0001$; $\eta p^2 = .727$]. Also in this case there was a significant interaction story*group (Wilk's Lambda = .009) (Fig. 8).

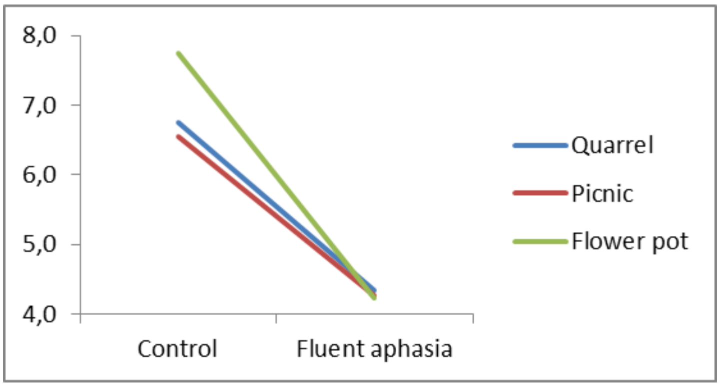


Fig. 7: story*group interaction in MLU measure

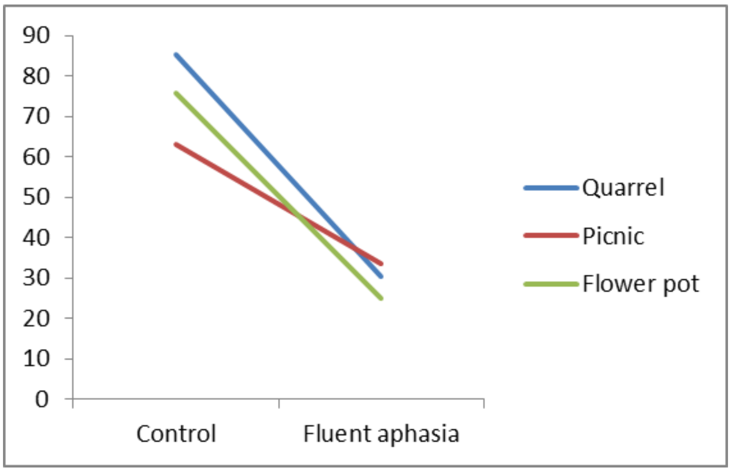


Fig. 8: Story*group interaction in Complete Sentences measure

Table 2. Results of the Microlinguistic analysis

Microlinguistic analysis	**Control**	**Fluent Aphasia**	**Level of significance**	**Effect size** *ηp2*
Words	86.6 (21.95)	98.66 (28.95)	$p = .341$	.024
Speech Rate *	133.70 (32.88)	57.65 (11.56)	$\mathbf{p < 0.0001}$	.575
MLU *	7.01 (1.5)	4.27 (0.71)	$\mathbf{p < 0.0001}$	.483
% Phonological errors *	.26 (0.36)	4.92 (1.81)	$\mathbf{p < 0.0001}$	.325
% Semantic paraphasias*	.60 (0.82)	6.5 (5.44)	$\mathbf{p < 0.0001}$	.393
% Substitutions of bound morphemes	.14 (0.24)	.46 (0.43)	$p = .026$	.124
% Complete sentences *	74.71 (17.14)	29.69 (12.71)	$\mathbf{p < 0.0001}$	.727

* Indicate when the group-related difference is significant after Bonferroni correction for multiple comparisons.

5.3.2 Macrolinguistic analysis

The mean values for each group on each macrolinguistic measure are reported in Table 3 together with measures of Informativeness. Performances of fluent aphasics at macrolinguistic level significantly differ from healthy controls in every aspect. Indeed, fluent aphasics committed more error of cohesion [$F(1; 38) = 105.652$; $p < 0.0001$; $\eta p^2 = .735$] as well as more errors of both local [$F(1; 38) = 19.424$; $p < 0.0001$; $\eta p^2 = .338$] and global coherence [$F(1; 38) = 22.901$; $p < 0.0001$; $\eta p^2 = .376$].

5.3.3 Informativeness analysis

The mean values for each group on each measure of informativeness are reported in Table 3 together with macrolinguistic measures. The percentage of lexical informativeness is significantly lower in fluent aphasics [$F(1; 38) = 26.253$; $p < 0.0001$; $\eta p^2 = .409$]. The percentage of thematic selection was lower in fluent aphasics [$F(1; 38) = 10.786$; $p = .002$; $\eta p^2 = .221$], whereas the two groups did not differ in the production of details to main themes [$F(1; 38) = 3.581$; $p = .066$; $\eta p^2 = .086$].

Table 3: Results of the Macrolinguistic and Informativeness analysis

Macrolinguistic and Informativeness analysis	**Control**	**Fluent Aphasia**	**Level of significance**	**Effect size** *ηp2*
% Cohesion errors *	12.61 (9.40)	42.17 (11.25)	**p < 0.0001**	.735
% Local coherence errors *	4.22 (4.66)	13.99 (10)	**p < 0.0001**	.338
% Global coherence errors *	7.35 (5.97)	23.72 (10.96)	**p < 0.0001**	.376
% Lexical Informativeness *	85.16 (7.31)	62.94 (11.18)	**p < 0.0001**	.409
% Thematic Informativeness *	61.15 (6.43)	44.57 (8.94)	**p = .002**	.221
% Details to Main Themes *	52.92 (28.88)	40.66 (27.22)	p = .066	.086

* Indicate when the group-related difference is significant after Bonferroni correction for multiple comparisons.

5.3.4 Further analysis of the participants' grammatical skills

As the aphasic participants produced fewer grammatically complete sentences that the group of healthy control participants but a normal rate of substitutions of bound morphemes, I investigated whether this grammatical deficit was due to specific morphosyntactic disturbances. Consequently, I focused on the following measures: substitutions of function words, omission of function words and omissions of morphosyntactic information. The mean values for each group on each measure are reported in Table 4. Interestingly, results showed that fluent aphasics produced more violations than healthy controls in each of these aspects. Indeed, they produced more substitutions of function words [F(1; 38) =

21.738; $p < 0.0001$; $\eta p^2 = .364$] as well as more omissions of function words [$F(1; 38) = 16.232$; $p < 0.0001$; $\eta p^2 = .299$] and more omissions of morphosyntactic information [$F(1; 38) = 37.631$; $p < 0.0001$; $\eta p^2 = .498$].

Table 4: Results of morphosyntactic and grammatical measures

Morphosyntactic and grammatical measures	**Control**	**Fluent Aphasia**	**Level of significance**	**Effect size** ***ηp2***
% Substitutions of function words *	.25 (0.37)	4.09 (3.88)	**p < 0.0001**	.364
% Omissions of function words *	.66 (0.85)	3.03 (3.45)	**p < 0.0001**	.299
% Omissions of * morphosyntactic information	11.06 (8.23)	26.60 (11.68)	**p < 0.0001**	.498

* Indicate when the group-related difference is significant after Bonferroni correction for multiple comparisons.

5.3.5 Further analysis of the quality of the errors of global coherence produced by the group of aphasic participants

Fluent aphasics produced more errors of global coherence than healthy controls. There is evidence that some clinical populations produced more global coherence errors because they have difficulties in the conceptual phase of the message production. Therefore, I explored global coherence measures in order to detect which was the typology of errors committed by fluent aphasics. The mean values for each group on each measure are reported in Table 5. Noteworthy, this analysis showed that fluent aphasics produced more filler utterances [$F(1; 38) = 24.952$; $p < 0.0001$; $\eta p^2 = .396$] and repeated utterances [$F(1; 38) = 21.947$; $p < 0.0001$; $\eta p^2 = .366$]. However, their percentage of semantically incongruent utterances [$F(1; 38) = .725$; $p = .400$; $\eta p^2 = .019$] and tangential utterances [$F(1; 38) = .420$; $p = .521$; $\eta p^2 = .011$] did not differ significantly from that of controls.

Table 5: Results of global coherence measures

Global coherence measures	**Control**	**Fluent Aphasia**	**Level of significance**	**Effect size** ***ηp2***
% Filler utterances *	2.44 (3.53)	10.59 (6.4)	**p < 0.0001**	.396
% Repeated utterances *	1.16 (1.47)	7.89 (4.62)	**p < 0.0001**	.366
% Semantically incongruent utterances	1.24 (1.63)	1.82 (2.77)	p = .400	.019
% Tangential utterances	2.5 (2.83)	3.41 (3.57)	p = .521	.011

* Indicate when the group-related difference is significant after Bonferroni correction for multiple comparisons.

5.3.6 Correlations among narrative measures

Result showed that persons with fluent aphasia experience impairments at both micro- and macrolinguistic level. Further analyses of participants' grammatical skills and on the quality of global coherence errors allowed us to determine more specifically the typology of errors that these patients perform the most. However, I also wanted to investigate the inter-relations between the two levels of linguistic processing. In particular, since patients with fluent aphasia experience impairments in lexical retrieval, I focused on the potential impact of semantic processing on macrolinguistic measures. This issue was explored with a bivariate correlational analysis focusing on the relationship between words, % semantic paraphasias, % filler utterances, % repeated utterances, % tangential utterances, % semantically unrelated utterances. The analysis showed that words were positively correlated with tangential utterances ($p = .002$; $r = .640$), indicating that the even if a person with aphasia produces a high percentage of words, they may not be informative words. However, as described in the macrolinguistic analysis section, percentage of tangential utterances was not significan in these patients. The analysis also revealed a positive correlation between % semantic paraphasias and % filler utterances ($p = .002$; $r = .660$). This finding is particularly interesting since it suggests that the difficulty in lexical retrieval leads these patients to the production of semantic errors as well as to the use of lexical fillers to overcome their difficulty. The analysis didn't show any significant correlation between semantic processing and repeated utterances or semantically unrelated utterances.

5.4 Discussion

The current study was designed to explore in detail the linguistic and narrative features of persons with fluent aphasia. The narrative assessment included the analysis of both micro- and macrolinguistic aspects of language processing in speech samples elicited with picture description tasks. All aphasic participants included in the study were in the phase of neurological stability and had undergone a rehabilitative program aimed at increasing their linguistic skills. However, results showed that, when engaged in spontaneous speech, they still committed errors at both micro- and macrolinguistic levels of processing. Indeed, the first analysis (Table 2) revealed that the two groups produced a comparable number of words but persons with fluent aphasia performed a significantly lower speech rate. This finding suggests that a fluent aphasia syndrome still allows producing a high number of words but they are told at a slower pace with respect to a group of healthy controls. It is likely that persons with fluent aphasia need more time to retrieve words from their mental lexicon: for this reason they probably introduce more pauses. This seems to be confirmed by a significant lower Mean Length of Utterances in persons with fluent aphasia. Probably, aphasic participants also used more filler and repeated words: indeed, a further analysis of Informativeness revealed that also the percentage of Lexical Informativeness is significantly lower in fluent aphasics, indicating that the amount of words they produce is just partially made up of informative words, whereas many of them are probably filler or repeated words. Furthermore, results indicate that aphasic participants make more errors in their narratives both at phonological and semantic level: percentages of phonological errors and semantic paraphasias are significantly higher than the group of controls.

