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PÓS-GRADUAÇÃO EM LETRAS / INGLÊS E LITERATURA CORRESPONDENTE

THE PROCESS OF INFERENCE MAKING IN READING COMPREHENSION: AN ERP ANALYSIS

LUCIANE BARETTA

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José Luiz Meurer
Coordenador do Programa

BANCA EXAMINADORA:

Lêda Maria Braga Tomitch
Orientadora e Presidente

Karen Elisabeth Waldie
Examinadora

Márcia Zimmer
Examinadora

Rosângela Gabriel
Examinadora

Ana Cláudia de Souza
Examinadora

Celso Soufen Tumolo
Examinador

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To my family for the support

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ABSTRACT

The process of inference making in reading comprehension: an ERP analysis

Luciane Baretta

UNIVERSIDADE FEDERAL DE SANTA CATARINA
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Supervising Professor:

Lêda Maria Braga Tomitch, PhD

Much of recent research on discourse comprehension has centered on the readers' ability to construct coherent mental representations of texts. In order to form a unified representation of a given text, a reader must be able to join the information presented in the text with his background knowledge to construe the meaning that may not be explicitly stated in the text, through the generation of inferences. In this is study, the process of inference making by native speakers of English while reading two different types of text was investigated, using Electroencephalography (EEG). Subjects read narrative and expository paragraphs, and judged the plausibility of the final sentence of each four-sentence long paragraph by reference to the previous information. The analysis of data focused on two ERP (Event-related brain potential) components, the N1 and the N400 and on accuracy of behavioral responses. N400 amplitudes revealed that exposition was more demanding than narration in terms of semantic processing, whereas behavioral data showed that subjects were more prone to generate inferences when reading exposition. Concerning the involvement of the right and left hemispheres in the process of inference making, there were no significant differences in terms of the ERPs amplitudes, although the right hemisphere showed a tendency for greater participation when subjects were reading the last sentence of the paragraphs and had to judge whether this sentence was coherent to the previous sentences. Overall, this study suggests that the two types of text investigated are processed differently by the brain, as revealed by the nuances showed in the N1 and N400 components across the two last sentences of the paragraphs. Even though it was not possible to delineate a clear picture in terms of brain processes, given the lack of robust results, this study might be the first of many steps towards a complete understanding of the cognitive processes involved in discourse comprehension.

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RESUMO

Pesquisas recentes na área de compreensão textual têm enfocado a habilidade dos leitores em construir uma representação mental coerente daquilo que lêem. Para que a representação uniforme de um texto seja obtida, o leitor deve ser capaz de compilar as informações presentes no texto com o seu conhecimento prévio para a construção do significado - que pode não estar explícito -, através do processo de inferência. Nesse estudo, o processo de inferência foi investigado mediante a leitura de dois tipos diferentes de texto, por meio da utilização da eletroencefalografia (EEG). Os sujeitos, falantes nativos do inglês, leram parágrafos expositivos e narrativos, e julgaram a plausibilidade da sentença final de cada parágrafo, tendo como referência, a informação das três sentenças anteriores. A análise dos resultados enfocou dois potenciais relacionados a eventos (ERPs): os componentes N1 e N400, e a acuidade nas respostas comportamentais. As amplitudes do N400 revelaram que o texto expositivo exigiu mais dos sujeitos em termos de processamento semântico, enquanto que as respostas comportamentais mostraram que os sujeitos tiveram uma tendência maior a gerar inferências enquanto liam esse mesmo tipo de texto. Com relação ao envolvimento dos hemisférios esquerdo e direito no processo de inferência, não houve diferenças significativas em relação à amplitude dos ERPs, embora o hemisfério direito tenha se mostrado mais participativo no momento em que os sujeitos liam a última sentença dos parágrafos, e tinham que julgar se a mesma era

coerente com as sentenças anteriores. No geral, esse estudo sugere que os dois tipos de texto são processados diferentemente pelo cérebro, conforme demonstrado pelas nuances dos componentes N1 e N400, gerados durante a leitura das duas últimas sentenças de cada parágrafo. Embora não tenha sido possível uma clara visualização com relação aos processos cerebrais subjacentes ao processo de inferência, em função dos resultados pouco robustos, o presente estudo contribui como mais um dos primeiros passos a serem dados no longo caminho, até que uma compreensão mais detalhada dos processos cognitivos inerentes à compreensão textual seja alcançada.

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CHAPTER 1

INTRODUCTION

The issue of what goes on in the reader's brain, from the focusing of the eyes on the printed page until comprehension is achieved, is a topic that has been the focus of much research and debate. Behavioral studies and, more recently, the use of brain-activation measures have shown that the variables of readers' characteristics, types of texts, reading purpose, subsequent task of reading comprehension and language: native or foreign, do influence the way one approaches a text.

Despite these variables, it is common ground in the discourse comprehension literature that when reading a text, one has to construct a mental representation of it through the integration of information across sentences (e.g., Kintsch & van Dijk, 1978; Graesser and collaborators, 1993; 1995; 2001; van den Broek, Risden & Husebye-Hartman, 1995, among many others). This mental representation is thought to be the final product of the text-based information and the reader's background knowledge, which is achieved through the generation of inferences.

According to Zwaan and Singer (2003), almost every aspect involved in comprehension is to some extent inferential. It is well known that people cannot speak or write fully explicitly everything they intend to communicate. Therefore, speakers and writers rely on their audiences' ability to determine the intended message by filling the gaps that may exist through the process of inference making.

In the specific case of reading, text comprehension researchers have been challenged in trying to answer which inferences readers can be counted on to reliably draw. This is mostly guided by the fact that, unlike listening to someone talk, readers cannot ask for clarifications from the author(s) and the message may not be correctly understood. Therefore, knowing which inferences are routinely drawn while one is reading a text will not only help writers to write better texts, but also educators and linguists to design more adequate reading instruction materials, and discourse comprehension researchers to better envision a general model of language comprehension.

Research on inferencing has been one of the central issues in psycholinguistics and other related areas (e.g., computational linguistics, text linguistics, discourse psychology) for the past thirty years (Singer, 1995; Zwaan & Singer, 2003). Although this issue is still in its infancy in the history of discourse comprehension research, there is a large number of paradigms and times (during, immediately after, or long after reading) that have been used to study the process of inference making. According to Keenan, Potts, Golding and Jennings (1990) these methods to detect inference making can roughly be divided into two categories: memory and activation measures. Memory measures, as the name already suggests, require readers to retrieve the text representation from memory to check if inferences were made and are part of the representation of the text. They can be subdivided into cued recall, sentence verification, question-answering, and recognition measures. Activation measures, on the other hand, are used to measure the availability (or the activation level) of information to readers as they process the text. Examples of these measures are reading time (or gaze duration), naming, lexical decision, and modified Stroop task.

More recently, thanks to the evolution of technology, the category of activation measures mentioned by Keenan et al. can be subdivided into brain-activation measures. The use of technological tools such as Electroencephalogram (EEG), Positron-Emission Tomography (PET), functional Magnetic Ressonance Imaging (fMRI) and Near-Infrared Spectroscopy (NIRS), - see a brief introduction to these tools below - is quite recent, but the few studies developed at the level of discourse provide evidence that these tools are reliable to help us understand how the brain processes a text and consequently, how inferences are made. In fact, as will be reviewed in Chapter 2, there are only four studies – to my knowledge – that investigated the process of inference making in the brain.

The aim of the present study is twofold: (1) to investigate the issue of inference making using Electroencephalography (EEG), with native speakers in order to verify the possible differences in terms of brain process, that is to say right versus left hemisphere involvement, while reading two different types of texts, namely exposition and narration, and (2) to investigate the patterns of behavioral response (accuracy) in relation to the process of bridging inference across these two types of text. The comparison of the results may provide insights concerning the nature of the cognitive processes that underlie inference making across different types of texts.

1.1 STATEMENT OF THE PROBLEM

There has been considerable controversy among researchers over matters of inference generation. Questions regarding the types and frequency of inferences that are generated online or during a later task, the sources of information that are necessary to elicit them, and the set of cognitive processes that are involved during their generation, are some of the spirited topics that have stimulated discourse psychologists and linguists, to understand how readers construct situation models.

Inference generation studies that used the narrative type of text as stimuli abound in the literature. Little is known about the process of inference making in expository texts. Moreover, from the few studies that considered exposition to investigate inference making, there are even fewer that have compared the effects that narration and exposition have on the generation of inferred information. Therefore, there is a need of studies to investigate to what extent different types of text influence cognitive process across the two hemispheres. Clinical and brain lesion literature, and more recently, neuroimaging evidence, suggest that the right hemisphere (RH) is particularly involved in the process of inference generation

(St. George, Kutas, Martines & Sereno, 1999; Mason & Just, 2004; Tomitch, Newman, Carpenter & Just, 2008).

Having this in mind, the main purpose of this study is to investigate how different text types - exposition and narration - influence the process of inference making at the level of discourse. In order to attain this objective, the investigation is divided into behavioral data (accuracy of responses) and EEG data (amplitude of brain waves generated during reading), originated when native speakers of English read four sentence long paragraphs.

1.2 WHAT IS EEG, WHAT ARE ERPs AND HOW ARE THEY RELATED?

There is a variety of non-invasive tools available to researchers to investigate the neural correlates of brain functioning. These methods can be categorized according to the type of information they provide on brain activity: high spatial or temporal resolution (OCDE, 2003).

Among the techniques that have high spatial resolution, there is Positron Emission Tomography (PET scan) and functional Magnetic Resonance Imaging (fMRI). Both of these techniques use radioisotopes to monitor the increase of the blood flow, glucose and oxygenation in brain areas, assuming that those areas are involved in the performance of a given cognitive task, such as reading (Tomitch, Just & Newman, 2004; Just, 2006, personal communication). A lesser-known technology: the near-infrared spectroscopy (NIRS), although presenting reasonable spatial resolution, has excellent temporal sensitivity when compared to fMRI (Scherer, 2007); this tool has being considered a good alternative for behavioral studies, for its optical fibers allow a subject to move while performing a task.

The techniques that provide high temporal resolution are magnetoencephalography (MEG), which registers the magnetic fields produced by neuronal activity, and electroencephalogram (EEG), which records the electrical brain activity. Given the fact that this research used EEG to study the neuronal correlates involved in the process of inference making, let us discuss this method a bit further.

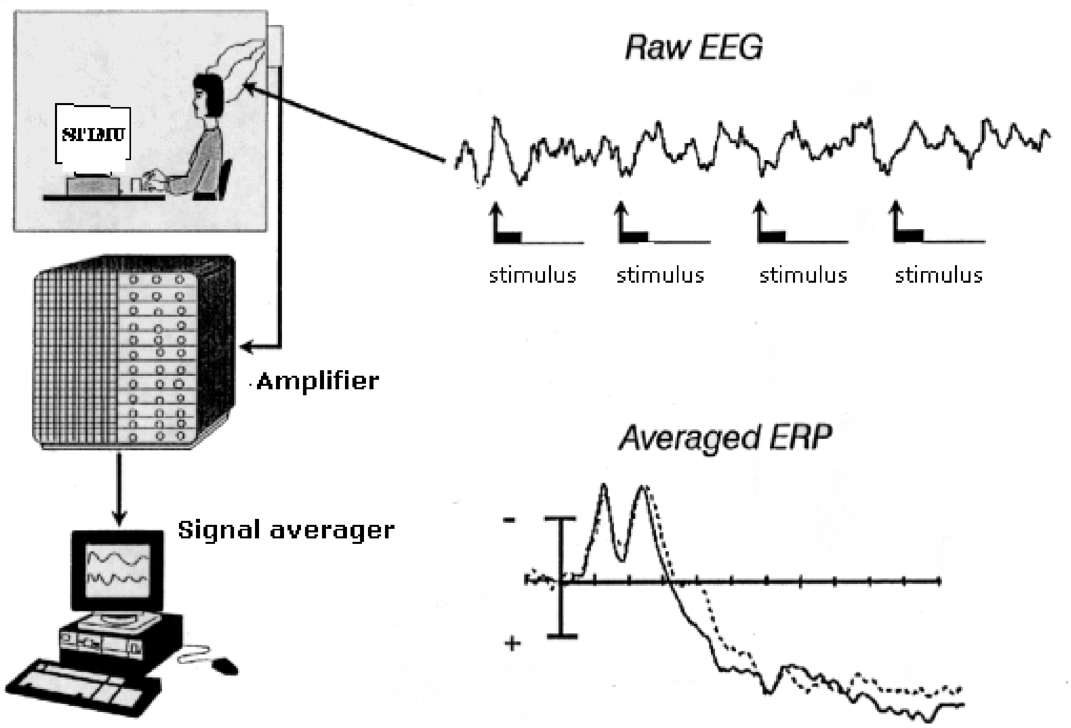
EEG stands for Electroencephalogram or Electroencephalography. Traditionally, this tool has been associated with clinical use (e.g., brain disorder diagnostics, such as epilepsy and sleep disturbances), but advances in technologies have provided researchers the possibility of measuring brain activity associated with sensory and cognitive functioning by a different recording of electrical activity, the ERP. Each one of these will be discussed further.

Basically, EEG records the electrical activity of the brain considering the fact that transmission of information in the brain occurs through the flow of ions. Although the activity produced by a single neuron is only detected through intracranial recording, a larger population of neighboring neurons generate voltage fluctuation fields that can be detected from the scalp through the use of electrodes (see Figure 1 below). This makes the EEG a non-intrusive technique to investigate on-going processing (Kutas & van Petten, 1994; Coles & Rugg, 1995). These voltage fluctuations produce traces of EEG which mirror the spontaneous electrical activity of the brain across time. The EEG gives good information about the general mental state (e.g., relaxed, alert, awake, sleeping) of a person. However, raw EEG is not sensitive enough to detect fine-grained changes in mental activity, such as the cognitive processes involved in discourse comprehension (Brown & Haggort, 2000; Kutas & Schmitt, 2003).

Figure 1 – Subject ready for EEG recording

For this reason, a different aspect of the scalp-recorded activity, namely ERP (event-related brain potential) has been developed to obtain an estimate of activity which is time-locked or synchronized to some external stimuli or event, like reading a word, listening to a tune or seeing a picture. The ERP signal is relatively weak (5-10 μV) when compared to the noisy EEG signal (50-100 μV); therefore, it is necessary to extract the former from the latter by an averaging procedure. This is done by time-locking multiple trials of EEG traces which are then averaged to eliminate the spontaneous (noisy EEG) activity and to maintain the event-related brain activity (Coles & Rugg, 1995; see Figure 2 below).

Figure 2 – ERP data collection and averaging (adapted from Kutas & Schmitt, 2003)



EEG has been used in a considerable number of language studies for the past years (e.g., Kutas & Hillyard, 1984; Raney, 1993; St. George, 1995; Federmeier & Kutas, 1999; Coulson & van Petten, 2002; Federmeier, May & Kutas, 2005, and others). As seen previously, EEG does not have a high spatial resolution when compared to other neuroimaging tools. Nonetheless, despite this, there are several advantages for using this technique:

- EEG / ERPs provide a continuous, real measure of the process under investigation for it can be recorded in synchrony with events of interest. In the case of reading comprehension for example, every word may elicit an ERP - given it is time-locked - so as the researcher can analyze and distinguish the various processes involved in sentence comprehension, from early perceptual processes to later cognitive processes (Brown & Haggort, 2000);
- A single experiment can provide different levels of analysis, for instance: semantic context, word frequency, and word repetition, given that stimulus is appropriately coded (Kutas & van Petten, 1994);
- No extraneous task demands are necessary, therefore contamination due to tasks effects (e.g., lexical decision) can be avoided;
- EEG recording is relatively cheap when compared to fMRI.

The technique has some drawbacks. The first one, already mentioned above, is its restricted spatial resolution, but this can be compensated with the use of other software. A second disadvantage is the limitation for motor activity: excessive eye blinks, tongue movements, facial muscle activity and movement in general, must be avoided because they obscure EEG recording. Another disadvantage is the time required for preparing the subject for EEG recording and the number of trials necessary to get a consistent averaged waveform; the longer a session is, the higher the effects of tiredness and lack of motivation.

1.3 OBJECTIVES AND HYPOTHESES

The main objective of the present dissertation is to investigate, through the use of EEG, the cognitive processes and the neural correlates that underline reading comprehension, specifically the process of inference making, as subjects read expository and narrative types of text. This objective is subdivided into three segments.

First, the scalp areas underlying the process of bridging inference generated by readers as they approach exposition and narration will be compared in order to investigate possible differences in terms of right hemisphere (RH) involvement. Second, the processing of inference generation of higher and lower span readers will be compared across text types to examine the influence of working memory capacity on this crucial aspect of reading comprehension. Finally, the accuracy of behavioral responses will be compared regarding the type of text and working memory capacity.

1.3.1 Hypotheses

The hypotheses are presented by type of data (behavioral and electrophysiological) and they refer to the expected performance of the fourteen native English-speaking subjects of this study in the experiment carried out in this dissertation.

Hypotheses related to behavioral results

Hypothesis 1: Given the evidence provided by the literature that narration is easier to understand than exposition, it is expected that readers will have a higher percentage of accurate responses when judging the suitability/unsuitability of the final sentence of narrative paragraphs.

Hypothesis 2: Higher span readers will have a higher percentage of accurate responses when judging the suitability/unsuitability of the final sentence of both expository and narrative paragraphs.

Hypotheses related to EEG data

Hypothesis 3: Again, given the evidence presented by the literature, it is expected that readers will generate inferences more easily in the narrative type of text, as revealed by small N400 amplitudes.

<ins>Hypothesis 4:</ins> Higher span readers will generate inferences more easily than lower span readers in the expository type of text, as revealed by small N400 amplitudes.

<ins>Hypothesis 5:</ins> The RH will be more involved in the process of inference making, as revealed by high N400 and / or lower N1 amplitudes, particularly in the expository type of text.

1.4 SIGNIFICANCE OF THE STUDY

As already stated in the first paragraphs of this introduction, knowledge about which inferences are routinely drawn while one is reading a text may be helpful not only for educators and writers, but also to other domain areas, such as discourse comprehension, text and computational linguistics, psycholinguistics, artificial intelligence, philosophy of mind, and others. Investigation concerning the neural correlates involved in the process of "putting the words together" while reading expository and narrative texts may provide us with a better understanding of the underlying processes involved in reading by bringing evidence on how readers generate bridging inferences when reading different types of texts. Furthermore, as reported by brain lesion literature, the RH seems to be particularly more involved in the generation of inferences (Beeman, 1993;

Raimundo, 2004). The electrophysiological data of this study may add further evidence for such studies.

Besides the above-mentioned contributions of the study presented in this dissertation, the present research attempts to expand previous research in the following ways:

- there is no brain imaging study – to my knowledge – that has investigated the relationship between working memory capacity and the process of inference making across the hemispheres; St. George (1995) investigated only five scalp sites while Virtue, Haberman, Clancy, Parrish & Jung-Beeman (2006) worked with a listening paradigm;
- there are few behavioral and no brain imaging studies – to my knowledge – that have compared the process of inference making in two different types of texts.

Therefore, the development of this study may be relevant for investigating a core process in our everyday routine, the process of inference making in reading through the use of a technological tool. As already pointed out, studies in this area are reduced, and the present research expects to contribute to a better understanding of the intricate process of reading comprehension.

1.5 ORGANIZATION OF THE DISSERTATION

In order to attain the objectives pursued in this study, this dissertation has been organized in five chapters.

In chapter 1, the main focus of this study, namely, the process of inference generation, is introduced. The importance, purposes and hypotheses of the study are presented together with an overview of the electrophysiological tool adopted to investigate inference generation.

Chapter 2 presents the review of the literature concerned with the process of inference making, memory, language and the brain. The chapter opens with the definition and presentation of the different types of inferences and the factors that may influence their generation. Next, the different types and forms of memory, particularly the working memory construct are presented and the intricate relationship between memory and language comprehension is discussed in the light of empirical data. Finally, an overview on the hemispheric contributions to the processing of discourse is presented and followed by studies that used advanced tools to investigate the process of language comprehension, particularly the process of inference making.

Chapter 3 describes the methods adopted in the present study, conducted at the Center for Cognitive Neuroscience at The University of Auckland in New Zealand. This chapter describes the subjects, the materials, the parameters adopted for EEG recording, as well as the procedures for data collection and analysis.

Chapter 4 presents and discusses the results generated by the behavioral and EEG data.

Lastly, in chapter five, some final considerations, the limitations of the study, and suggestions for further research are discussed.

CHAPTER 2

REVIEW OF THE LITERATURE

This chapter presents the review of the literature concerning the issues involved in this research: the process of inference making, working memory capacity and the brain. In the first part, the importance of inference making for reading comprehension will be discussed, followed by an overview on the different types of inferences and what factors may be involved in their generation. Next, the neurophysiology of memory will be presented with an emphasis on the working memory construct and how it relates to language and the process of inference making. Finally, some issues related to brain functions and its hemispheric contributions for language processing are discussed and a review of recent studies that adopted technological tools to investigate the process of discourse comprehension and inference making will be presented.

2.1 READING COMPREHENSION AND INFERENCE MAKING

Recent research on discourse comprehension[1] has focused on the reader's

[1] The terms *text* and *discourse* comprehension will be used interchangeably in this dissertation to refer to language beyond the sentence. That is to say the study of any set of utterances/sentences as part of a context of use (McCarthy, 2001), as traditionally used in the cognitive psychology literature.

ability to construct coherent mental representations of texts. This mental representation is thought to be a “joint product” (Whitney, Ritchie & Clark, 1991) of the information presented in the text and the reader’s general knowledge in long-term memory (Kintsch & van Dijk, 1978; van Dijk & Kintsch, 1983; Gernsbacher, 1990; 1997; Suh & Trabasso, 1993; O’Brien, 1995; van den Broek, Risden & Husebye-Hartmann, 1995; Halldorson & Singer, 2002; van den Broek, Risden, Fletcher, & Turlow, 1999). Therefore, in order to form a unified, coherent representation of a given text, a reader must be able to join the information presented in the text with his background knowledge to construe the meaning that is not explicitly stated in the text, through the generation of inferences (Kintsch & van Dijk, 1978; Noordman & Vonk, 1992; Suh & Trabasso, 1993; Gernsbacher, 1997, van den Broek et al. 1999). This process of inference making is a cornerstone of reading competence and as such, several aspects of the inferencing process have been considered in the last three decades of research, including the quantity and types of inferences readers make and the circumstances involved in it.

But what is inferencing? At a general level, inferencing may be equated to reasoning since it is a cognitive process that is part of our everyday experiences (Winne, Graham & Prock, 1993). For example, when a new computer program is used for the first time, one has to activate from long-term memory the steps involved in operating a computer and infer differences and similarities between the new program and what is known about other programs. Similarly, when we have friends over and have to make coffee for more people than the usual, we are able to infer that as we need more water, we will need to add more coffee; otherwise it will be too weak. As we can notice, these simple examples demonstrate that the process of inference-making is not an obscure, difficult task that is only contingent upon the acts of reading; in fact, it is part of our everyday routine.