Since the percentage of phonological errors gather neologisms, phonological paraphasias and words interruptions, this data may confirm the difficulty experienced by fluent aphasics in retrieving words: it is likely that they may 1) start uttering a word and then they interrupt because they can't easily remind the phonological sequence, or 2) remembering a wrong phonological sequence. In this case their difficulty is related to the second phase of the model proposed by Levelt, the linguistic expression, in which the speaker has already activated the mental concept he/she is intentioned to say but find troubles in converting it into the speech plan (cfr. § 1.2). However, results showed that sometimes aphasic participants have also problems in activating the right mental concept, since they produce a significantly higher percentage of semantic paraphasias with respect to healthy controls. Interestingly, the percentage of substitutions of bound morphemes did not significantly differ between the two groups, suggesting that participants with fluent aphasia select quite adequately this information. The rate of complete sentences though, was significantly lower in aphasic participants and this may be related to some macrolinguistic measures. Results from macrolinguistic analysis (cfr. Table 3) outlined that fluent aphasics have important impairments at this level. Indeed, percentages of cohesion and both local and global coherence errors are significantly higher than healthy controls. As we described in § 1.2 cohesion is determined by the correct connectivity among contiguous utterances. Therefore, cohesive errors are, for instance: misuse of anaphoric pronouns, errors in number and gender agreement between pronouns or nouns phrases across utterances, or misuse of either cohesive function words or semantically related content words and abrupt interruption of utterances. Since aphasic participants committed phonological errors also due to interruption of words, it is likely that cohesion errors are determined by the abrupt interruptions of utterances, reflecting their difficulty in retrieving words. Local coherence errors, which are also significantly higher in aphasic participants, reflect the ambiguous use of references and their omissions. Indeed, topic switches are not scored in these narratives, suggesting that even if they frequently introduced omissions of morphosyntactic information, that information was completed in the following utterances. Global coherence errors as well are significantly elevated in fluent aphasics' narratives. These errors may reflect a high use of filler and repeated utterances or a difficulty in maintaining the topic of description producing semantically incongruent or tangential utterances. In literature we find clinical populations performing high percentages of global coherence errors due to their difficulties in planning the plot of the picture. For instance, an experiment conducted on patients who suffered a brain damage on right hemisphere showed that these patients produced more global coherence errors with respect to healthy controls and to a group of non-aphasic left hemisphere damaged (Marini, Carlomagno, Caltagirone, and Nocentini, 2005). These errors were mainly due to a lower number of thematic informativeness and to the introduction of irrelevant utterances. Authors suggested that these derailments may be explained by some difficulties in the organization of informational content and in the retrieval of a general story plot. Similarly, a study aiming at investigating linguistic features in patients with schizophrenia found out that in narrative descriptions these patients performed more derailments and less informative content than healthy controls (Marini et al., 2008b). According to the authors, also in this case performances were biased by difficulties in action planning. Therefore, we wanted to investigate which were the causes of the amount of global coherence errors in fluent aphasics. For this reason another analysis was conducted on global coherence measures (Table 5). Noteworthy, results from this analysis showed that fluent aphasics didn’t commit more tangential or semantically unrelated utterances than healthy controls, suggesting that they don’t have difficulties in focusing on the description of the story. However, they performed high percentages of filler and repeated utterances, confirming their difficulties in lexical retrieval. Indeed, while they are searching a word they repeat well-known words and introduce lexical fillers and utterances to overcome their difficulty. These data confirm previous findings by Andreetta et al. (2012) who produced a qualitative inspection of global coherence errors in a reduced group of participants of the present study. The analysis confirmed that 32% of the words produced by aphasic participants were lexical repetitions (16.96%) and lexical fillers (15.19%).

The analysis of Informativeness (see Table 3) showed that participants with fluent aphasia produced fewer Lexical Information Units than healthy controls. This finding as well is likely related to the large introduction of lexical fillers and repeated words: indeed these words are not computed as LIUs. Interestingly, thematic informativeness is somehow affected in participants with aphasia since it results significantly lower. However, the effect size of significativity isn’t large. Furthermore, the percentage of details to main themes did not differ between the two groups, confirming that persons with fluent aphasia don’t have difficulties in the conceptual planning of descriptions but their impairments in macrolinguistic measures are the epiphenomenon of a microlinguistic difficulty, the word retrieval.

A further analysis was conducted to explore the morpho-syntactic and grammatical aspects on narrative discourse in fluent aphasics (see Table 4).

Results showed that aphasic participants performed large impairments in every measure: substitutions of function words, omissions of function words and omissions of morphosyntactic information. These data may be related as well to a lexical retrieval impairment: participants with fluent aphasia have difficulties in finding the target words, therefore they omit grammatical information or produce the wrong function words.

In summary, our analysis showed that narrative skills of fluent aphasics are characterized by four main features: 1) reduced abilities of lexical retrieval; 2) increased difficulties in grammatical and morphosyntactic abilities; 3) increased production of global coherence errors caused by filler utterances and repeated utterances; 4) reduced amount of lexical informativeness. These features show the complex interplay between micro- and macrolinguistic levels. Indeed, significant correlations were found between semantic processing and macrolinguistic level, indicating that a difficulty in the microlinguistic dimension can lead to impariments at textual and pragmatic level. Other studies confirmed the interaction between the two levels: in the already mentioned investigation on schizophrenic patients (Marini et al., 2008), the production of global coherence errors caused deficits at microlinguistic level in terms of semantic errors. Similarly, in a group of persons with traumatic brain injury (Marini et al., 2011) the production of cohesion errors caused a reduction in speech rate. In the present study it is assumable that microlinguistic impairments related to lexical retrieval difficulties influenced the reduction of cohesion and both local and global coherence; therefore they are reflected on macrolinguistic level.

5.5 Clinical implications of the use of the multi-level approach to the analysis of speech samples produced by persons with aphasia

Commonly in clinical practice speech therapists use standardized tests to make diagnoses on linguistic disorder. There are many of them specific for aphasia; one of the most used in Europe is the Aachener Aphasie Test (Luzzatti et al., 1991). AAT is a complete standardized test which investigates many aspects of language. It is constituted by: **a**) a spontaneous speech session, in which the examiner should involve the patient in a conversation, **b**) the Token Test (De Renzi e Vignolo, 1962), designed to assess verbal comprehension and working memory, **c**) a Naming task, **d**) a Reading task, **e**) a Writing task, **f**) a Repetition task, **g**) a Comprehension task.

In an attempt to investigate the clinical implications of the multi-level approach, the relationship between AAT tests and narrative measures was investigated using a bivariate Pearson product-moment correlation. Results are presented in Tables 6,7,8,9,10.. According to Cohen (1988), a Pearson's value between .10

and .29 is small; a value between .30 and .49 is medium; a value between .50 and 1.0 is large. When significant, correlations are evidenced in bold.

Analyses were divided into five main sections: 1) correlations between AAT tests and narrative measures of productivity and informativeness (words, speech rate, Mean Length of Utterances and Lexical Informativeness); 2) correlations between AAT tests and lexical aspects of narrative measures (phonological errors, semantic paraphasias and substitutions of bound morphemes); 3) correlations between AAT tests and grammatical aspects of narrative measures (substitutions of function words, omissions of function words and omissions of morphosyntactic information); 4) correlations between AAT tests and macrolinguistic aspects of narrative measures (cohesion errors, local coherence errors, global coherence errors, filler utterances, repeated utterances, semantically unrelated utterances, tangential utterances); correlations between AAT tests and conceptual aspects of narrative measures (thematic informativeness and relations of details to main themes).

I will describe here the main features for each analysis. Notably, I will refer to measures of AAT spontaneous speech with the subgroups provided by the test: 1) communicative behaviour, mainly assessing speech rate; 2) articulation and prosody; 3) automatic language, mainly investigating the use of stereotypes and automatisms; 4) semantic structure, assessing the use of anomias and semantic paraphasias; 5) phonological structure; 6) syntactic structure.

1) **Correlations between AAT tests and narrative measures of Productiviy and Informativeness**

The sizes of Pearson correlations for this analysis are reported in Table 6. Significant negative correlations emerged between words produced in narratives and AAT Naming Test ($p < .04$, $r = -.48$). It is not surprisingly that correlation is negative, since, as we described in narrative measures, the amount of words was also filled with lexical fillers and repeated words. Therefore, a large amount of words doesn't indicate a preserved ability in Naming tasks. Indeed, Naming task is also positive correlated with the percentage of Lexical Informativeness ($p < .004$, $r = .65$), suggesting that the counting of Lexical Information Units is an accurate indicator of naming ability. A positive correlation was found between Mean Length of Utterances and Semantic structure ($p < .027$, $r = .69$), implying that a better semantic access allows the speaker producing longer utterances.

Lexical Informativeness positively correlated with comprehension test ($p < .017$, $r = 55$), suggesting that both measures indicate the preservation of the stages of comprehension model: indeed, as described in §1.2, comprehension requires the transmission of the phonological stimulus to the mental lexicon, in which it is transformed into a word and a concept. Therefore, an adequate access to the last stages of comprehension also includes a preserved ability of selecting appropriate concepts and producing them. For the same reason, Lexical

Informativeness is positively correlated with automatic language ($p < .005$, $r = .80$) and positively correlated with semantic structure ($p < .024$, $r = .7$). Indeed, the ability to produce correct informative words means that the speaker introduces less automatisms or semantic paraphasias. Notably, in these cases correlations are very strong. Interestingly, speech rate doesn't find any correlation in AAT tests, suggesting that this measure isn't assessed by AAT.

2) Correlations between AAT tests and Lexical Aspects of narrative measures

The sizes of Pearson correlations for this analysis are reported in Table 7. Significant negative correlations emerged between phonological errors produced in narratives and AAT Communicative behaviour measure ($p < .02$, $r = -.69$). This was an expected finding, since Communicative behaviour exactly assesses difficulties in fluency during conversation. Clearly, a patient producing a lot of phonological errors also performs a low speech rate. A significant negative correlation was found between semantic paraphasias produced in narratives and Naming test in AAT ($p < .01$, $r = -.57$). Also in this case we might expect this finding since both measures outline lexical retrieval skills in the speaker. Semantic paraphasias negatively correlated also with Comprehension test ($p < .02$, $r = -.52$). As already outlined for the correlation between LIUs and Comprehension test, this negative correlation suggests that a disorder in the last stages of comprehension might cause the production of lexical errors. Lexical impairments may also be reflected in the use of stereotypes or perseveration if the speaker produces them when he/she can't find the target word. Therefore, a significant negative correlation was found between semantic paraphasias and automatic language ($p < .03$, $r = -.66$). As expected then, semantic paraphasias negatively correlated with semantic structure in AAT ($p < .002$, $r = -.85$). Indeed, a high rate in AAT semantic structure indicates absence of anomias and paraphasias. Notably, absence of correlations between substitutions of bound morphemes and AAT tests suggests that this feature is assessed only by narrative measures.

3) **Correlations between AAT tests and Grammatical Aspects of narrative measures**

The sizes of Pearson correlations for this analysis are reported in Table 8. As for substitutions of bound morphemes and speech rate, any correlation was found between both substitutions and omissions of function words and AAT tests as well as between omission of morphosyntactic information and AAT tests. Also in this case, these findings indicate that these measures are exclusively assessed by narrative tasks. The only grammatical aspect that finds correlations with AAT tests is the percentage of complete sentences. Indeed, a significant positive correlation was found between complete sentences and Communicative behaviour ($p < .03$, $r = -.67$), outlining that a better fluency in discourse implies a better capacity in producing grammatically correct utterances. Similarly, a significant positive correlation was also found between complete sentences and Semantic structure ($p < .04$, $r = .65$). Indeed, also a better semantic access in linguistic production influences the construction of complete sentences.