In the realms of language comprehension, the term refers to “any information about events, relations, and so on that the reader [or speaker] adds to the information that is explicitly presented” in discourse (van den Broek et al., 1995, p. 353). For instance, when reading:

Jane left early for the party. She spent an hour shopping at the mall.

(from Shears & Chiarello, 2004), most readers are able to infer that Jane decided to leave earlier to get something for the party, which is possibly a birthday gift. The ability to draw inferences in reading comprehension is, therefore, a constructive cognitive process in which the reader strives for meaning and expands knowledge by formulating and evaluating hypotheses about the information of the text.

The act of inferencing in text understanding is paramount because it makes possible for readers to establish a meaning representation of the text in memory on the basis of its coherence relations and the readers’ general knowledge (van Dijk & Kintsch, 1983; Noordmann & Vonk, 1992; Trabasso & Magliano, 1996; Long, Oppy & Seely, 1997; Gernsbacher, 1990; 1997; Magliano, Trabasso &

Graesser, 1999; Halldorson & Singer, 2002; Linderholm, 2002, among others). Hence, if readers fail to execute processes that integrate different portions of a text and to make inferences based on their general knowledge to elaborate on the text representation, they may feel that they have not understood the text and present difficulties in remembering it (Trabasso, & Suh, 1993; Trabasso, Suh, Payton & Jain, 1995; Long, Oppy & Seely, 1997; Horiba, 2000; Linderholm & van den Broek, 2002).

Recent research has sought to identify and categorize the type, number, function and frequency of inferences that are generated while one understands a text (Graesser, Wiemer-Hastings & Wiemer-Hastings, 2001). Nevertheless, as highlighted by Léon (2001), this endeavor has not been simple, given the fact that most of the cognitive processing involved in any reading situation occurs automatically and in a fast manner. Having this in mind, one can understand why there is such a diversity of models for text comprehension and, consequently, different proposals for the classification of inferences, as it will be presented as follows.

Some researchers distinguish inferences by the *type of function* they exert on discourse, that is, to establish local or global coherence (Graesser & Kreuz, 1993; van den Broek et al., 1995, O'Brien & Myers, 1999; Graesser et al., 2001). Other investigators have considered the *automaticity* and the *speed* in which inferences are generated, establishing that they are either generated *on-line* because they are obligatory for comprehension to be attained, which is the case of the so-called *bridging* inferences; or *off-line*, representing the so-called *elaborative* inferences, which are often referred as optional for comprehension (McKoon & Ratcliff, 1992; Singer, Andrusiak, Reisdorf & Black, 1992; O'Brien, 1995; St. George, Mannes & Hoffmann, 1997; Iza & Ezquerro, 2000).

Another classification that is frequently addressed in the literature regards the *explanations* for causal relations in the text, dividing inferences into two other classes: *forward* (or predictive) and *backward* inferences (Daneman & Carpenter, 1980; Trabasso & Suh, 1993; Linderholm, 2002). Forward inferences refer to the anticipation of events which are made by the reader based on focal information; backward inferences, on the other hand, are related to previous read information (e.g., a pronoun referent, the instrument used for doing something) which is necessary for the comprehension of a focal sentence.

The classifications presented above are not exhaustive. More detailed taxonomies are proposed in the literature (e.g., Graesser & Kreuz, 1993; Singer, 1995; Graesser, Bertus & Magliano, 1995). Graesser and Kreuz (1993), for example, nominate eleven different classes of inferences, which were categorized according to their content, their relation to the text and the background knowledge involved in reading a parable (for the visualization of this taxonomy, see Graesser & Kreuz, 1993, p. 148-149). Although there are other categorizations for the classes of inferences proposed in the literature, they will not be addressed here, given the fact that the present research will concentrate on one class of inference, the bridging type of inference. The following is the definition that will be considered throughout this study.

As briefly stated above, *bridging inferences* refer to those inferences that are generated quite automatically, require few processing resources and are crucial for comprehension (Keenan et al., 1990; Singer, Andrusiak, Reisdorf & Black, 1992; Zwaan & Singer, 2003, among others). Therefore, understanding the sequence:

a. Beverly ate a lot of candy.

b. The dentist found that she had five cavities.

(from Singer, 1995), depends on the reader's detection that sugar causes tooth decay. Even though sentence (a) does not mention the word "sugar", the reader can draw on world knowledge that candies are made of sugar and that this is the cause for Beverly's cavities. It is by identifying the connections between the two sentences, that bridging inferences preserve text coherence. If this "bridge" is not drawn by the reader, simple texts like the one just cited above, would sound disconnected and incoherent.

Evidence derived from different measures indicates that bridging inferences usually come hand in hand with comprehension. Trabasso and Magliano (1996) and Zwaan and Brown (1996), for instance, used the think-aloud paradigm and found that understanding the sentences of a narrative text is for the most part, guided by the generation of bridging inferences[2].

[2] The authors used another terminology for bridging inference, i.e., explanation/explanatory inference. By its definition, explanation inference serves to join the current sentence with either text information or reader's prior knowledge (Trabasso & Magliano, 1996, p.259). Therefore, it is assumed that explanation/bridging inferences are synonyms.

Millis and Graesser (1994) used short scientific texts presented via a rapid serial visual presentation and a lexical decision task (inference words, unrelated words and nonwords) to investigate whether readers routinely draw causal antecedents and causal consequences inferences. Results demonstrate that for the most part, readers generated causal antecedent but not causal consequences while reading the texts, which is in agreement with previous studies using narration, such as the studies of Trabasso and Magliano (1996) and Zwaan and Brown (1996) mentioned above.

Beeman, Bowden and Gernsbacher (2000) investigated through the lexical decision task, hemispheric differences in the processing of predictive and coherence (or bridging) inferences. Subjects listened to stories that promoted inferences, and during this task they had to stare at a computer screen for reading aloud visually presented words (to left visual field–right hemisphere or right visual field–left hemisphere) at random intervals. Results showed that the right hemisphere is more involved in the generation of predictive inference whereas the left hemisphere shows a greater involvement for coherence (bridging) inferences. Results also demonstrated that both hemispheres are equally involved at the resolution point of the stories, suggesting therefore, that both hemispheres are involved in the process of inference making.

More recently, Schmallhofer, Friese, Pietruska, Raabe and Rutschmann (2005) used Functional Magnetic Ressonance Imaging (fMRI) to explore the brain processes involved in the coherence relations among sentences. Analysis of data demonstrated that superior and prefrontal brain regions form a network that is consistently involved to cope with the demands imposed by the task of inference making. Besides this study, there are other researchers that used a technological tool to investigate how inference making is processed in the brain; these studies will be approached in section 2.3.2.

The studies presented above represent just a fraction of the innumerous studies on inference generation that have been carried out during the last three decades. Even though researchers tend to agree that bridging inferences are reliably drawn by comprehenders - and this is shared by the present investigation - (Kintsch & van Dijk, 1978; Johnson-Laird, 1983; McKoon & Ratcliff, 1992; Graesser & Kreuz, 1993; Beeman, Bowden & Gernsbacher, 2000; Zwaan & Singer, 2003, among others), the establishment of the different facts that determine the process of inference making during the comprehension of discourse is still an open debate. This is the topic that will be discussed in the following paragraphs of this review of literature.

2.1.1 What determines inference making?

Evidence concerning the nature and the extent of inferences that are generated on-line (during the course of comprehension) or off-line (during a later task) has been mixed (Graesser & Kreuz, 1993; O'Brien, 1995; van Den Broek, Risden & Husebye-Hartmann, 1995; Wiley & Myers, 2003; Allbritton, 2004). Researchers nowadays have begun to explore what factors may explain such conflicting results. One of these factors concerns the question of what determines the inference making process during text understanding.

In general terms, there are two contrasting views regarding the process of inference making in the literature: the constructionist and the minimalist position. The *constructionist* position, taken by most researchers in the discourse comprehension area, establishes that readers make inferences about the causes of events and the relationship among them. When reading a story, for instance, the reader makes inferences to construct a "microworld" of the events presented in the text based on his everyday experiences in the physical and social world (Graesser & Kreuz, 1993; Graesser et al., 2001). This position is considered constructionist because the reader is constantly striving for meaning and for the integration of information at both local and global levels of discourse (O'Brien & Myers, 1999).

The *minimalist* position, on the other hand, argues that readers are mainly concerned with maintaining local coherence; if the text is locally coherent, no connections are made with earlier portions of the text nor is the activation of relevant background knowledge needed. This view is seen as minimalist because the reader assumes a passive role in assessing the information clearly stated in the text. According to this view, inferences are only generated when there is a coherence break, forcing the reader to institute a search for additional information (O'Brien & Myers, 1999). This proposal, which has its main advocates in McKoon and Ratcliff (1992), has generated many criticisms from theoreticians and researchers, mainly due to its reductionist view of the processes involved in language comprehension (Kintsch, 1998).

The distinction between the constructionist and the minimalist positions for inference generation has certainly contributed a great deal to our understanding about the role of inferencing in text understanding, since several studies have been carried out in order to support either of these views. Despite this fact, research has also shown that there is no simple answer to explain which inferences are necessary and which are normally generated during text comprehension (Wiley & Myers, 2003). In addition, different factors have been highlighted by different researchers as the "triggers" for inference generation. Let us consider some of the current proposals.

Van den Broek, Risden and Husebye-Hartmann (1995) for instance, propose that readers make inferences in order to create a mental representation of textual information that is coherent with their particular "standards of coherence". In this way, it is the readers' standards for causal coherence that determine whether they feel that comprehension is achieved or that additional inferences are necessary. Hence, a reader has comprehended an event when, according to his knowledge, this event has received sufficient causal explanation from preceding events; local coherence is, then, achieved. Nevertheless, if the reader notices a gap between the focal sentence and previous events (or cycles, in Kintsch & van Dijk's (1978) terms) further inferences are needed in order to suffice the cause of the current event. These inferences, in turn, are based on two sources of activation: (1) the reader's memory of previously read events that are suppressed and/or (2) the reader's background knowledge which refers to information not presented in the text. Thus, if the enhanced information contributes to the strength of activation of the current event, one or more global relations are established, comprehension is successful and the reader can then, proceed in reading. Therefore, according to van den Broek et al. (1995), the standards of coherence that readers adopt[3] and the constraints pertinent to the text determine whether local or global inferences are generated during the reading process (see also Long, Seely, Oppy & Golding, 1996 and Trabasso, Suh, Payton & Jain, 1995, for a similar view).

Taking a schema theory perspective, several researchers have argued that the comprehension of a text is dependent on the generation of inferences that integrate the textual propositions with the readers' background knowledge (Noordman & Vonk, 1992; Fincher-Kiefer, 1992; Singer, 1995; Halldorson & Singer, 2002). According to these authors, when the inferred information is part of the readers' background knowledge, it is easily integrated into the text; on the other hand, when information is not familiar, readers have to evaluate the plausibility of the generated inference against the information already presented in the text. Therefore, in order to accept that

Dorothy poured the bucket of water on the bonfire. The fire went out.

(Singer, 1995), as a plausible statement, readers must be able to: (a) understand that the first sentence caused the effect reported in the second and (b) validate that

[3] According to the authors, comprehenders may be aware of their standards of coherence when reading a text – when for instance, one is reading an article for further presentation - but traditionally, the standards will be implicit, guiding the readers' attainment of comprehension without their awareness.