4) Correlations between AAT tests and Conceptual Aspects of narrative measures

The sizes of Pearson correlations for this analysis are reported in Table 9. Interestingly, any correlation was found between the percentage of cohesion errors and AAT tests. This finding is particular remarkable since evidence showed that cohesion is a very important aspect in discourse (§ 2.3.2). Therefore, the absence of correlation gives constrain to the role of narrative tasks to assess this aspect. A significant negative correlation was found between both local and global coherence errors and Comprehension test (local coherence: $p < .04$, $r = .-47$; global coherence: $p < .003$, $r = .-65$). Errors of local and global coherence may be the consequence of a microlinguistic problem, therefore, as we described for semantic paraphasias and LIUs, a stage in linguistic processing of comprehension might be affected. Global coherence also negatively correlate with automatic language ($p < .005$, $r = -.802$), since global coherence errors may be filler or repeated utterances, sometimes characteristics of an automatic language. Similarly, a significantt negative correlation was found between global coherence and semantic structure ($p < .01$, $r = -.747$). In fact, a high rate in semantic structure excludes anomias and circumlocutions; therefore it also excludes filler and repeated utterances. Indeed, an inspection of filler utterances showed the same result, revealing a significant negative correlation between filler utterances and semantic structure ($p < .011$, $r = -.76$). A significant negative correlation was also found between filler utterances and Naming ($p < .01$, $r = .-55$), clearly due to the difficulty in lexical retrieval that oblige patients to use lexical fillers to such extent that they ended up producing filler utterances. The lexical impairment causing the increment of lexical fillers probably causes also a comprehension deficit, since a significant negative correlation was found between filler utterances and comprehension ($p < .02$, $r = -.51$). Notably, repeated utterance didn't find any correlation in AAT tests, suggesting that this measure as well can be assessed just with a narrative task. The percentage of semantically unrelated utterances negatively correlated with Naming task ($p < .01$; $r = -56$), indicating that the inability to adequately access semantic information may influences the production of incongruent sentences. A significant negative correlation was found between semantically unrelated utterances and Comprehension: this could be explained by the fact that sometimes utterances result unrelated because the subject didn't correct understood the story depicted in images ($p < .009$; $r = -.59$). Interestingly, as well as semantically unrelated utterances correlate with Comprehension, they also positively correlate with Token test ($p < .03$, $r = .49$), which measures comprehension and working memory in patients with aphasia. We remind that Token is the only AAT test in which the higher the rate is, the more amount of errors the patient committed. Token test positively correlated also with Tangential utterances ($p < .05$, $r = -.47$), since tangential utterances are often the consequence of a deficit in comprehending the story plot and keeping the focus on it. Similarly in fact, tangential utterances also negatively correlated with Comprehension task ($p < .002$, $r = -.67$). A significant negative correlation was found between tangential utterances and Naming task ($p < .002$, $r = -.69$), reflecting a general deficit in adequately select correct information for discourse. Similarly, a significant negative correlation was found between tangential utterances and Semantic structure ($p < .08$, $r = -.57$). Finally, the negative correlation between tangential utterances and Repetition test ($p < .008$, $r = -.6$) may be explained by the fact that a preserved ability in repetition also involves a conceptual planning ability which hasn't been affected.

5) Correlations between AAT tests and Conceptual Aspects of narrative measures

The sizes of Pearson correlations for the second part of this analysis are reported in Table 10. Significant positive correlations were found between Thematic Informativeness and automatic language ($p < .04$, $r = .64$) and Thematic

Informativeness and semantic structure ($p < .01$, $r = .76$). These results indicate that an adequate access to semantic information with an adequate fluency also imply an adequate conceptualization of the story plot. For the same reason, the percentage of details to main themes positively correlate with Semantic structure ($p < .05$, $r = .63$).

In summary, these correlations demonstrated that the multi-level approach is a valid instrument for the clinical use. In general, we observed that it provides many data about linguistic processing in patients with aphasia; therefore it would be useful for both researchers and clinicians. Indeed, from a theoretical point of view it allows understanding deep connections in linguistic production and comprehension whereas, from a clinical point of view, it investigates specific skills in patients as well investigating their relations. In conclusion, standardized tests to assess aphasia are useful supports to test abilities that a narrative task can't assess, such as repetition. However, a clinician should also taking into account time-consuming aspects: in fact, a complete administration of the AAT test lasts about one hour, whereas the administration of up to three pictures to describe may last twenty minutes, allowing the speech therapist to save more than 50% of time. Furthermore, from a narrative task it is possible using a unique data sample to obtain several information about patient's abilities.

	Words	Speech Rate	MLU	Lexical Informativeness	AAT Repetition	AAT Naming	AAT Comprehension	AAT Token	AAT Communicative behaviour	AAT Articulation and prosody	AAT Automatic language	AAT Semantic structure	AAT Phonetic structure	AAT Syntactic structure	AAT Written
Words	--														
Speech Rate	.38	--													
MLU	.11	.08	--												
Lexical Informativeness	-.67	-.21	.44	--											
AAT Repetition test	-.36	.11	.25	.41	--										
AAT Naming	**-.48**	-.01	.37	**.65**	.82	--									
AAT Comprehension	-.44	.19	.33	**.56**	.85	.94	--								
AAT Token	.29	-.29	-.22	-.36	-.89	-.75	-.82	--							
AAT Communicative behaviour	-.10	.08	.33	.45	.59	.57	.66	-.54	--						
AAT Articulation and prosody	.22	.63	-.13	-.13	-.11	-.24	-.19	.34	.52	--					
AAT Automatic language	-.26	-.17	.44	**.80**	.51	.83	.69	-.70	.55	-.15	--				
AAT Semantic structure	-.13	-.41	**.69**	**.70**	.63	.86	.78	-.71	.65	-.09	.74	--			
AAT Phonetic structure	.35	.37	.22	.00	.16	.08	.18	.01	.80	.79	.10	.35	--		
AAT Syntactic structure	-.17	.06	.34	.52	.25	.56	.48	-.46	.71	.21	.77	.64	.47	--	
AAT Written	-.29	-.21	**.54**	**.54**	.70	.76	.71	-.45	.74	-.08	.64	.86	.33	.51	--

Table 6 : correlations between AAT tests, measures of productivity and lexical informativeness of the multi-level approach.

	Phonol. Errors	**Semantic paraph.**	**Substitutions bound morphemes**	**AAT Repet.**	**AAT Naming**	**AAT Compreh.**	**AAT Token**	**AAT Written**	**AAT Commun. behaviour**	**AAT Articulation and prosody**	**AAT Automatic language**	**AAT Semantic structure**	**AAT Phonetic structure**	**AAT Syntactic structure**
Phonological errors	--													
Semantic paraphasias	.33	--												
Subst. bound morphemes	-.25	-.01	--											
AAT Repetition	-.03	-.36	.18	--										
AAT Naming	.11	**-.57**	.07	.82	--									
AAT Comprehension	.22	**-.52**	.07	.85	.94	--								
AAT Token	-.31	.10	-.21	-.89	-.75	-.82	--							
AAT Written	-.43	**-.73**	.17	.70	.76	.71	-.45	--						
AAT Commun. behaviour	**-.69**	-.62	.24	.59	.57	.66	-.54	.74	--					
AAT Articulation and prosody	-.35	.19	-.05	-.11	-.24	-.19	.34	-.08	.52	--				
AAT Automatic language	-.30	**-.66**	. 45	.51	.83	.69	-.70	.64	.55	-.15	--			
AAT Semantic structure	-.60	**-.85**	.09	.63	.86	.78	-.71	.86	.65	-.09	.74	--		
AAT Phonetic structure	-.59	-.20	-.01	.16	.08	.18	.01	.33	.80	.79	.10	.35	--	
AAT Syntactic structure	-.19	-.40	.18	.25	.56	.48	-.46	.51	.71	.21	.77	.64	.47	--

<u>Table 7: correlations between AAT tests and measures of lexical processing of the multi-level approach.</u>

	Substit funct. words	**Omiss. function words**	**Omiss. morphosynt. info**	**Compl. sent.**	**AAT Repet.**	**AAT Naming**	**AAT Compreh.**	**AAT Token**	**AAT Written language**	**AAT Communic. behaviour**	**AAT Articulat. and prosody**	**AAT Automatic language**	**AAT Semantic structure**	**AAT Phonetic structure**	**AAT Syntactic structure**
Substit. function words	--														
Omiss. funct. words	.23	--													
Omiss. morphosynt. info	.27	.09	--												
Complete sent.	-.44	.13	-.37	--											
AAT Repetition	.08	-.14	.24	.05	--										
AAT Naming	-.09	.01	.16	.11	.81	--									
AAT Compreh.	-.05	-.10	.11	.03	.85	.93	--								
AAT Token	.05	.33	.02	.09	-.89	-.75	-.82	--							
AAT Written	-.22	.14	.27	.45	.7	.75	.71	-.45	--						
AAT Commun. behaviour	-.49	-.01	-.06	**.67**	.58	.56	.65	-.53	.73	--					
AAT Articuland prosody	-.31	-.20	-.14	.20	-.10	-.23	-.18	.33	-.08	.52	--				
AAT Automatic language	-.43	.46	-.01	.5	.51	.82	.69	-.70	.64	.54	-.15	--			
AAT Semantic structure	-.45	-.03	.19	**.65**	.62	.85	.78	-.71	.85	.64	-.08	.74	--		
AAT Phon. structure	-.51	-.36	-.14	.50	.15	.08	.17	.0	.32	.79	.79	.10	.34	--	
AAT Syntactic structure	**-.77**	.28	-.30	.60	.25	.56	.48	-.46	.51	.71	.20	.76	.63	.47	--

Table 8: correlations between AAT tests and measures of grammatical processing of the multi-level approach.

	Cohesion errors	**Local coherence errors**	**Global coherence errors**	**Filler utterances**	**Repeated utterances**	**Sem. unrel. utterances**	**Tangential utterances**	**AAT Repet.**	**AAT Naming**	**AAT Compreh.**	**AAT Token**	**AAT Written language**	**AAT Communic. behaviour**	**AAT Articulat. and prosody**	**AAT Automatic language**	**AAT Semantic structure**	**AAT Phonetic structure**	**AAT Syntactic structure**
Cohesion errors	--																	
Local coher.err.	-.28	--																
Global coher. err.	.09	.37	--															
Filler Utter.	-.07	.68	.77	--														
Repeat. Utter.	.37	-.17	.61	.08	--													
Semantically unrelat. utter.	-.12	.03	.48	.04	.51	--												
Tangent. utter.	-.08	.27	.72	.59	.08	.24	--											
AAT Repetition	.03	-.35	-.45	-.36	-.04	-.3	**-.6**	--										
AAT Naming	.06	-.43	**-.7**	**-.55**	-.22	**-.56**	**-.68**	.81	--									
AAT Compreh.	.1	**-.47**	**-.65**	**-.51**	-.16	**-.59**	**-.67**	.85	.93	--								
AAT Token	.12	.28	.46	.18	.29	**.49**	**.47**	-.89	-.75	-.82	--							
AAT Written	.11	**-.54**	**-.57**	**-.73**	.03	-.1	**-.56**	.7	.75	.71	-.45	--						
AAT Commun. behaviour	-.12	-.26	-.33	-.48	.16	.12	-.38	.58	.56	.65	-.53	.73	--					
AAT Articuland prosody	-.14	.22	.37	.36	.12	.13	.18	-.1	-.23	-.18	.33	-.08	.52	--				
AAT Automatic language	-.32	-.19	**-.8**	-.6	-.44	-.29	-.45	.51	.82	.69	-.70	.64	.54	-.15	--			
AAT Semantic structure	.1	-.49	**-.74**	**-.76**	-.09	-.27	**-.57**	.62	.85	.78	-.71	.85	.64	-.08	.74	--		
AAT Phon. structure	.05	-.19	.07	-.07	.16	.12	.05	.15	.08	.17	.0	.32	.79	.79	.1	.34	--	
AAT Syntactic structure	-.39	-.09	-.56	-.36	-.44	-.32	-.15	.25	.56	.48	-.46	.51	.71	.2	.76	.63	.47	--

<u>Table 9: correlations between AAT tests and macrolinguistic measures of the multi-level approach</u>

	Thematic Informativ.	Details to main themes	AAT Repet.	AAT Naming	AAT Compreh.	AAT Token	AAT Written language	AAT Communic. behaviour	AAT Articulat. and prosody	AAT Automatic language	AAT Semantic structure	AAT Phonetic structure	AAT Syntactic structure
Thematic Informativ.	--												
Details to main themes	.31	--											
AAT Repetition	.17	.21	--										
AAT Naming	.4	.07	.81	--									
AAT Compreh.	.31	-.02	.85	.93	--								
AAT Token	-.01	-.03	-.89	-.75	-.81	--							
AAT Written	**.55**	.45	.7	.75	.71	-.45	--						
AAT Commun. behaviour	.47	.63	.58	.56	.65	-.53	.73	--					
AAT Articuland prosody	-.09	.16	-.1	-.23	-.18	.33	-.08	.52	--				
AAT Automatic language	**.64**	.42	.51	.82	.69	-.7	.64	.54	-.15	--			
AAT Semantic structure	**.76**	**.63**	.62	.85	.78	-.71	.85	.64	-.08	.74	--		
AAT Phon. structure	.23	.39	.15	.08	.17	.0	.32	.79	.79	.1	.34	--	
AAT Syntactic structure	.32	.34	.25	.56	.48	-.46	.51	.71	.2	.76	.63	.47	--

Table 10: correlations between AAT tests and measures of the multi-level approach assessing conceptual organization of the narratives.

6

Conclusions and future developments

The methodologies and the experimental design described in this thesis aimed at investigating linguistic abilities in patients with fluent aphasia using a multi-level approach that challenges the traditional assessment instruments used in clinical practice. As described in §3.4, the multi-level approach has proved useful in several clinical populations and, for patients presented in this study, it provided remarkable data that standardized tests didn't reveal. Noteworthy, it presented strong theoretical framework from both linguistic and psychological theories, as well as giving back to these fields a valid bases for future developments of language models. Indeed, the multi-level approach gathers structuralist and functionalist perspectives and, in one analysis, it assesses both micro- and macrolinguistic dimensions. Therefore, it allows linguists, psychologists and clinicians to observe how the linguistic levels interact on the bases of quantitative and pragmatic measures.

Interestingly, the worth of the application of this approach together with neuroimaging experiments has been described (§ 3.5). This confirms the important role of neuroimaging techniques which nowadays are fundamental for both research and clinical practice. Clearly, their role in clinical practice is essential for patients who suffered brain damages: diagnosis, surgery and rehabilitation are now largely supported. In research, literature showed that neurosciences rapidly developed since the introduction of neuroimaging techniques. Indeed, they helped in the discovery of brain damages causing cognitive deficits as well as allowing collection of large samples of data, marking an important change with respect to the data obtained before their introduction, coming just from autopsies. In aphasia field in particular, knowledge grew up: as described in § 2.8.3 for instance, it was possible studying subcortical aphasias only after the introduction of neuroimaging techniques. For our studies in particular, we could use tDCS and TMS for, respectively, rehabilitation and experimental issues, giving new significant inputs to research.

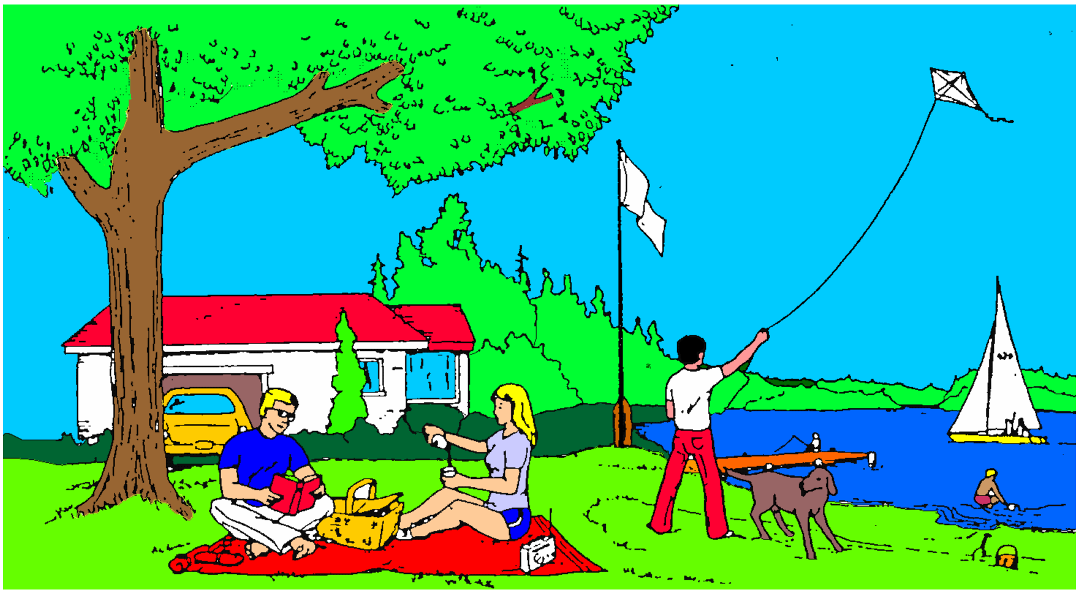
In conclusion, new findings in aphasia field showed us the great importance of keeping on use neuroimaging instruments as well as a linguistic multi-level approach for the assessment of the linguistic disorder. The scientific community seems to have definitely grasped the role of discourse in the assessment of aphasia; indeed, the creation of AphasiaBank largely demonstrates the need of collecting, sharing and studying this data. Moreover, this study, together with other experiments presented in the first session, demonstrated the importance of adopting a multi-level approach. Furthermore, correlations with standardized tests that have been used for many years by speech therapists suggested us that narrative tasks represent a valid instrument for the assessment of linguistic skills of patients with aphasia.

In the future it will be important to implement the Italian sample for AphasiaBank as well as developing softwares used for the automatized morphosyntactic analysis. Indeed, the subjective role of the researcher is still the only source for these analyses and it would be important developing an objective methodology.

Furthermore, it will also be interesting getting in touch speech therapists with narrative task evaluations, not only to work with adults suffering from linguistic disorder but also with children. Indeed, the multi-level approach is also useful to assess language development. In general, a deeper cooperation between clinicians and researchers is plausible.

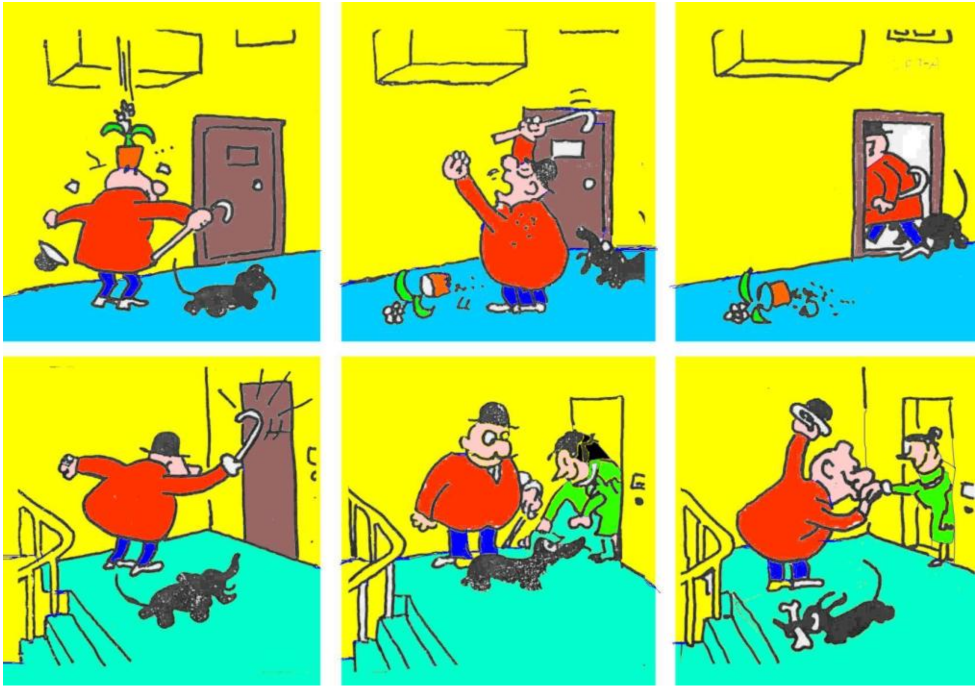
A

Stimuli for speech elicitation in the multi-level approach



The Picnic (Kertesz, 1982).

Appendix A



The Flower pot (Huber and Gleber, 1982).

The Quarrel (Nicholas and Brookshire, 1993).

B

Examples of speech samples

B.1 Transcription with CHAT

Example of a transcription made with CHAT format.

Most used symbols:

(.)	**Pause**
[/]	**Repetition**
+//	**interrupted utterance**
+..	**incomplete but not interrupted utterance**
&	**indicating a phonological fragment**
@d	**dialectal form**
@n	**Neologism**
%err	**indicates comments about errors and the correct form**

Appendix B

@Begin

@Languages: ita

@Participants: PAR S1 Participant, INV Investigator

@ID: ita|A|PAR||Participant||

@ID: ita|A|INV||||S1|Investigator|||

@Comment: initial exchange not transcribed until first protocol question

*INV: come pensi che sia il tuo linguaggio in questi giorni?

*PAR: se è meglio rispetto al solito o (.) così come passa il tempo.

*PAR: diciamo ne+il (.) [/] ne+il anno (.) un anno e mezzo 0c è stato il tiro e quindi come passa il tempo riesco a parlare di più.

*PAR: però è una questione di (.) un anno e mezzo.

*PAR: e ogni il (.) [/] ogni momento è meglio.

*PAR: così almeno mi sembra.

*INV: ti ricordi di quando hai avuto l' ictus?

*PAR: sono andato in bicicletta e mi hanno fatto (.) bere (.) non acqua ma (.) vino.