‘water extinguishes fire’ with reference to their knowledge of the world. If this information conforms to the readers’ knowledge, the inference is validated, integrated into the text and reading proceeds. If not, readers must evaluate the plausibility of the inference in terms of the information provided by the different portions of text.

Having in mind the influence of background knowledge in inferencing, Noordman and Vonk (1992) propose that the inferences people draw during reading may be approached from two perspectives: in terms of the interactions between textual propositions and in terms of the textual proposition relations and the world. According to these authors, the mental representation constructed during the reading of a text “can be described in terms of the relation between the elements in the representation as well as in terms of the relation of the representation to (a model of) the world” (p. 374). As argued by these researchers, most inference making investigations have confounded these two perspectives and few investigators have considered the influence of readers’ pertinent knowledge on the process of inferencing, which according to them, is an important factor in controlling this process.

Nonetheless, Noordman and Vonk point out that if the information necessary to draw the inference is not part of the reader’s background knowledge, this does not necessarily mean that it cannot be made. As demonstrated in one of their experiments where readers had to infer the causal relations in ‘because’ sentences, such as

Connors used Kevlar sails because he expected little wind. (p. 377)

it was noticed that, after reading the text, readers took longer to verify the statements that had to be inferred during reading but that were not explicitly stated. That is to say, in the explicit condition, the target sentence was preceded by *Kevlar sails are advantageous when the weather is calm,* providing the reader with the background knowledge necessary to infer the use of Kevlar sails in the subsequent sentence. When verifying the statements related to the explicit condition, readers were faster and more accurate in their decisions than when verifying the statements related to the *implicit* condition, i.e., when the information about Kevlar sails was not present in the text. Therefore, the authors assumed that in the implicit condition the inferences were made after reading and probably only because readers were requested to check them in the verification task (Noordman & Vonk, 1992, p. 379). As seems to be the case in many reading situations, when background knowledge is somehow faulty, readers tend to simply accept the causal relation expressed by the sentence because the writer says so, as demonstrated by the similar reading times of both explicit/implicit condition in this experiment.

In a different line of thought, some recent studies have suggested that it is the reader's strategic control, in addition to textual properties that influence the type and frequency of inferences. When Narvaez, van den Broek and Ruiz (1999) asked readers to read two texts aloud and two texts silently under different reading conditions (for entertainment and for study), they observed that reading purpose did not influence the reader's comprehension product (answers to comprehension questions), but did influence their on-line behavior (evaluated through think-aloud methodology). In general, readers with a study purpose were more prone to repeat, evaluate and indicate knowledge-coherence breaks than their counterparts in the entertainment condition. Furthermore, when reading expository texts, readers tended to generate more associations, repetitions, evaluations and more indications of knowledge-based coherence breaks, independent of the reading instruction (p. 493). Similar findings were reported by Magliano, Trabasso and Graesser (1999) who instructed readers to either explain, predict, associate or understand. These authors observe that depending on the reading instruction, readers produced inferences that were consistent with their goals and assessed the kind of information (prior context or world knowledge) necessary to make those inferences. Nonetheless, results also indicated that trade-offs occurred as a result of strategic processing, that is, an increase in explanations led to a decrease in predictions and vice-versa. This factor was highlighted by the researchers who suggested that further investigations are necessary "to assess the extent to which reading strategies hinder readers from generating inferences that are essential for deep understanding (e.g., explanations)" (p. 626). The study of Horiba (2000) may shed some light on this issue.

In an investigation with native and nonnative readers of Japanese, Horiba studied the effects of two text types (essays and stories) under two different reading conditions: read freely and read for coherence. In agreement with the studies of Narvaez et al. (1999) and Magliano et al. (1999) addressed above, native readers demonstrated having good control over their own processing to engage in different tasks, i.e., read an essay or a story freely or for coherence. Contrary to the author's prediction, however, native readers recalled quite similar type and quantity of information under the two reading conditions, a fact that is explained by the type of expository text used in the study. As for the nonnative readers, results demonstrated that, on the whole, they did not process essays any differently when reading for coherence than when reading freely; nevertheless, some readers demonstrated a tendency to attend to text structural cues and connections between sentences[4]. This observation was in fact, reflected on the readers' recall in the "read for coherence" which was better than in the "read freely" condition. Therefore, as demonstrated by the study of Horiba (2000) and as suggested by Magliano, Trabasso and Graesser (1999), readers' strategic processing in terms of the inferences generated seem to have some impact on the understanding of some text types, as measured by the recall task. Future studies, as already suggested by Magliano et al., are needed before stronger conclusions can be drawn.

Finally, in an attempt to conciliate the assumptions regarding the factors involved in inference making process and to refine the claims related to the aspects of cognitive representations that are built on-line, Graesser and Kreuz (1993) propose a four-component constructionist theory of inference generation. According to the theory, the continuum of inference activation can be attributed to fluctuations of different factors, such as readers' goals and abilities, nature of the

[4] The author observes that it is possible that nonnative readers were not able to verbalize all their thoughts in the read for coherence condition due to their extra effort in integrating sentences (p. 256).

text, and readers' world knowledge (Graesser & Kreuz, 1993). In this way, depending on the reading situation as a whole, different types of inferences will be drawn. As the authors explain, when one reads a text, s/he does that for a particular purpose and this purpose is mediated in the form of questions that are addressed through the generation of inferences.

For example, when skimming a weekly magazine, one might be interested in just checking what is going on in the world or in just looking for an explanation about the current economic crisis in the country, differently from a news reporter, who will probably read those texts more attentively because he has more complex questions to answer due to the demands imposed by his job. The same would occur when readers approach different types of texts. According to the model, readers generate more inferences when reading narratives than when reading exposition since they are more prone to look for answers that explain why characters perform actions and why involuntary events occur than to 'constancies' involved in exposition[5]. Lastly, the model establishes that local coherence will be pursued if the reader is conscientiously striving for meaning, and inferences including (a) connections among propositions; (b) pronominal reference and (c) causal antecedents are generated. According to the theory, all these inferences are drawn on-line, together with the so-called *activation-based* inferences which are activated by a single world-knowledge structure or by various sources of information.

[5] Nevertheless, recent investigations have shown that this is not so clear-cut. Narvaez, van den Broek and Ruiz (1999) and Horiba (2000) observed that the difference relies more on the type of inferences across these two text types than on the total amount of inferences generated.

The different views regarding the question of what determines the inference making process during text understanding presented here seem to be in agreement on the essential role of memory operations to orchestrate the textual input with the information retrieved from the reader's background knowledge into a meaningful message. Therefore, even though there are disagreements in relation to the factors that enhance long-term memory activations, that is, readers' standards for coherence, reader's background knowledge, readers' control or a fluctuation of these factors, researchers involved in discourse comprehension studies recognize the importance of working memory for the maintenance and storage of information for the generation of inferences and the flow of reading. The next section of this review of literature will address the memory construct with its respective types and forms, aiming at demonstrating how memory is intrinsically related to language comprehension.

2.2 MEMORY AND LANGUAGE

What is memory? This is an enquiry that, together with the understanding of the brain, dates back to early philosophers and continues to intrigue psychologists and neuroscientists nowadays. The first historical reference in psychology starts with Aristotle (Sternberg, 2000; Matlin, 2004), who was the first of the great thinkers to adopt an empirical based natural approach to science and to provide a reasonable account of how memory and learning occur. His ideas are not accepted by modern scholars as a theory of memory, but his contributions have figured in most psychological theories of the 20th century (Ashcraft, 1994).

The scientific investigation of memory per se only began about a hundred years ago with Ebbinghaus's famous study of human memory under rigid control conditions of learning and recall of more than two thousand nonsense syllables by a single subject: himself (Baddeley, 1990; 1999; Matlin, 2004). The importance of his research resides more on the methods he adopted than on the results obtained, since he demonstrated that the study of complex constructs such as memory and learning were possible through the experimental method (Sternberg, 2000).

As a consequence of this new approach to the study of mental faculties, a considerable number of theoretical questions about the underlying mechanisms, functions and nature of memory and its impact on learning and cognition have been pursued by researchers for the last century. Nevertheless, as Cohen, Eysenk and LeVoi (1986) and Baddeley (1990; 1999) point out, much of the research carried out for the past hundred years is somehow simplified and artificially laboratory-based, since researchers were much preoccupied in controlling the variables and in designing experiments that had, after all, little if not any ecological validity.

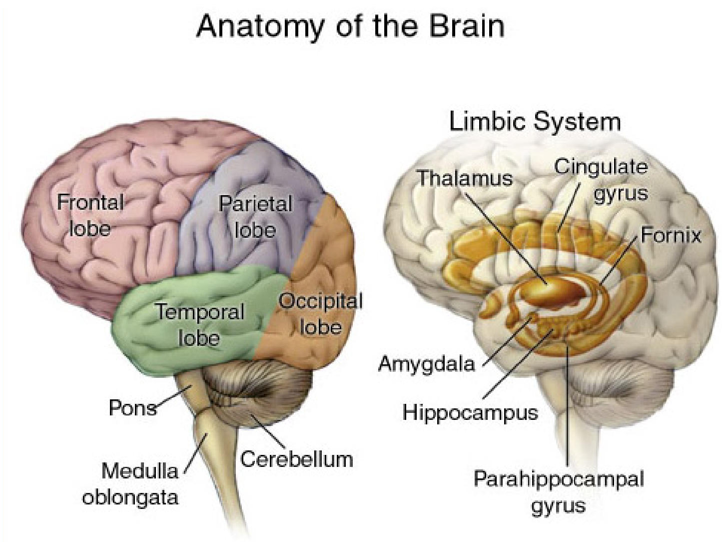
Despite this, the past four decades have witnessed important contributions to the understanding of human memory. Among them, are the studies on the neuropsychology of memory which focus on the identification of the brain areas involved in the storage and in the processes involved to generate memories; the types, forms and models proposed to explain the nature and structure of memory and how this construct relates to language. These are the issues that will be addressed in the following subsections.

2.2.1 The neuropsychology of memory

According to Izquierdo (2002), human and mammals possess similar memories in what concerns the basic mechanisms and nervous areas involved in the creation of memory traces. The only difference between human and animal memories resides in the content: humans are capable of remembering tunes and their respective lyrics, driving a car, making use of language at the age of two or three to acquire, encode, store and retrieve information, whereas no animal is capable of performing any of these tasks. Therefore, with the exception of the language areas, humans use the same brain regions and similar molecular mechanisms to encode and retrieve different kinds of memories.

Nonetheless, although researchers have learnt a lot from studies with different types of animals at the molecular biology and at the neurocognitive levels of analysis, they still know very little about how and where memory functions reside (Squire & Kandel, 2003). In general terms, researchers know that there are several brain structures involved in memory, mainly the hippocampus and other neighboring areas such as the temporal lobe (Sternberg, 2000; Bear, Connors & Paradiso, 2002; Izquierdo, 2002; see Figure 3 below), but they do not know how these structures and substructures interact with other parts of the cortex (Squire & Kandel, 2003). Much of what is known nowadays is related to experiments with animals and to evidence with brain-lesioned humans and the deficits they present in remembering different types of knowledge.