*PAR: e (.) quindi (.) avevo +//

*PAR: e poi mi avevano &fat i giorni scorsi mi avevano sbagliato le medicine

*PAR: mi hanno +//

*PAR: che avevo già da prima ,, no?

*PAR: un po di medicine.

*PAR: cioè tutto devo parlarlo?

*PAR: ci sono &q quattro cinque cose ,, no?

*PAR: che sono lavoro.

*PAR: lavoro troppo (.) ho lavorato troppo.

*PAR: e cioè il lavoro era (.) a roma a milano a trieste a udine.

*PAR: poi hanno &sba [/] hanno cambiato delle medicine.

*PAR: e mi hanno fatto lavorare &dap da+la sera [*] fino a+la notte.

Appendix B

%err: sera=mattina

*PAR: e (.) ho bevuto un po di caffè un po di birra e ho fatto un qualche giro in bicicletta e (.) ho bevuto un (.) po di vino xxx

*PAR: ho mangiato (.) &c ands (.) altre cose.

*PAR: quindi ho mangiato anche troppo.

*PAR: ho fatto troppe cose con i miei bambini.

*PAR: e quindi una settimana veramente terribile troppe cose.

*PAR: e quindi mi è andato il [*] tilt.

%err: il=in

*PAR: il tilt è durato forse (.) un minuto ma anche meno.

*INV: quali sono le cose che hai fatto per cercare di stare meglio dopo l'ictus?

*PAR: ho cercato di parlare (.) ogni momento e con ogni persona (.) anche quasi con tutti.

*PAR: con certe persone ho &elimi (.) meno perché con [*] certe cose è più difficile parlare.

%err: con=di

*INV: pensando al passato puoi raccontarmi qualcosa della tua vita?

*INV: può essere qualcosa di triste o di felice accaduto in qualsiasi momento.

*PAR: la cosa importante è avere altri (.) i miei bambini (.) che sono tre bambini una femmina e due maschi e sono la cosa importante in+il (.) mio momento

*PAR: e (.) bon@d basta.

*PAR: se vuole pensiamo ci sono altre cento cose fatte però le cose &incompla [/] le cose veramente &i importanti sono il fatto di avere altre (.) altri bambini figli.

*PAR: poi va bene anche &mogli moglie mia.

*INV: adesso ti farò vedere delle immagini.

*INV: prenditi un po di tempo per osservare questa immagine.

*INV: dovrai raccontarmi una storia con un inizio uno sviluppo e una fine.

*INV: puoi guardare l' immagine mentre mi racconti la storia.

Appendix B

*PAR: i bambini hanno lanciato una palla con cui hanno rotto una finestra
e il pallone è caduto in casa dove un signore è un po’ arrabbiato
perché si è rotto [*] la finestra.

%err: rotto=rotta

*INV: questa è un' altra immagine.

*INV: prenditi un po di tempo per osservarla e poi raccontami una storia con un inizio uno sviluppo e una fine.

*PAR: il bambino ha preso la (.) [/] l' orbrello [*] e (.) per darlo dalla [.] dalla (.) mamma non ha [/] non [/] non ha chiesto.

%err: orbrello=ombrello

*PAR: non l' ha preso.

*PAR: quindi dopo è andato a scuola ma è venuto brutto tempo e quindi è rimasto senz' acqua.

*PAR: quindi è tornato in &gi indietro probabilmente perché è venuta l' acqua ed è stato (.) &rip si è dormito@n.

*PAR: si è &v (.) [/] si è (.) venuta acqua.

*PAR: però si è venuto con 0l ombrello di nuovo per andare in giro [/] in giro.

*INV: adesso vediamo questa immagine.

*INV: osserva bene tutto quello che succede e poi ti chiederò di raccontarmi una storia con un inizio uno sviluppo e una fine.

*INV: puoi osservare l' immagine mentre racconti la storia.

*PAR: con i pompieri sono andati di corsa perché ci sono stati due cose strane.

*PAR: una (.) è quella di trovare +//

*PAR: *ah ok (.) probabilmente il gatto è stato preso dentro ne+il (.) in alto e [/] ed è stato un signore per (.) fare un giro per prendere il gatto.

*PAR: ma facendo il (.) [/] il giro de+il signore de+il ragazzo in quel momento si è &r [/] si è scaduto [*] la scala.

%err: scaduto=caduta

Appendix B

*PAR: e ne+lo stesso minuto il bambino la bambina cercava di prendere il gatto da+il basso.

*PAR: il cane giocava probabilmente &so da (.) sotto

*PAR: e intanto sono arrivati i pompieri.

*PAR: e bon@d basta.

*PAR: in questo gioco è probabilmente strano che ci sia un uccello fermo perché visto 0che c'è il cane scappa l'uccello.

*PAR: va via.

@Comment: for cinderella task initial exchange not transcribed until participant begins telling it.

@G: Cinderella.

*PAR: questa è una storia in cui a+il inizio c' era una bambina che è stata probabilmente presa da (.) un papà e però un papà è morto mentre la (.) &m (.) moglie (.) ha preso (.) due figlie con qualcun altro che non è presente.

*PAR: comunque quando è morto questo papà la (.) moglie di altra (.) ha [/] ha preso la casa.

*PAR: la (.) sì ha preso (.) questa donna ha preso andtut di queste tre bambine.

*PAR: ha fatto qualche giochi

*PAR: e allora ci sono due ragazze (.) che sono due brutte donne donnezze@n donnette (.) che prima erano piccole e dopo sono diventate un poco più grandi.

*PAR: e (.) la ragazzina anche era piccola.

*PAR: adesso vive con le altre due bruttissime ragazze.

*PAR: a questo punto c' è un re credo che sta facendo (.) un giro più avanti per fare [/] per fare per trovare una [/] un [un] &mo moglie.

*PAR: e (.) questa ragazzina intanto &s lavora (.) in casa (.) cercando di +//

*PAR: un giorno stava cercando di fare qualche lavoretto per andare ne+il (.) [/] ne+la &fe festa e lei non c' è riuscita la possibiltà di andare con il (.) &r re o con il (.) &ca &pa de+il re.

Appendix B

*PAR: ma è andato per fortuna con una (.) &stre (.) non è una streva@n ma il contrario.

*PAR: cioè il (.) la &sez strega (.) è la &s.

*PAR: *beh questa non è proprio una strega [/] la strega per cui anzi è una che fa tanti giochi e cose.

*PAR: e quindi hanno (.) [/] hanno fatto qualcosa per andare in &p [/] in &pe (.) festa e gli hanno messo delle (.) dei (.) [/] delle (.) cose nuove molto bella.

*PAR: le [/] le scarpe sono fate di [/] sono fatte di (.) queste scarpe sono di (.) [/] di (.) andpe +..

*PAR: *eh a parlarci.

*PAR: (que)ste scarpe sono di (.) +..

*PAR: (que)ste scarpine sono piccole perché questa bambina poverina ha un grossissimo problema ne+la storia.

*PAR: che ha (.) un &pie [/] un piede troppo piccolo però purtroppo ne+la storia (.) c' è questa piedi^no piccolissimo.

*PAR: infatti poverina nonostante era tanto piccola è riuscita a (.) prendere il re anche se piccolissimissimissima.

*PAR: aveva un piede tanto piccolo che non esiste.

*PAR: allora il (.) [/] il re (.) e (.) la [/] la +//

*PAR: e (.) bon@d di un altro &pie &pie (.) a+il +..

*PAR: questo piede è di tritallo@n tristallo@n

*PAR: dillo tu?

*INV: cristallo.

*PAR: cristallo.

*PAR: ok a questo punto (.) quella sera e il &no fino a una certa ora doveva scappare e ha lasciato la scarpa in +..

*PAR: scappata via e aveva un piede già piccolissimo che già è scappata la &p s^carpa.

*PAR: quindi aveva un piede minuscolo che non esisteva perché chiaramente +//
*PAR: bon@d fatto sta che a quel punto (.) ha aspettato in casa perché il hanno &tor passato con &tu (.) per tutte le persone per capire se +..
*PAR: il [/] il (.) re controllava se tutti avevano il piede giusto finché hanno trovato questa bambina che era chiusa in casa però e hanno controllato a chiunque &s qual è la gamba la (.) scarpa e hanno trovato (que)sta bambina.
*PAR: e (.) e quindi ha pensato di stare insieme con questo re.
*INV: adesso faremo qualcosa di diverso.
*INV: puoi dirmi come ti prepareresti un panino con burro e marmellata?
*PAR: si prende il [/] il la pane si taglia in due minimamente per mettere dentro la campabellata@n
*PAR: e poi si chiude e si mangia.
@End

B.2 Example of a CLAN analysis: the output of MLU

For this example we analyzed the Mean Length of Utterance for the session of speech sample in which the patient is talking about his stroke.

From file <c:\TALKBANK\CLAN\work\s1mlu.cha>
MLU for Speaker: *PAR:
MLU (xxx, yyy and www are EXCLUDED from the utterance and morpheme counts):

Number of: utterances = 16, words = 156
Ratio of words over utterances = 9.750
Standard deviation = 4.294

Appendix B

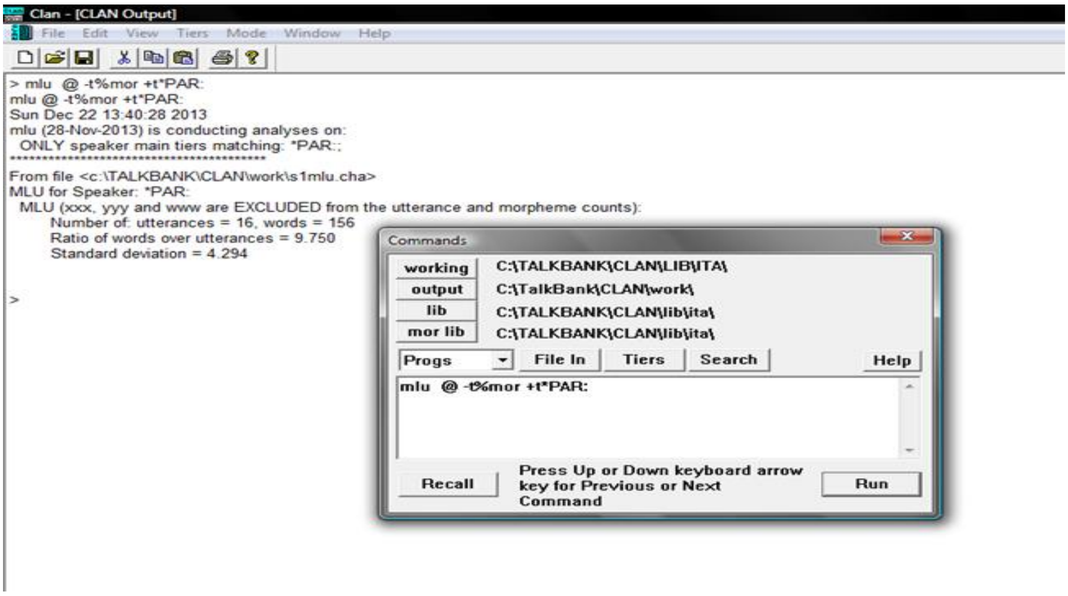


Fig. 9: screenshot from CLAN for the MLU analysis

B.3 Example of a CLAN analysis: the output of Type/Token ratio

Example of the count of type/token ratio. In this case the analysis is based on the whole sample produced by the patient.