Figure 3 – Anatomy of the Brain
Retrieved Aug. 25, 2008 from: http://www.clas.ufl.edu/users/nholland/sem05/brnpic2-5.htm



Experiments with animals, such as monkeys and laboratory rats which are trained to choose the right stimulus to obtain food, i.e., declarative knowledge[6], demonstrate that there is a decrease in the correct choice after ablation procedures, i.e., the surgical removal of different parts of the medial temporal lobes. Moreover, the wrong choices made by these animals tended to increase proportionally to the time delay between the correct choice of the stimulus and the

[6] Declarative knowledge / memory involves the factual information one is capable of learning in a single trial and that is available for retrieval (sometimes, depending on the content of the information, more than one trial may be necessary) (Searleman & Herrmann, 1994). Knowing that the capital of France is Paris, that water boils at 100ºC, or that a particular face is a famous personality are all examples of declarative memories. Procedural knowledge / memory refers to the kind of information that is related to the 'know how' knowledge of rules and procedures which can become quite automatic with repetition, such as learning to read, riding a bike or swimming (further details about these will be discussed in the section related to the contents of memory).

subsequent trial. The results obtained from such kind of experiments seemed to provide a good model to human amnesia, since they added to a body of studies with amnesic patients (see Baddeley's 1990 book, for an overview of the study of amnesia), demonstrating that lesions in the medial temporal lobes yield deficits in declarative but not procedural knowledge, and that declarative knowledge seemed to be more impaired in terms of the long-term store (Bear, Connors & Paradiso, 2002; Squire & Kandel, 2003).

On the other hand, studies with patients suffering from amnesia reveal that different types of memory – declarative and procedural - are dependent on the efficient functioning of several different brain areas (Baddeley, 1990; Izquierdo, 2002; Squire & Kandel, 2003). As explained by Sternberg (2000), the dissociation of functions observed between normal and brain-damaged patients, that is, a specific function of memory is absent in a patient with a focal brain lesion, whereas it is present in normal individuals, does not necessarily mean that such particular area is the only responsible for the control of a given function. Despite this view, Sternberg presents some preliminary but interesting evidence signaling that specific areas of the brain seem to be more involved than others in several aspects of memory.

First, it seems that different areas of the cortex are responsible for the organized processing of sensory features (visual, spatial and olfactory) of particular experiences; therefore, the cortex may be an important participant for memory, due to the long-term storage of the type of information it helps to coordinate. Furthermore, the hippocampus and its nearby structures tend to be strongly related to declarative information, learning of complex material and in the consolidation of information for long-term storage. Finally, in regards to non-declarative or procedural information, it appears that the basal ganglia and the cerebellum are the main areas responsible for processing this type of information (Sternberg, 2000, p. 222).

According to Squire and Kandel (2003), the unification of molecular biology and cognitive neuroscience has also contributed to interesting insights and advances in the study of the memory systems and their subjacent mechanisms involved in storage. Accordingly, in terms of the microscopic structures of memory, scientists know nowadays that memory is not a unitary faculty, but that its two forms – declarative and procedural – present processes of short and long-term duration that are basically dependent on the alteration of synapses. Moreover, each of these forms of memory recruits different systems simultaneously, once they have their own logic, i.e., conscious remembering in declarative memory and unconscious performance in procedural memory. Researchers have also discovered that it is not the type of molecule produced in the synapses that will influence remembrance but the location and the extension involved in such synaptic alterations (p.227-228).

The information presented in the previous paragraphs represents a fraction of the studies that have been developed in this new area of research. The discoveries provided by this line of investigation add to a better understanding of the way different areas of our brain are involved in the storage of different types of information, crucial ingredients to most, if not all of our daily activities, like for instance, comprehending language. Taking a cognitive perspective of analysis, let us move now to the different types and forms of memories.

2.2.2 Types and forms of memory

According to Izquierdo (2002) there are different classifications regarding the construct of memory: according to its durability, its content and its function. Although these categories are somehow intertwined, that is, it is impossible to refer to the duration of a specific type of memory without mentioning its function and vice-versa, this classification will be considered here for the purposes of presentation.

2.2.2.1 Types of memory according to its durability

According to one of the earlier models to conceptualize how memory is organized, William James proposed, at the end of the 19th century, that memory is divided into two parts: one that is limited and immediately available for retrieval and another larger, hidden part that is the repository of one's past experiences (Ashcraft, 1994). This dual structure of memory is remarkably important in the literature because it is the precursor of an important and influential model of memory proposed later on by Atkinson and Shiffrin in 1968 (Baddeley, 1999). Basically, Atkinson and Shiffrin's model, as it became known, assumes that information comes in *sensory memory* through a parallel series of registers and goes into a common *short-term* store. This short-term store is conceived as a repository of information and as a workplace for processing information and the flow of it to *long-term* storage. Let us consider each memory component a bit more deeply.

Sensory memory, the briefest of all types of memory, is an important component of one's overall memory apparatus since it is the entrance door for input registration, processing and further storage. Although this memory is subdivided into the five senses, there are two varieties that are more frequently studied: the *auditory* and the *visual* memories, since most of the stimuli one receives come from these modalities (Baddeley, 1990; Ashcraft, 1994).

Auditory or echoic memory is the memory component responsible for receiving auditory input. As evidence demonstrates (see Baddeley 1990 for a review), any kind of auditory stimuli that is loud enough will be encoded into echoic memory automatically, independent of the identification or comprehension of the stimulus by the subject. Therefore, since encoding is automatic and all sort of noises get into our sensory memory, one can conclude that the capacity of echoic memory is very large.

Visual or iconic memory is a brief-duration memory system responsible for receiving and holding visual input. Similar to echoic memory, iconic memory apprehends all visual information by automatic processes and must be also quite large since it receives tremendous amounts of input and selects that which is pertinent for storage into short-term memory. The information that is not attended to within one-quarter to one-half of a second is lost very rapidly, just like auditory messages (Ashcraft, 1994; Baddeley, 1990; 1999). Being aware of the processes involved in sensory memory is practically impossible: for one, because sensory stimuli are very brief and for another, because our attention is devoted to the next memory component (Ashcraft, 1994).

Short-term memory is the memory component responsible for temporary storage – lasting about 30 seconds – of information that entered sensory memory and the information activated from long-term memory. Therefore, when information is within the short-term memory, this means it is available for conscious processing. Traditionally, this component is seen as rather limited, with its capacity being able to hold up to 7 plus or minus 2 units of information (Miller, 1956). A strategy like recoding, i.e., the grouping of codes into something meaningful, is a device for overcoming this limitation, saving capacity and avoiding memory burden. When items are within the domain of short-term memory, they are presumably retrieved in a serial fashion, a fact that would explain why one 'forgets' the whole sequence when only an item is not accessed correctly (Searleman & Herrmann, 1994).

The ultimate destination for the received, processed and temporally stored information is *long-term* memory. In this way, when one wants to learn some information, this has to be stored in this relatively permanent basis (Ashcraft, 1994). One of the ways to possibly achieve this permanent storage is through rehearsal – a metacognitive strategy that can form a long-term memory trace of the to-be-remembered information. Another way is through comprehension. When one comprehends what is being read or listened to, this person is probably forming a long-term memory record of the main ideas of the message by means of assessing and comparing previously stored with incoming information. This however, is only possible when attention, interest and comprehension are involved in the process (Ashcraft, 1994; Izquierdo, 2002; Matlin, 2004). Contrary to the other components of memory, long-term memory seems to have no limits in its capacity – forgetting occurs by virtue of competing, interfering information (Baddeley, 1990; 1999), except in cases of brain damage.

The model proposed by Atkinson and Schifrin does not account for the *remote* memory, as proposed in Izquierdo (2002). According to this researcher, long-term memories which can be easily remembered after months or even years after they had been encoded, are often referred as remote memories. In this way, although information can be forgotten from long-term memory due to lack of use or rehearsal, it seems that some kind of information, like the learning of a foreign language, for example, are processed at deeper levels - be it as a result of effective rehearsal or long periods of practice - and achieve a permanent store. The remote "kind" of memory would explain why learners of a foreign language are still able to communicate, even after years with no contact with the foreign language.

2.2.2.2 Types of memory according to its contents

Traditionally, for the purposes of better understanding the construct of memory, and based on experimental and neuropshychological evidence with brain damaged patients (Aschcraft, 1994; Paradis, 2004), cognitive psychologists tend to fractionate long-term memory into more specific categories: declarative and procedural memories.

Declarative memories are so called because we are able to talk about them and tell others how we have obtained them. These memories are subdivided and can refer to those events or episodes that have happened to us, like our first day in school – comprising the *episodic* memory – or can refer to our general knowledge about the world, like for instance, the difference between a Volkswagen and a Toyota – comprising the *semantic* type of memory.

The existence of these two subtypes of declarative memories is not new. According to Searleman and Herrmann (1994), different researchers have mentioned this distinction over the centuries, although the specific terms "episodic" and "semantic" were not used before Tulving in 1972. Later on, as a result of much research, Tulving proposes another type of memory, namely *procedural memory*. This memory refers to the knowledge that is obtained incrementally and that we generally have difficulty to verbalize; it refers to the knowledge involved in *how to* perform motor or sensory skills (i.e., riding a bike, learning to knit, pulling your hand away from the fire), and some cognitive skills (reading, spelling, writing) (Baddeley, 1999; Sternberg, 2000; Izquierdo, 2002; Squire & Kandel, 2003; Matlin, 2004).

Another approach to the study of long-term memory is its segmentation into *explicit* and *implicit* memories. Explicit memories refer to that type of knowledge that can be consciously recalled or recognized whereas implicit memories refer to that knowledge that is acquired in an automatic manner and that can be retrieved without conscious recollection (Squire & Kandel, 2003; Matlin, 2004). In general terms, implicit and procedural as well as explicit and declarative memories can be roughly considered as equivalents. Nonetheless, according to Izquierdo (2002), some recent researchers tend to divide both procedural and declarative memories into explicit and implicit memories, due to the fact that some of our declarative memories, e.g., L1 learning, are also implicitly acquired. As one can conclude, since researchers seem to have not reached an agreement in terms of the subdivisions related to long-term memory, it may be expected that current memory models will be revisited and that other theories will be raised.

2.2.2.3 Types of memory according to its function: the working memory

Working memory is the memory system that has, besides storage, a "managing" function that orchestrates the processing of incoming information with information activated from long-term memory (Baddeley & Hitch, 1974; Daneman & Carpenter, 1980; 1983; Turner & Engle, 1989; Baddeley, 1990; Shah & Miyake, 1999; Engle, 2002, Tomitch, 2003, among others). This management is responsible for deciding whether a new memory trace is necessary and worth of registering in short-term and/or long-term memory or yet, if the trace already exists so information can be suppressed. According to Izquierdo (2002), this type of memory leaves no trace and produces no file: it is responsible for the here and now, and has the function of maintaining the processing of information for seconds, with a maximum of few minutes. Therefore, working memory should not be confused with short-term memory, which produces files over brief intervals of time – since the very first seconds that follow learning until three to six hours, which is the time that long-term memories take to be encoded.

The term working memory was proposed by Baddeley and Hitch in 1974. This construct is seen as a multiple component system to account for the processing and decision making processes that take place here and now (Searleman & Herrmann, 1994; Aschcraft, 1994; Fortkamp, 2000). This multi-component model, as it became known, conceives that

> Working memory refers to aspects of on-line cognition – the moment-to-moment monitoring, processing, and maintenance of information (…) it comprises those functional components of cognition that allow humans to comprehend and mentally represent their immediate environment, to retain information about their immediate past experience, to support the acquisition of new knowledge, to solve problems, and to formulate, relate, and act on current goals (Baddeley & Logie, 1999, p. 28-29).

The framework of the working memory model - originally presented by Baddeley and Hitch in 1974 - comprises an attentional control system, namely: the central executive, and two subsidiary 'slave' systems, the phonological loop and the visuospatial sketchpad (Baddeley, 1990; 1996). The central executive is a supervisory system involved in the control and regulation of working memory including: (a) the coordination of the two slave systems, (b) the focusing and (c) switching of attention and (d) the activation of representations from long-term memory. The phonological loop is responsible for processing the phonological code and is subdivided into a passive *phonological store* which holds information that is suppressed with time, and an active *rehearsal process*, which recycles this information in the phonological store in order to keep it enhanced. The visuospatial sketchpad is also subdivided into two systems: a passive *visual cache*, responsible for holding visual information and an active spatially based system, the *inner scribe*, responsible for retaining sequences of movements (Baddeley, 1990; 1999; Baddeley & Logie, 1999).

A considerable number of studies on working memory have been carried out after Baddeley and Hitch's seminal work was published. Other theories and models have been proposed and different accounts for the nature, structure and function of the working memory construct have been presented – see for instance, Miyake and Shah's 1999 book on the discussion of ten different models for working memory. Hence, even though there is an agreement among researchers in terms of working memory definition, i.e., that it is a system responsible for simultaneous processing and storage of information (Baddeley & Hitch, 1974; Daneman & Carpenter, 1980; 1983; Turner & Engle, 1989; Tomitch, 2003; Shah & Miyake, 1999, Fortkamp, 2000; Torres, 2003; 2005, Mota, 2005, among others), there is a dispute for some unresolved issues, such as the number of components involved and the influence that the task being performed might have (not) on the capacity limitations of working memory. This topic will be retaken in a subsequent section. Now, since the types and forms of memory have been reviewed, let us move to the relationship between working memory and language.

2.2.3 Working memory and language

Nobody doubts that memory is paramount for language processing. Without memory there would be no records of words, sentences could not be produced, conversations would not take place. The act of reading would not be possible either, once there would be no records of written input, letters would not be recognized and texts could not be interpreted. As a matter of fact, when one thinks about memory it is almost impossible to dissociate it from most if not all of our everyday activities, as Baddeley puts in the very first page of his 1999 book:

> Perhaps the best way to appreciate the importance of memory is to consider what it would be like to live without it, or rather without them, as memory is not a single organ like the heart or liver, but an alliance of systems that work together, allowing us to learn from the past and predict the future (p.1).

The opposite – language is paramount for memory - is also true. In agreement with Baddeley (1999), most of the investigations that consider the study of human memory have been based on verbal and written coding. As one can infer, language is important for memories because it can either supplement or translate other types of visual, tactile or olfactory presented items in words (Izquierdo, 2002). Furthermore, as the literature on the Alzheimer's disease has suggested, the language deficits -at the semantic, syntactic and phonological levels- presented by patients in different stages of this illness is related to the deterioration of certain brain areas that are connected to declarative and working memories (see Rodrigues, 2004 for an extensive review of studies on this issue). Therefore, it is plausible to infer that if access to semantic and episodic memories is impaired or if working memory is deficient in processing the information accessed from long-term memories, it seems a *sine qua non* condition that language processing and production will be impaired too.

Parallel to the studies with brain-injured people (Phelps, 1999; Fontanini & Weissheimer, 2005; Finger-Kratochvil & Baretta, 2008) and patients suffering from dementias (Rodrigues, 2004), a considerable number of research has been conducted with normal subjects aiming at investigating the relationship between working memory and language. The reason for this interest probably resides on the fact that working memory is *the* system responsible for *orchestrating* the incoming input with the information activated from long-term memory, as discussed in the previous section. If working memory is somehow impaired or if the processes under execution overload its limited capacity, language comprehension and production are known to suffer, as many studies investigating the different language skills, that is, reading (Daneman & Carpenter, 1983; Daneman & Green, 1986; Whitney, Ritchie & Clark, 1991; Just & Carpenter, 1992; Tomitch, 1996; 1999-2000; 2003; Torres, 2003; 2005 and others), speaking (Fortkamp, 2000; Mota, 2005; Guará Tavares, 2005), listening (Rosen & Engle, 1998; Penney & Godsell, 1999; Hambrick & Engle, 2002) and writing (McCutchen, 2000; Olive & Kellogg, 2002), have demonstrated.

Nevertheless, as mentioned previously, although there is agreement in the literature regarding the definition of working memory, researchers have investigated it under different perspectives, and obtained different evidence. One of these perspectives, as explained by Baddeley (1992), is labeled as the *dual-task* *neuropshychological* approach. It is concerned with the use of dual-task methodology and neuropsychological evidence from brain-damaged patients to investigate the structure and the subcomponents of the working memory system and has its main advocates in Baddeley and collaborators (Baddeley & Logie, 1999). The other perspective, known as the *psychometrical correlational approach*, concerns the investigation of individual differences in the performance on complex cognitive activities, which may mirror differences in working memory capacity (Daneman & Carpenter, 1980; 1983; Just & Carpenter, 1992; Engle, Cantor & Carullo, 1992; Tomitch, 2003; Torres, 2003). These differences are thought to be reflected in the trade-off between processing and storage of information, for these two functions - processing and storage - compete for working memory limited capacity.

Researchers within the psychometrical correlational approach, in pursuing the question about the effect(s) of working memory on language comprehension tasks, have carried out various studies in the last decades. The interpretation of the data obtained in these studies has provided much of the theoretical frameworks that attempt to explain individual differences in language-related tasks. The next section of this review of literature will consider three of the current views.

2.2.3.1 Working memory and what it can tells us about individual differences

One of the first proposals to explain individual differences is postulated by Daneman and Carpenter who argue that the two functions of working memory -

storage and processing - compete for the same pool of resources and that differences in its capacity are peculiar to the task being performed, that is to say, the limitations of working memory capacity, as measured by the Reading Span Test, is dependent on one's processing efficiency in *language comprehension*. This assumption has been mainly founded on their two seminal studies (1980 and 1983) that signaled a positive correlation between reading comprehension measures (fact questions, pronominal reference questions, and the ability to perceive lexical ambiguity in garden path sentences) and the Reading Span Test.

Differently from short-term memory measures, such as the digit span and the word span which only measure storage, the reading span test engage participants in online processing and simultaneous maintenance of the last word of each sentence trial for later recall. In this way, participants have to read aloud three sets of two, three, four, five and six unrelated sentences and memorize the last words of each sentence. Accordingly, in the case of a two-sentence trial, such as:

"When at least his eyes opened, there was no gleam of triumph, no shade of anger."

"The taxi turned up Michigan Avenue where they had a clear view of the lake."

participants were supposed to recall "anger" and "lake" in the order they occurred as they reached a blank card that signaled the end of the trial (Daneman & Carpenter, 1980, p. 453).

As explained by Daneman and Carpenter, the task of reading sentences aloud would require the involvement of a considerable portion of working memory capacity, limiting the resources available for the storage of the last words of the sentences. This test, according to its proponents, simulates the cognitive processes involved in reading comprehension, being therefore, a good predictor of individual differences of language comprehension because it measures overall efficiency and captures many of the processes of normal reading (Daneman & Carpenter, 1983), which are similar to those involved in the comprehension of discourse. In this way, individual differences in working memory are due to differences in the capacity of processing, that is to say, the more efficient a reader is in processing information from a given text, the more resources he has available for storing information that is active in memory. More demanding processing would therefore, require more working memory resources, decreasing the amount of additional information that can be stored in working memory, a fact that would obstruct comprehension.

The theory called *Capacity Constrained Comprehension* proposed by Just and Carpenter (1992) posits that individual differences in reading comprehension are related to working memory capacity for *language*. These authors assume that as “both storage and processing are fuelled by the same commodity: activation” (p.123), there are two ways in which individuals may differ in terms of working memory capacity: the total capacity and the processing efficiency accounts. In the *total capacity* account, individuals differ in the amount of activation they have available to cope with language processing, that is, individuals with larger working memory capacity will be better able to comprehend discourse in a faster and more accurate fashion because they have more resources available to cope with the task demands. The *processing efficiency* account, similar to the view proposed by Daneman and Carpenter (1980, 1983), posits that the individual's efficiency for language processing will be impinged on the limits of working memory capacity. Hence, if an unskilled reader has difficulty in executing any of the reading processes properly (matching, recoding, lexical access, parsing…), s/he will tax his memory resources and, consequently, s/he will have fewer resources to allocate to the processing and storage components involved in the comprehension of a given text. Just and Carpenter argue that these two explanations for individual differences in working memory capacity are compatible, but highlight the fact that these differences were only substantially apparent when readers with different spans performed demanding tasks, corroborating the total capacity account (p.145).

An alternative interpretation for Daneman and Carpenter's and Just and Carpenter's views is proposed by Engle, Cantor and Carullo (1992) who advocate that working memory is *not* task dependent and that individual differences in working memory spans reflect stable differences in the overall amount of activation available to the system. The authors understand working memory as being composed of temporary or permanent knowledge units from long-term memory that are currently enhanced at different levels of activation, which is the limited "fuel or resource that drives the system" (p. 990). Besides this, Engle et al. point out that the ability to shift attention away from the task being attended to (as a consequence of an intrusive thought, for instance), and then back to the task to recover the train of thought, is another important characteristic of the working memory system. Hence, independently of the task being performed – reading a text or solving math calculations – it is the individual's capacity for controlled, sustained *attention* that will influence his performance in the task. Therefore, when reading a text, it is the reader's capacity of focused attention that will influence his performance on a comprehension task, as demonstrated by various studies that adopted the operation-span test[7] and found significant correlations between this test and reading comprehension abilities (Turner & Engle, 1989; Engle, Cantor & Carullo, 1992; Cantor & Engle, 1993; Conway & Engle, 1996, among others).

Engle and collaborators have been pursuing this *General Capacity* model for the past two decades and have carried out several studies to corroborate their assumptions (besides the ones just cited above, consider also Engle, Kane, Tuholski, 1999; Hambrick & Engle, 2002; Heitz, Unsworth & Engle, 2004). Recently, they have proposed that working memory capacity, i.e., the ability one has to control attention, particularly in situations involving interference, is, in some way, related to general fluid intelligence (gF) – the ability to solve novel problems. According to this updated model, attentional control and gF probably do not depend on differences in general knowledge or specific procedural skills, as argued by Carpenter and colleagues (Engle, Kane & Tuholski, 1999; Engle, 2002; Heitz, Unsworth & Engle, 2004).

Independently of the view adopted to explain empirical results: *task-specific* (as postulated by Daneman & Carpenter and Just & Carpenter) or

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[7] It is a variation of the reading span test in which the processing component is a math operation (e.g., "Is 4/2 + 6 = 6? (yes or no) and the storage component is a word (e.g., DOG) (Engle, 2002, p. 19).

general-capacity view (as postulated by Engle and his group), studies on individual differences in working memory capacity and reading comprehension have found significant correlations between the Reading Span Test (Daneman & Carpenter, 1980; 1983) and/or the Operation Span Test (Turner & Engle, 1989) and (a) scores on standardized multiple-choice reading comprehension tests, e.g., Nelson-Denny and VSAT (Turner & Engle, 1989; Engle, Cantor & Carullo, 1992); (b) the ability to use contextual cues to find the meaning of new words (Daneman & Green, 1986); (c) the ability to perceive text structure, and to recall predictive signals and predicted elements respectively (Tomitch, 1996; 1999-2000; 2003); (d) the ability to adjust cognitive processes on the processing of texts under different reading purposes (Linderholm & van den Broek, 2002; Horiba, 2000); (e) the ability to construct main ideas in L1 and L2 (Torres, 2003; 2005); and (f) the ability to generate inferences (Whitney, Ritchie & Clark, 1991; Singer, Andrusiak, Reisdorf & Black, 1992; Linderholm & van den Broek, 2002; Baretta & Guará Tavares, 2005). On the whole, these studies have found evidence that higher span readers are more prone to exhibit a better performance on different reading comprehension tasks due to their larger capacity to control working memory processing and storage functions. The present study will consider the *task-specific* framework (Daneman & Carpenter, 1980, 1983; Just & Carpenter, 1992) described above as the guiding definition to account for individual differences in the process of inference making. Given the focus of this research, the following section of this review of literature will concentrate on the studies that have investigated the relationship between working memory capacity and the process of inference making.