340 Total number of different item types used

970 Total number of items (tokens)

0.351 Type/Token ratio

Appendix B

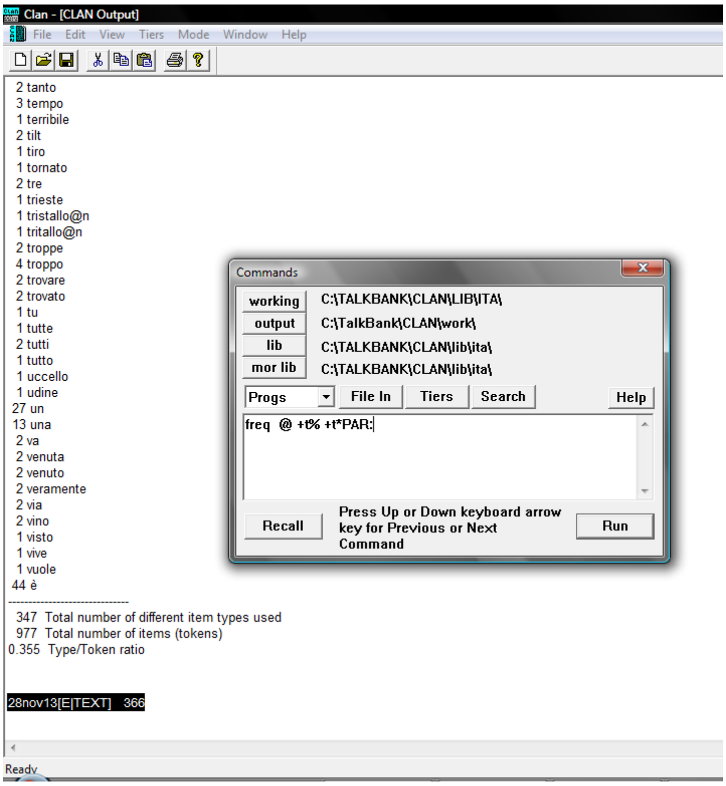


Fig. 10: screenshot from CLAN for the Type/Token analysis

B.4 Example of the MOR analysis for Italian

@Begin

@Languages: ita

@Participants: PAR S1 Participant, INV Investigator

@ID: ita|A|PAR||male||

@ID: ita|A|INV||||S1|Investigator|||

@Comment: initial exchange not transcribed until first protocol

question
*INV: come pensi che sia il tuo linguaggio in questi giorni ?
*PAR: se è meglio rispetto al solito o (.) così come passa il tempo .
%mor: pro:pers|seand3SandOBJ=him^pro:clit|siand3SP^conj|se v|esse-3SandPRES=be
adv|meglio^adj|meglioandmasc-MASCandSG
v|rispetta-1SandPRES=respect^n|rispettoandmasc-MASCandSG
prepart|alandmasc-MASCandSG
v|sole-PPARTandSGandMASC=be_used^adj|solitoandmasc-MASCandSG conj|o adv|così
pro:int|come=how^conj|come^adv|come
v:imp|passa-2SandIMP=spend^v|passa-3SandPRES=spend art|ilandMASCandSG
n|tempoandmasc-MASCandSG .
*PAR: diciamo ne+il (.) [/] ne+il anno (.) un anno e mezzo 0c è stato il tiro
e quindi come passa il tempo riesco a parlare di più .
%mor: v|dice-1PandPRESandSUB=say^v:imp|dice-1PandIMP=say^v|dice-1PandPRESandSUB=say
?|ne+il n|annoandmasc-MASCandSG art|unoandMASCandSG n|annoandmasc-MASCandSG
conj|e n|mezzoandmasc-MASCandSG^adj|mezzoandmasc-MASCandSG ?|0c
v|esse-3SandPRES=be v|esse-PPARTandSGandMASC=be^n|statoandmasc-MASCandSG
art|ilandMASCandSG v|tira-1SandPRES=pull conj|e adv|quindi
pro:int|come=how^conj|come^adv|come
v:imp|passa-2SandIMP=spend^v|passa-3SandPRES=spend art|ilandMASCandSG

Appendix B

n|tempoandmasc-MASCandSG v|riusci-1SandPRES=succeed prep|a=to
v:inf|parla-INF=speak
prep|di=from^v:imp|dice-2SandIMP=say^n|dioandmasc-MASCandPL=god
prep|più=plus^adv|più^adj|più=more .

*PAR: però è una questione di (.) un anno e mezzo .

%mor: conj|però v|esse-3SandPRES=be
art|unoandFEMandSG^v|uni-SGandSUB=join^v:imp|uni-3SandIMP=join
n|questioneandfem
prep|di=from^v:imp|dice-2SandIMP=say^n|dioandmasc-MASCandPL=god
art|unoandMASCandSG n|annoandmasc-MASCandSG conj|e
n|mezzoandmasc-MASCandSG^adj|mezzoandmasc-MASCandSG .

*PAR: e ogni il (.) [/] ogni momento è meglio .

%mor: conj|e det|ogni=every det|ogni=every n|momentoandmasc-MASCandSG
v|esse-3SandPRES=be adv|meglio^adj|meglioandmasc-MASCandSG .

*PAR: così almeno mi sembra .

%mor: adv|così adv|almeno pro:clit|miand1S
v:imp|sembra-2SandIMP=seem^v|sembra-3SandPRES=seem .

*INV: ti ricordi di quando hai avuto l' ictus ?

%mor: pro:clit|tiand2S
v|ricorda-SGandSUB=remind^v:imp|ricorda-3SandIMP=remind^v|ricorda-2SandPRES=remind^n|ricordoandmasc-MASCandPL
prep|di=from^v:imp|dice-2SandIMP=say^n|dioandmasc-MASCandPL=god
conj|quando^adv|quando v|ave-2SandPRES=have v|ave-PPARTandSGandMASC=have
pro:clit|loand3S^art|ilandSG ?|ictus ?

*PAR: sono andato in bicicletta e mi hanno fatto (.) bere (.) non acqua ma (.) vino .

%mor: v|esse-3PandPRES=be^v|esse-1SandPRES=be v|anda-PPARTandSGandMASC=go

Appendix B

prep|in=in n|biciclettaandfem-FEMandSG conj|e pro:clit|miand1S
v|ave-3PandPRES=have v:part|face-PPARTandSGandMASC=do^n|fattoandmasc-MASCandSG
v:inf|bebe-INF=drink adv|non n|acquaandfem-FEMandSG=water conj|ma
n|vinoandmasc-MASCandSG=wine .

*PAR: e (.) quindi (.) avevo +//.

%mor: conj|e adv|quindi v|ave-1SandPAST=have +//.

*PAR: e poi mi avevano &fat i giorni scorsi mi avevano sbagliato le medicine .

%mor: conj|e conj|poi^adv|poi pro:clit|miand1S v|ave-3PandPAST=have
art|ilandMASCandPL n|giornoandmasc-MASCandPL
v|scorre-1SandPRET=flow^v|scorre-PPARTandPLandMASC=flow^v|scorge-1SandPRET=perceive^v|scorge-PPARTandPLandMASC=perceive^adj|scorsoandmasc-MASCandPL=past
pro:clit|miand1S v|ave-3PandPAST=have v|sbaglia-PPARTandSGandMASC=mistake
pro:clit|leand3PandFEM^art|ilandFEMandPL
n|medicinaandfem-FEMandPL=medicine^n|medicoandmasc-DIM-MASCandSG=doctor^adj|medicoandfem-DIM-FEMandPL=medical^adj|medicoandmasc-DIM-MASCandSG=medical.

*PAR: mi hanno +//.

%mor: pro:clit|miand1S v|ave-3PandPRES=have +//.

*PAR: che avevo già da prima ,, no ?

%mor: pro:rel|che=that^pro:int|che=what^det|che=which v|ave-1SandPAST=have
co:adv|già^adv|già
prep|da=from^v|da-SGandSUB=give^v:imp|da-2SandIMP=give^v|da-3SandPRES=give
adv|prima^num:ord|primoandfem-FEMandSG cm|cm cm|cm adv|no ?

Appendix B

*PAR: un po di medicine .
%mor: art|unoandMASCandSG ?|po
prep|di=from^v:imp|dice-2SandIMP=say^n|dioandmasc-MASCandPL=god
n|medicinaandfem-FEMandPL=medicine^n|medicoandmasc-DIM-
MASCandSG=doctor^adj|medicoandfem-DIM-
FEMandPL=medical^adj|medicoandmasc-DIM-MASCandSG=medical.
*PAR: cioè tutto devo parlarlo [*] ?
%mor: conj|cioè
adv|tutto^pro:det|tuttoandmasc-MASCandSG=all^det|tuttoandmasc-
MASCandSG=all
v|dove-1SandPRES=must^v|da-1SandPAST=give
v:inf|parla-INF~pro:clit|3SandMASC=speak ?
*PAR: ci sono &q quattro cinque cose ,, no ?
%mor: pro:clit|ciand1P v|esse-3PandPRES=be^v|esse-1SandPRES=be
num:card|quattro
num:card|cinque n|cosoandmasc-MASCandSG=whatsit^n|cosaandfem-
FEMandPL cm|cm
cm|cm adv|no ?
*PAR: che sono lavoro .
%mor: pro:rel|che=that^pro:int|che=what^det|che=which
v|esse-3PandPRES=be^v|esse-1SandPRES=be
v|lavora-1SandPRES=work^n|lavoroandmasc-MASCandSG .
*PAR: lavoro troppo (.) ho lavorato troppo .
%mor: v|lavora-1SandPRES=work^n|lavoroandmasc-MASCandSG
adv|troppo^pro:det|troppoandmasc-
MASCandSG=too_much^det|troppoandmasc-MASCandSG=too_much
v|ave-1SandPRES=have v|lavora-PPARTandSGandMASC=work

adv|troppo^pro:det|troppoandmasc-MASCandSG=too_much^det|troppoandmasc-MASCandSG=too_much.
*PAR: e cioè il lavoro era (.) a roma a milano a trieste a udine .
%mor: conj|e conj|cioè art|ilandMASCandSG
v|lavora-1SandPRES=work^n|lavoroandmasc-MASCandSG v|esse-3SandPAST=be
prep|a=to ?|roma prep|a=to ?|milano prep|a=to ?|trieste prep|a=to
v:imp|udi-2SandIMP~pro:clit|part=hear .
*PAR: poi hanno &sba [/] hanno cambiato delle medicine .
%mor: conj|poi^adv|poi v|ave-3PandPRES=have v|ave-3PandPRES=have
v|cambia-PPARTandSGandMASC=exchange prepart|delandfem-FEMandPL
n|medicinaandfem-FEMandPL=medicine^n|medicoandmasc-DIM-MASCandSG=doctor^adj|medicoandfem-DIM-FEMandPL=medical^adj|medicoandmasc-DIM-MASCandSG=medical.
*PAR: e mi hanno fatto lavorare &dap da+la sera [*] fino a+la notte .
%mor: conj|e pro:clit|miand1S v|ave-3PandPRES=have
v:part|face-PPARTandSGandMASC=do^n|fattoandmasc-MASCandSG
v:inf|lavora-INF=work
prepart|dalandfem-FEMandSG^v:imp|da-2SandIMP~pro:clit|3SandFEM=give
n|seraandfem-FEMandSG prep|fino=until^adj|finoandmasc-MASCandSG
prepart|alandfem-FEMandSG n|notteandmasc-MASCandSG .
%err: sera=mattina
*PAR: e (.) ho bevuto un po di caffè un po di birra e ho fatto un qualche
giro in bicicletta e (.) ho bevuto un (.) po di vino xxx .
%mor: conj|e v|ave-1SandPRES=have v|beve-PPARTandSGandMASC=drink
art|unoandMASCandSG ?|po

Appendix B

prep|di=from^v:imp|dice-2SandIMP=say^n|dioandmasc-MASCandPL=god n|caffè

art|unoandMASCandSG ?|po

prep|di=from^v:imp|dice-2SandIMP=say^n|dioandmasc-MASCandPL=god

n|birraandfem-FEMandSG conj|e v|ave-1SandPRES=have

v:part|face-PPARTandSGandMASC=do^n|fattoandmasc-MASCandSG art|unoandMASCandSG

det|qualche=some v|gira-1SandPRES=turn^n|giroandmasc-MASCandSG prep|in=in

n|biciclettaandfem-FEMandSG conj|e v|ave-1SandPRES=have

v|beve-PPARTandSGandMASC=drink art|unoandMASCandSG ?|po

prep|di=from^v:imp|dice-2SandIMP=say^n|dioandmasc-MASCandPL=god

n|vinoandmasc-MASCandSG=wine .