2.2.3.2 Working memory capacity and inference making

As already pointed out, working memory is conceived as a multi-component system responsible for simultaneous processing and storage of information (Baddeley & Hitch, 1974; Turner & Engle, 1989; Just & Carpenter, 1992; Shah & Miyake, 1999; Baddeley, 1990; 1999; Baddeley & Logie, 1999; Engle, Kane & Tuholski, 1999; Engle, 2002 and others). The storage and processing requirements of language comprehension imply a central role for working memory in the process of inference making, given the different sources of information i.e., focal and previous portions of the text and the reader's background knowledge that must be active so that inferences can be made.

For the past years, given the significant correlations obtained between reading comprehension and working memory capacity, as measured by the Reading Span Test and derivatives of it (Daneman & Carpenter, 1980; 1983; Turner & Engle, 1989; Just & Carpenter, 1992; Torres, 2003; Tomitch, 1996; 2003, among others), and the critical importance of the process of inference generation in reading ability, as discussed in earlier parts of this chapter (van Dijk & Kintsch, 1983; Noordmann & Vonk, 1992; Winne, Graham & Prock, 1993; Trabasso, Suh, Payton & Jain, 1995; Trabasso & Magliano, 1996; Long, Oppy & Seely, 1997; Gernsbacher, 1990; 1997; Magliano, Trabasso & Graesser, 1999;

Horiba, 2000; Halldorson & Singer, 2002; Linderholm, 2002; Linderholm & van den Broek, 2002; Allbritton, 2004, among others), various behavioral studies have been carried out aiming at investigating the impact of working memory capacity on the readers' ability to make (a) bridging inferences (Singer, Andrusiack, Reisdorf & Black, 1992; Singer & Ritchot, 1996; Linderholm & van den Broek, 2002; Virtue, van den Broek & Linderholm, 2006); (b) elaborative inferences (Whitney, Ritchie & Clark, 1991); (c) predictive inferences (Estevez & Calvo, 2000; Linderholm & van den Broek, 2002; Linderholm, 2002) and inferences in general (Daneman & Green, 1986; Cain, Oakhill & Lemmon, 2004). Of particular importance to the present research are the studies that investigated bridging inferences which will be reviewed next.

Recall that *bridging* inferences are those that contribute to the message coherence and are seen as obligatory for comprehension (Keenan et al., 1990; Singer, Andrusiak et al., 1992; Zwaan & Singer, 2003, among others). For example, when reading:

"*Then she found that the milk was three weeks old.*
The smell turned her stomach"

(from Singer et al., 1992), one has to make a *bridge* between the textual information - the milk is spoiled - and his/her background knowledge that spoiled food produces bad smell. Singer and collaborators (1992) studied this kind of causally related ideas that were presented either near or far apart in passages of short and moderate length by measuring the time taken to respond true/false to statements related to the inference. The authors observed that higher spans were more able to generate bridging inferences than lower spans, especially in the far inference condition in which three sentences intervened between the target and its antecedent sentences. Singer et al. interpreted this result in the light of the functional capacity of working memory, meaning that higher spans have more resources to reinstate one or more pieces of information from previous cycles in long-term memory, and to connect it with the focal sentence to make a successful "bridge".

In a subsequent study, Singer and Ritchot (1996) observed that higher spans and high-access readers[8] exhibit qualitatively different processes than their lower counterparts on the process of bridging inference generation. The time taken to answer questions posed to validate inference processing was lower for high reading span and high-access readers, suggesting that their extra capacity allowed them the access to their critical knowledge in both inference and control conditions. Lower spans and low-access knowledge readers, on the other hand, took longer to answer the posed questions, suggesting that they do not make inferences as automatically as higher spans readers.

Linderholm and van den Broek (2002) investigated the effect of working memory capacity on the reader's ability to adjust cognitive processes and

[8] The classification of high / low access readers is based on an integration task to measure knowledge access skill. Basically, this task requires the readers to study a set of sentences on relations between nonsense creatures and real creatures: A JAL is larger than a pony. Responding correctly to subsequent verification statements requires the reader to access his/her knowledge about the real world while processing the sentences. According to the number of correct answers, subjects were categorized as high or low access readers (Singer & Ritchot, 1996).

strategies to fit a reading purpose (reading for entertainment or for study). The authors observed through the verbal protocol methodology that both higher and lower span readers adjusted their processing to fit reading purposes, but they demonstrated different cognitive processes and strategies. Although there were no differences between working memory groups in regards to two types of inferences, i.e., bridging and elaborative, lower spans made fewer metacognitive comments, repeated the text more often and recalled less information than higher span readers in the reading for study condition. As the researchers observe, it is probable that lower spans were aware of their limitations and opted to "strike a balance" between more and less demanding processes to optimize their learning of the text (p. 782), which has shown to be less efficient than that of the higher spans, as measured through the subsequent recall.

More recently, Virtue, van den Broek and Linderholm (2006) investigated through the lexical decision task, hemispheric differences in the processing of bridging and predictive inferences by low and high span readers. Readers were presented with texts such as: "*After the rugby match, Justin's friends teased him for not knowing the rules. He gathered around his friends and joked about beating them next time. In order to look macho, Justin grabbed a beer from the cooler.*" The texts were followed by either the strong textual constraint: "*His friends were soon covered in beer.*" or the weak textual constraint: *"His friends were soon cheering him."* and subjects were instructed to complete a lexical decision task with inference-related targets (word: *spray* or nonword), which were presented to the left visual field–right hemisphere or right visual field–left hemisphere. The authors reported that both right and left hemispheres showed facilitation for both bridging and predictive inferences, once they were imbedded in strong causal constraints and that the right hemisphere is more involved than the left when inferences are made in weak constrained contexts. Regarding the effects of working memory, results showed that higher span readers had greater facilitation for strongly constrained inferences in both hemispheres, whereas low span readers had greater facilitation in the left hemisphere; in addition, low spans presented equal facilitation in the right hemisphere for both strongly and weakly constrained inferences.

The abovementioned studies add to a large body of literature on individual differences demonstrating that working memory does influence one's performance in reading comprehension. In particular, the process of inference making has shown to be directly correlated with the reader's working memory capacity, which provides more resources to keep the different sources of information active, i.e., the focal and previous read information and the reader's background knowledge, necessary conditions for the attainment of inferences.

The studies on individual differences and inference making reviewed above used sentence verification (Singer and collaborators, 1992; 1996), on-line question answering (Linderholm & van den Broek, 2002) and lexical decision task (Virtue et al., 2006) methodologies, the first ones defined as memory measures and the last as activation measure, according to Keenan et al. (1990). In the past decade, as a consequence of the advances in technology, studies that adopt innovative activation measures paradigms to investigate cognitive processes such as attention, memory and language have become more frequent. Consequently, the interest for visualizing and understanding what occurs in one's brain while performing a cognitive task has increased. Given the fact that this study used an activation measure paradigm (Keenan et al., 1990) - EEG - to investigate the process of inference making, the last part of this review of literature will present, first, an overview of brain functions and their specialized sites of location to language comprehension and production, which will be followed by a detailed presentation of EEG and the review of recent studies that used advanced tools to investigate the process of discourse comprehension in general, and finally, the process of inference making.

2.3 BRAIN AND LANGUAGE

Since the early days of the concept of cerebral dominance in the mid-1800s with Broca's and Wernicke's findings, a considerable amount of research has been carried out with brain damaged, callosotomized and hemispherectomized patients to understand the role of particular brain areas in different cognitive tasks (Code, 1997; Bogen, 1997; St. George et al., 1999, among others). Scientists have used different methodologies including neuropathology, lesion studies, cerebral flow and metabolism, electric activity and stimulation (galvanism) and the effect of anesthetizing the hemispheres (Wada test), together with different behavioral measures (e.g., finger tapping, eye and eyebrow movements) to try to identify the role of each hemisphere in language processing (Code, 1997). Despite some disagreements concerning the results of these studies, researchers agree nowadays that both hemispheres work conjointly to attain the global level comprehension of discourse (Gazzaniga et al. 1996; Federmeyer & Kutas, 1999; Beeman, Bowden & Gernsbacher, 2000; OCDE, 2003; Tomitch, Just & Newman, 2004; Jung-Beeman, 2005, among others).

The acceptance of this fact, however, is quite recent. Although there has been evidence that the right hemisphere (henceforth RH) contributes to subjects' performance in several behavioral and cognitive tasks since the very beginning of the doctrine of cerebral dominance, it is not until the two last decades, with the advances in technological tools for imaging ongoing brain activity, that scientists began to consider the RH as an active participant in the process of language comprehension (Gazzaniga et al., 1996; Heny, 1998; Lundy-Ekman, 2000; Newman, Just & Mason, 2004; Perfetti & Bolger, 2004; Jung-Beeman, 2005). The main reason for this fact seems to reside in the literature, which has emphasized the role of the left hemisphere (henceforth LH) as "the" half of the brain responsible for speech and other higher-functions. The RH, on the other hand, tended to be regarded as having a minor role, being subordinate to the dominant left.

Evidence for this unintended secondary role of the RH abounds in clinical and brain lesion literature which documents that lesions in the RH are generally not accompanied by drastic changes in behavior, such as the language disorders that left-hemispheric damaged aphasics reveal. Moreover, once RH lesions tend to disrupt patients' behavior in fairly subtle ways, the impairments caused by it are not easy to analyze and diagnose and to fit into the traditional ideas about brain function (Bogen, 1997; St. George et al., 1999; Raimundo, 2004; Fachini, 2006; Mason & Just, forthcoming), giving researchers a difficult task in their attempts to interpret and correlate the deficits observed with a particular RH brain area (McCaffrey, 1998-2001).

Despite this fact, current literature concerning hemispheric specialization tends to agree that the hemispheres are different not only anatomically, i.e., size, asymmetry, ratio of gray and white matter, neuronal number and size, but also in the functions they are specialized in. In agreement with various researchers (Code, 1997; Henny, 1998; Federmeyer & Kutas, 1999; Gellatly & Zarate, 1999; Raimundo, 2004; Coulson & Lovett, 2004), Table 1 below presents an overview on how the two sides of the brain process information.

Table 1 – Hemispheric specialization (adapted from Henny, 1998 and Raimundo, 2004)

	Left hemisphere	**Right hemisphere**
Input processing	Sequential and analytical manner	Holistic and abstract manner
Language	Generation; recognition of words and numbers (as words)	Interpretation; recognition of faces, places, objects and music
Memory	Construction of false memories	Reliable in recall
Events	Finds reasons for occurrence	Frames them into spatial patterns
Calculation	Invariable and arithmetic	Relational and mathematical
Sensitive to	Temporal relations	Spatial relations
Better at	Dealing with outside stimuli	Internal processing

As Table 1 demonstrates, the LH is devoted to language *production* and is dominant in the recognition of words which are processed in an analytical manner. The RH, on the other hand, is an expert in the *interpretation* of language, relying on contextual information (faces, places, objects) as an aid to process input in a global manner.