*PAR: ho mangiato (.) &c &s (.) altre cose .

%mor: v|ave-1SandPRES=have v|mangia-PPARTandSGandMASC=eat

pro:det|altroandfem-FEMandPL=another_one^pro:det|altroandmasc-MASCandSG=another_one^det|altroandfem-FEMandPL=other

n|cosoandmasc-MASCandSG=whatsit^n|cosaandfem-FEMandPL .

*PAR: quindi ho mangiato anche troppo .

%mor: adv|quindi v|ave-1SandPRES=have v|mangia-PPARTandSGandMASC=eat

conj|anche^n|ancaandfem-FEMandPL=hip

adv|troppo^pro:det|troppoandmasc-MASCandSG=too_much^det|troppoandmasc-MASCandSG=too_much.

*PAR: ho fatto troppe cose con i miei bambini .

%mor: v|ave-1SandPRES=have

v:part|face-PPARTandSGandMASC=do^n|fattoandmasc-MASCandSG

pro:det|troppoandfem-FEMandPL=too_much^pro:det|troppoandmasc-MASCandSG=too_much^det|troppoandfem-FEMandPL=too_much

n|cosoandmasc-MASCandSG=whatsit^n|cosaandfem-FEMandPL prep|con=with
art|ilandMASCandPL pro:poss|mio-1SandMASCandPL=my
n|bambinoandmasc-MASCandPL=child .
*PAR: e quindi una settimana veramente terribile troppe cose .
%mor: conj|e adv|quindi
art|unoandFEMandSG^v|uni-SGandSUB=join^v:imp|uni-3SandIMP=join
n|settimanaandfem-FEMandSG adv:adj|vero-ADV adj|terribileandboth-SG
pro:det|troppoandfem-FEMandPL=too_much^pro:det|troppoandmasc-MASCandSG=too_much^det|troppoandfem-FEMandPL=too_much
n|cosoandmasc-MASCandSG=whatsit^n|cosaandfem-FEMandPL .
*PAR: e quindi mi è andato il [*] tilt .
%mor: conj|e adv|quindi pro:clit|miand1S v|esse-3SandPRES=be
v|anda-PPARTandSGandMASC=go art|ilandMASCandSG ?|tilt .
%err: il=in
*PAR: il tilt è durato forse (.) un minuto ma anche meno .
%mor: art|ilandMASCandSG ?|tilt v|esse-3SandPRES=be v|dura-PPARTandSGandMASC=last
adv|forse^v:inf|esse-INF~pro:clit|REFL=be art|unoandMASCandSG
n|minutoandmasc-MASCandSG^adj|minutoandmasc-MASCandSG conj|ma
conj|anche^n|ancaandfem-FEMandPL=hip adv|meno^adj|menoandmasc-MASCandSG .

Appendix B

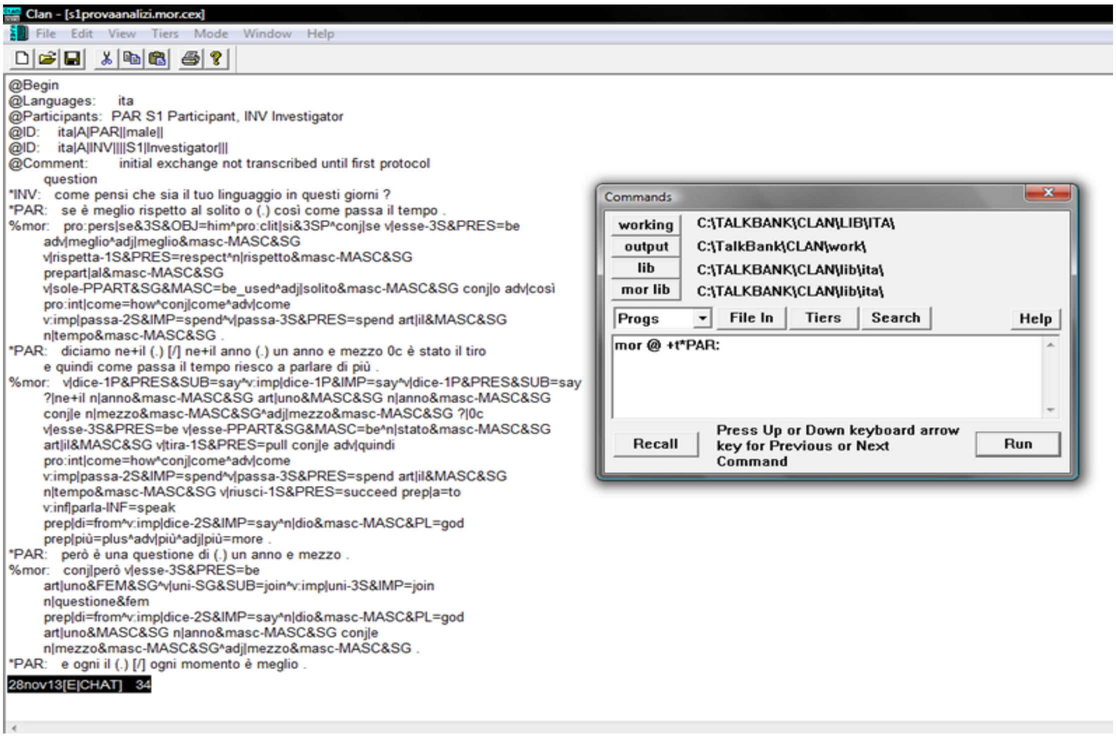


Fig. 11: screenshot from CLAN for mor analysis

B.5 Example of transcription and utterances segmentation with the multi-level approach

Example of transcription and analysis of a speech sample. Errors are reported in italics.

Story: Picnic Time: 78”

Appendix B

La sena..[*sena* = *scena* →*phonological paraphasias*] è di un pinc-nic .. [*pinc-nic* = *pic-nic* → *phonological paraphasias*] (3 sec) / in niva [*niva* = *riva* → *phonological paraphasia*] a+il lago../ di una famiglia.. che.. [*aposiopesis+omission of morphosyntactic information*] / c'è in [*in=un*→ *phonological paraphasia*] papà.. e la mamma.. e.. un figlio con l'aquilone e in [*in=un*→ *phonological paraphasia*] cane / e… [*aposiopesis*](5 sec) / *e* [*repetition*] c'è una casa dieto [*dieto=dietro*→*phonological paraphasia*] *che non so si sia la casa di quelli che sanno facendo il pinc-nic* ..[*lexical fillers*] (3 sec) / e vedo una banca [*banca=barca*→ *phonological paraphasia*].. (4 sec) / e un pescatore /

Utterances = 8

Units = 59

Words = 53

Speech rate = 40.76%

LIUs = 69.81%

Appendix B

MLU = 6.6

Phon. Errors = 10.16%

Semantic paraphasias = 6.6%

Substitutions of bound morphemes = 0%

Substitutions of function words = 0%

Omission of function words = 0%

Omission of morphosyntactic information = 12.5%

Complete sentences = 50%

Cohesion errors = 25%

Local coherence errors = 0%

Global coherence errors = 0%

References

Andreetta, S. and Marini, A. (in press) Narrative assessment in patients with communicative disorders. Travaux neuchâtelois de linguistique, 5x.

Andreetta, S., Cantagallo, A., and Marini, A. (2012). Narrative discourse in anomic aphasia. Neuropsychologia, 50, 1787–93.

Armstrong, E. (2000). Aphasic discourse analysis: The story so far. Aphasiology, 14, 875–892.

Baddeley, A.D. (1986) Working Memory. Clarendon Press, Oxford.

Basso, A. (2005). Conoscere e rieducare l'afasia. Il Pensiero Scientifico, Roma.

Benton, A. L., and Joynt, R. J. (1960). Early descriptions of aphasia. Archives of Neurology, 3, 205-222.

Caplan, D. (1992). Language: Structure, processing and disorders. MIT Press, Cambridge (MA).

Carlesimo, G.A., Caltagirone, C., Gainotti, G., 1996. The Mental Deterioration Battery: normative data, diagnostic reliability and qualitative analyses of cognitive impairment. The Group for the Standardization of the Mental Deterioration Battery. Eur. Neurol. 36, 378-384.

Carlomagno, S., Zulian, N., Razzano, C., De Mercurio, I., and Marini, A., (2005) Coverbal gestures in the recovery from severe fluent aphasia: a pilot study. Cortex, 41(4), 535-546.

Catani, M., Jones, D. K., and ffytche, D. H. (2005). Perisylvian Language Networks of the Human Brain. Annals of Neurology, 57, 8-16.

Catani, M., Dell'Acqua, F., Bizzi, A., Forkel, S. J., Williams, S. C., Simmons, A., Murphy, D. G., and Thiebaut de Schotten, M. (2012). Beyond cortical localisation in clinico-anatomical correlation. Cortex, 1-26.

Chomsky, N. (1959). A Review of B. F. Skinner's Verbal Behavior, Language, 35, 1, 26-58.

Chomsky, N. (1995). The minimalist programme. MIT Press, Cambridge (MA).

Christiansen, J. A. (1995). Coherence violations and propositional usage in the narratives of fluent aphasics. Brain and Language, 51, 291‑317.

Coelho, C. A., and Flewellyn, L. (2003). Longitudinal assessment of coherence in an adult with fluent aphasia: a follow-up study. Aphasiology, 17, 2, 173‑182.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Erlbaum, Hillsdale, NJ.

Davis, G., and Wilcox, M. (1985). Adult aphasia rehabilitation: Applied pragmatics, Windsor, UK: NFER-Nelson.

De Bleser, R. (2001). History of research on adult language and its disorders. Handbook of neuropsychology, 2nd Edition, Vol. 3, R. S. Berdt (Ed.), 3- 18.

De Renzi, E. and Vignolo, L. (1962). The Token Test: A sensitive test to detect receptive disturbances in aphasics. Brain, 85, 665-78.

Denes, G. and Pizzamiglio, L. (a cura di) (1996), Manuale di neuropsicologia, Zanichelli, Bologna.

Domanski, C. W. (2013). Mysterious “Monsieur Leborgne”: The mystery of the famous patient in the history of neuropsychology is explained. Journal of the history of the neurosciences, 22, 47–52.

Dronkers, N. F. (1996). A new brain region for coordinating speech articulation. Nature, 384, 159–161.

Dronkers, N. F., and Larsen, J. (2001). Neuroanatomy of the classical syndromes of aphasia. In Berndt, R. S. (ed. by), Handbook of Neuropsychology, 2nd edition, vol. 3, 19-30.

Dronkers, N. F., Plaisant, O., Iba-Zizen, M. T., and Cabanis, E. A. (2007). Paul Broca's historic cases: high resolution MR imaging of the brains of Leborgne and Lelong. Brain, 130, 5, 1432-1441.

Easterbrook, A., Byers Brown, A., and Perera, K. (1982). A comparison of speech of adult aphasic subjects in spontaneous and structural interaction. International Journal of Language and Communication Disorders, 17, 3, 93-107.

Fabbro, F., Gagliardi, C., Martelli, S., Marini, A., and Borgatti, R. (2010). Narrative language in Williams Syndrome and its neuropsychological correlates. Journal of Neurolinguistics.

Fex, B., and Mansson, A. C. (1998). The use of gestures as a compensatory strategy in adults with acquired aphasia compared to children with specific language impairment (SLI). Journal of Neurolinguistics, 11, 191-206.

Finger, S. (1994). Origins of Neuroscience, Oxford University Press, New York.

Flourens, P. (1824). Recherches expérimentales sur les propriétés et les fonctions du système nerveux, dans les animaux vertébrés. Crevot, Paris.

Fodor, J. A. (1983). The Modularity of Mind, MIT Press, Cambridge (MA).

Frederiksen, C. H., Bracewell, R. J., Breuleux, A., and Renaud, A. (1990). The cognitive representation and processing of discourse: Function and dysfunction. In Y. Joanette and H. Brownell (Eds.), Discourse ability and brain damage: Theoretical and empirical perspectives. Springer Verlab, New York.

Gazzaniga, M. S., Ivry, R. B., Mangun, G. R. (2005). Neuroscienze cognitive, Zanichelli, Bologna.

Geschwind, N. (1972). Language and the Brain, Scientific American, 226, 4, 76-83.

Glosser, G., and Deser, T. (1990). Patterns of discourse production among neurological patients with fluent language disorders. Brain and language, 40, 1, 67-88.

Glosser G., Wiley, M. J., and Barnoski, E. J. (1998) Gestural communication in Alzheimer’s disease. Journal of Clinical and ExperimentalNeuropsychology, 20, 1-13.

Goodglass, H. (1993). Understanding Aphasia, Academic Press, San Diego (CA).

Goodglass, H., and Kaplan, E. (1972). The Boston Diagnostic Aphasia Examination. Lea and Febiger, Philadelphia, PA.

Graffi, G. and Scalise, S. (2003). Le lingue e il linguaggio, Il Mulino, Bologna.

Grimes, J. E. (1975). The thread of discourse, The Hague, Mouton.

Halliday, M. A. K., and Hasan, R. (1976). Cohesion in English. Longman, London.

Halliday, M. A. K. (1985). An introduction to functional grammar, Edward Arnold, London.

Helm-Estabrooks, N. A., Fitzpatrick, P. M., and Barresi, B. (1981). Response of an agrammatic patient to a syntax stimulation progamme for aphasia. Journal of Speech and Hearing disorders, 46, 422-427.

Haravon, A., Obler, L., and Sarno, M. (1994). A method for microanalysis of discourse in brain-damaged patients. In R. Bloom, L. Obler, S. De Santi, and J. Erlich (Eds), Discourse analysis and applications: Studies in adult clinical populations (pp. 47-80). Lawrence Erlbaum Associates Inc. Hillsdale (NJ).

Hauser, M. D., Chomsky, N., and Fitch, W. T. (2002). The faculty of language: what is it, who has it, and how did it evolve? Science, 298, 1569–1579.

Huber, W., and Gleber, J. (1982). Linguistic and non-linguistic processing of narratives in aphasia. Brain and Language, 16, 1-18.

Huber, W. (1990). Text comprehension and production in aphasia: analysis in terms of micro and macroprocessing. In: Y. Joanette, and H. H. Brownell (Eds.), Discourse Ability and Brain Damage (pp. 154‑179). Springer-Verlag, New York.

Indefrey, P., and Levelt, W. J. M. (2004), The spatial and temporal signatures of word production components. Cognition, 92, 101-144.

Kent, R. D. (2004) (ed. by). The MIT Encyclopedia of Communication Disorders. MIT Press, Cambridge (MA).

Kertesz, A. (1982). Western Aphasia Battery. Grune and Stratton, New York.

Kintsch, W. (1994). Text comprehension, memory, and learning. The American psychologist, 49, 294–303.

Levelt, W. J. M. (1989). Speaking: from intention to articulation. MIT Press, Cambridge (MA).

Levelt, W. J. M., Roelofs, A., and Meyer, A. S. (1999). A theory of lexical access in speech production. The Behavioral and brain sciences, 22, 1–38; discussion 38–75.

Luzzatti, C., Willems, K., and DeBleser, R. (1991). Aachener Aphasie Test (Versione italian). Organizzazioni Speciali, Firenze, Italy.

MacWhinney, B. (2000). The CHILDES Project: Tools for Analyzing Talm. 3rd Edition. Lawrence Erlbaum Associates, Mahwah (NJ).

MacWhinney, B., Fromm, D., Forbes, M., and Holland, A. (2011). AphasiaBank: Methods for studying discourse. Aphasiology, 25, 11, 1286-1307.

Marangolo, P., Fiori, V., Calpagnano, M. A., Campana, S., Razzano, C., Caltagirone, C., and Marini, A. (2013). tDCS over the left inferior frontal cortex improves speech production in aphasia. Frontiers in Human Neuroscience, 7, 539, 1-10.

Marangolo, P., Fiori, V., Campana, S., Calpagnano, M. A., Razzano, C., Caltagirone, C., and Marini, A. (2014). Something to talk about: enhancement of linguistic cohesion through tDCS in chronic non fluent aphasia. Neuropsychologia, 53, 246-253

Marini, A. (2001). Elementi di psicolinguistica generale, Springer Verlag, Milano.

Marini, A., Nocentini, U. (2003). Comunicazione verbale e emisfero destro, Sprigner Verlag, Milano.

Marini, Andrea, Carlomagno, S., Caltagirone, C., and Nocentini, U. (2005a). The role played by the right hemisphere in the organization of complex textual structures. Brain and Language, 93, 46–54.

Marini, A., Boewe, A., Caltagirone, C., and Carlomagno, S. (2005b). Age-related differences in the production of textual description. Journal of psycholinguistic research, 34, 5, 439-463.

Marini, A, Lorusso, M. L., D'Angelo, M. G., Civati, F., Turconi, A. C., Fabbro, F., and Bresolin, N. (2007a). Evaluation of narrative abilities in patients suffering from Duchenne Muscular Dystrophy. Brain and language, 102, 1–12.

Marini, Andrea, Carlomagno, S., Caltagirone, C., and Pasqualetti, P. (2007b). Patterns of language improvement in adults with non-chronic non-fluent aphasia after specific therapies. Aphasiology, 21, 2, 164-186

Marini, A. (2008). Manuale di Neurolinguistica, Carocci, Roma.

Marini, A., Spoletini, I., Rubino, I.A., Ciuffa, M., Bria, P., Martinotti, G., Banfi, G., Boccascino, R., Strom, P., Siracusano, A., Caltagirone, C., and Spalletta, G. (2008). The language of schizophrenia: An analysis of micro and macrolinguistic abilities and their neuropsychological correlates. Schizophrenia Research, 105, 144-155.

Marini, A, Andreetta, S., Del Tin, S., and Carlomagno, S. (2011a). A multi-level approach to the analysis of narrative language in aphasia. Aphasiology, 25, 11, 1372–1392.

Marini, A., Galetto, V., Zampieri, E., Vorano, L., Zettin, M., and Carlomagno, S. (2011b). Narrative language in traumatic brain injury. Neuropsychologia, 49, 2904-2910.

Marini, A. (2012a). Characteristics of Narrative Discourse Processing after Damage to the Right Hemisphere. Seminars in Speech and Language, vol. 33, 1, 68-78.

Marini A., Urgesi C. (2012b) Please get to the point! A cortical correlate of linguistic informativeness. Journal of Cognitive Neuroscience. 24, 11, 2211-2222.

McClelland, J. L., and Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception. I: an account of basic findings, Psychological review, 88, 375-407.

Nicholas, L. E., and Brookshire, R. H. (1993). A system for quantifying the informativeness and efficiency of the connected speech of adults with aphasia. Journal of speech and hearing research, 36, 338–350.

Olness, G. S., Matteson, S. E., and Stewart, C. T. (2010). "Let me tell you the point": how speakers with aphasia assign prominence to information in narratives. Aphasiology, 24, 6-8, 697-708.

Prins, R., and Bastiaanse, R. (2004). Review: Analysing the spontaneous speech of aphasic speakers. Aphasiology, 18, 1075–1091.

Raven, J. C. (1938). Progressive Matrices: A Perceptual Test of Intelligence. H.K. Lewis, London.

Saffran, E. M., Berndt, R. S., and Schwartz, M. F. (1989). The quantitative analysis of agrammatic production: Procedure and data. Brain and Language, 37, 440-479.

Sherratt, S. (2007). Multi-level discourse analysis: a feasible approach. Aphasiology, 21, 3/4, 373-393.

Shewan, C. M. (1988). The Shewan Spontaneous Language Analysis (SSLA) system for aphasic adults: Description, reliability and validity. Journal of Communication Disorders, 21, 103-138.

Skinner, B. F. (1957). Verbal behavior. Copley Publishing group, Acton (MA).

Spalletta, GF, Spoletini, I., Cherubini, A., Rubino, I.A., Siracusano, A., Piras; F., Caltagirone, C, Marini, A. (2010). Cortico-subcortical underpinnings of narrative processing impairment in schizophrenia. Psychiatry Research: Neuroimaging. 182, 77–80.

Tesak J. and Code C. (2008). Milestones in the history of aphasia. Theories and protagonists. Psychology Press, Hove and New York.

Thompson, C. K., Shapiro, L. P., Tait, M., Jacobs, B., and Schneider, S. L. (1996). Training wh-question production in agrammatic aphasia: Analysis of argument and adjunct movement. Brain and Language, 52, 175-228.

Ulatowska, H. K., Freedman-Stern, R., Doyel, A. W., Macaluso-Haynes, S., and North, A. J. (1983). Production of narrative discourse in aphasia. Brain and language, 19, 317–334.

Watson, J. B. (1913). Psychology as the Behaviorist Views it. Psychological Review, 20, 158-177.

Wright, H., and Capilouto, G. J. (2009). Manipulating task instructions to change narrative discourse performance. Aphasiology, 23, 1295-1308.

Yorkston, K. M., and Beukelman, D. R. (1980). An analysis of connected speech samples of aphasic and normal speakers. Journal of Speech and Hearing Disorders,45,27-36.

Subject Index