In accordance with Heny (1998), there is a tendency among researchers to believe that it is the type of processing and not the input processed that discriminates the two halves of the brain (p. 644). For this author, therefore, the first entry of Table 1 above – input processing – is the only one that can be considered as 'true difference' in terms of hemispheric functions, since the LH is recruited whenever fine-grained analysis is under process, say for instance, language and mathematics, while the RH is required when global processing is needed as in visual recognition.

Despite this view, however, it seems reasonable to expect that when the more specialized hemisphere takes the lead to process and organize information in a particular task, say, for example, understanding a joke, performance will be improved (Gellatly & Zarate, 1999). Nevertheless, if the specialized hemisphere is injured, in this case, the right half of the brain, performance will be disrupted and comprehension will probably not be achieved. This is what different studies with brain damaged patients have demonstrated.

As well documented in the literature, RH-lesioned people do not typically have the evident language impairments at the phonological, syntactic or semantic level observed in those with LH damage. Nevertheless, they frequently have other communicative and cognitive deficits, such as problems in performing one or more of the following tasks, designed to evaluate aphasics: (a) body part naming; (b) auditory comprehension of complex and/or difficult material, (c) word fluency, (d) writing, and (e) oral sentence reading (McCaffrey, 1998-2001). Furthermore, although RH-lesioned people are unlikely to display “speech” problems, in contrast to LH aphasics, they do have problems communicating.

The most common problem these RH-brain damaged face is their inability to integrate information from different sources as the behavioral studies of Hough (1990), Kaplan, Brownel, Jacobs and Gardner (1990) and Stemmer and Joanette, (1998) for instance, have shown. Another frequent problem for RH patients is that they do not make adequate use of context in their interpretation of messages (Molloy, Brownell & Gardner, 1990; Raimundo, 2004), demonstrating difficulty in distinguishing significant from unimportant information. Moreover, experimental investigations have showed that RH damaged people may be able to comprehend only the literal meaning of language (Kaplan et al., 1990; Beeman, 1993; Just, Carpenter, Keller, Eddy & Thurlow, 1996; Raimundo, 2004).

Further evidence demonstrates that RH damaged patients are unable to interpret body language and facial expressions and their speech is frequently aprosodic, or lacking variations in pitch and stress (Lundy-Ekman, 2000). Yet, studies reveal that these patients may fail to follow conversational rules and that they may make untrue statements, i.e., confabulations (Hough, 1990; Joanette & Goulet, 1990). Lastly, taking into account nonlinguistic deficits, RH damaged patients may have problems with disorientation to time and direction; left side neglect; anosognosia; visuospatial deficits and prosopagnosia (McCaffrey, 1998-2001; Lundy-Ekman, 2000).

As could be seen in the previous paragraphs, there is a wealth of experimental evidence to support the right hemispheric specialization shown in Table 1 above. Although most of the impairments described in this section are related to injuries in the RH, it is important to mention that there is also a considerable number of studies carried out with LH aphasics (Huber, 1990; Dressler, Wodak & Pleh, 1990; Sirigu, Cohen, Zalla, Pradt-Diehl, van Eeckhout, Grafman, & Agid, 1998; Fontanini & Weissheimer, 2005) and with both RH and LH damaged patients that corroborate the hemispheric differences in terms of processing (Hough, 1990; Shears & Chiarello, 2004).

Besides the specialization of each of the two hemispheres, the literature concerning brain functions has also emphasized that the four lobes of the brain: frontal, temporal, parietal and occipital – named as a function of the skull bones that cover them (Ashcraft, 1994) - are responsible for different processes of our everyday lives, such as emotions, reasoning, hearing, vision, language comprehension and other responsibilities, such as motor movements (Sternberg, 2000; OCDE, 2003; Raimundo, 2004; Jeffreys & Cooper, 2007). Let us examine in general terms, what is the expertise of each lobe.

The *frontal lobe*, localized around the forehead, is subdivided into three parts: the *motor cortex*, responsible for the production of movements; the *premotor cortex* that selects the movements, and the *prefrontal cortex* that is responsible for cognitive processes such as reasoning and planning, so that movement and behavior occur in proper time and place (Gellatly & Zarate, 1999; Lundy-Ekman, 2000). It is in the left side of this lobe that the so called Broca's area – responsible for language production - is located. Moreover, the prefrontal cortex has recently been associated with the localization site of working memory (Carpenter, Just & Reichle, 2000; Allain, Etcharry-Bouyx & Le Gall; 2001; Newman, Just & Carpenter, 2002; Izquierdo, 2002; Buchweitz, 2005; 2006, and others), an important construct for language comprehension and production, as discussed previously in this chapter. The *parietal lobe*, found behind the frontal lobe at the top back of the brain, is connected with the processing of nerve impulses related to the senses; it also has spatial processing, arithmetic and language functions (Orrison Jr., 1995; Jefferys & Cooper, 2007). The *temporal lobes* are found on both sides of the brain just above the ears and are responsible for interpreting and processing auditory and visual input. The temporal lobes also contain regions that are essential for learning and memory: the hippocampus, located in the medial part of this lobe, has been shown to have a crucial role in learning and memory, as revealed by the famous case of H.M.[9] (Squire & Kandel, 2003; Jefferys & Cooper, 2007). The *occipital lobe,* located in the back of the brain, receives and processes visual information that is mapped onto the cerebral cortex in a complex network. This lobe is specialized in word and facial recognition, being therefore, an important area for reading skills (Sternberg, 2000; Matlin, 2004; Raimundo, 2004).

[9] H.M. had a large amount of brain tissue surrounding the hippocampus area removed as a resource to cure him of epilepsy. Although the surgery was successful in curing his epilepsy, H.M. has never been able to remember anything that happened to him after the operation; this condition is known as anterograde amnesia (Squire & Kandel, 2003; Jefferys & Cooper, 2007).

This characterization of functions according to each lobe is generic and tends to be seen as a didactic tool (Raimundo, 2004), "since each lobe is subdivided into interconnected neuronal nets that are specialized in each specific processing of information" (OCDE, 2003, p. 74, my translation[10]). Complex cognitive tasks, such as discourse comprehension and production for instance, are dependent on several of these neuronal nets which are localized in different areas / lobes of the brain. Any damage occurred in any of these areas or in the connections among them may impair one's capacity of processing and generate different changes in behavior (Izquierdo, 2002). Therefore, as the brain is not a uniform mass (Code, 1997; Jefferys & Cooper, 2007), specific and localized brain lesions may generate different deficits as a consequence of the intricate connections among neurons. Furthermore, the opposite can also occur: it is possible that, through a process called plasticity, the brain may adjust and optimize its operations in the presence of a lesion in a specific brain area (Gazzaniga et al. 1996; Izquierdo, 2002; OCDE, 2003; Jefferys & Cooper, 2007).

Much of the information about brain functions and their specialized sites of location has been based on clinical observations and neurological procedures with patients during the past fifty years. More recently, with the advances of technological tools to register brain activation while one is performing a task, researchers have found further support for the assumptions raised from earlier brain-behavior studies about brain regions and their respective functions. This issue is the topic of the following section.

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[10] … já que cada lobo se subdivide em redes interligadas de neurônios especializados em cada processamento específico de informação (OCDE, 2003, p. 74).

2.3.1 Advanced techniques for studying language processing

As mentioned above, the refinement of technology in the past years has certainly contributed to the advances in tools that provide a clearer picture to the understanding of what goes on in the brain while someone is performing a cognitive task. Differently from the studies with brain-lesioned patients, another alternative to study and make assumptions about brain functioning, techniques such as neuroimaging (PET, fMRI, NIRS) and EEG tend to work with normal subjects when studying brain processing and language. Due to the fact that this study used EEG to investigate the process of inference making in reading comprehension, this technological tool will be presented first and discussed a bit thoroughly than the neuroimaging techniques.

The Electroencephalogram (EEG) is a common non-intrusive[11] technique that has been used to investigate brain and language processing. Advances in technologies have provided researchers the possibility of registering minor brain variations through electrophysiological measurements of Event-Related Brain Potentials (ERPs). As already discussed in the first chapter, the ERP is a signal which is the result of the electrical activity generated in the brain during the performance of an event, and can be registered by time-locking the recording of EEG to the onset of this event. In order to record ERPs, researchers must apply electrodes in a variety of predetermined locations in the subjects' scalp for

[11] From the techniques mentioned in this review of literature, PET is the only one that is considered an invasive technique. This is because subjects need to be injected with contrast agents or radioisotopes just before the cognitive task(s) under investigation, so blood flow can be measured (Binder, 1997).

measuring the electrical cerebral activity (Kutas & van Petten, 1994; Coles & Rugg, 1995). The ERP signals are measured in relation to a reference electrode placed on the subject's earlobe, chin, or in the case of the experiment carried out for this study, at the central area of the scalp, known as Cz, in accord with the international 10-20 system. The comparison of the electrical signals between the reference and the other electrodes, allows researchers to measure the difference in brain activity across the different areas of the scalp. To obtain good clean average ERPs, the number of trials in cognitive experiments range from 30 to 50 for each type of stimulus (Brown & Haggort, 2000).

ERP waveforms are commonly interpreted and represented according to three different parameters: *amplitude* (calculated in µV, relative to a baseline), *latency* (delay from stimulus onset) and *polarity* (P for positive and N for negative). The positive and negative-going fluctuations that can be visualized in any ERP waveform are defined as *components* and are labeled as a function of their polarity and their latency (in msec). For instance, N400 represents a negative change in amplitude – compared to a baseline prior to stimulus onset – occurring at about 400 msec after the onset of the stimulus or event of interest (Kutas & Schmitt, 2003). In general terms, researchers believe that components that occur prior to 100 ms are associated to information processing at the sensory level; they are considered to be *exogenous* or stimulus-bound because they tend not to be affected by a subject's state of alertness/attentiveness. Long-latency or *endogenous* components on the other hand, are the more informative brain waves which are elicited by perceptual and cognitive operations that may occur as a subject processes a given stimulus, like reading a sentence (Coles & Rugg, 1995; Kutas & Schmitt, 2003). The endogenous components have been the focus of higher order cognitive function studies, such as language. Some of the common ERP components investigated in language comprehension and production are briefly described next.

The N400 is probably one of the most investigated components, since the publication of the seminal article by Kutas and Hillyard in 1983 on semantic processing of written sentences. The N400 component is a negative wave, peaking at about 400 msec and is associated with readers' difficulty in integrating a lexical element in the preceding context. The N100 or N1 and P2 are elicited by auditory and visual stimuli and reflect early sensory and attentional processes associated with one's ability to process a channel of information (Raney, 1983). The P300 is a positive component that is elicited by any stimuli requiring a binary decision (e.g., word versus non-word); it tends to be sensitive to one's confidence in performing the task (Kutas & van Petten, 1994). The P600 or the syntactic positive shift (SPS) is a late peak elicited by syntactic violations (Kutas & Schmitt, 2003). The lateralized readiness potential (LRP) is a negative component that allows speech production researchers to investigate motor-related brain activity prior to an overt response. That is, by the pressing of a response button with the right/left hand (go response) or not responding (no-go response), researchers can determine when and how the brain prepares to give a response, even if the response is not in fact realized (Kutas & Schmitt, 2003).

Among the neuroimaging techniques mostly applied to investigate brain activation, there is Positron Emission Tomography (PET scan) and functional Magnetic Ressonance Imaging (fMRI). As briefly presented in the introduction of this dissertation, both techniques use radioisotopes to monitor the increase of the blood flow, glucose and oxygenation in brain areas, assuming that those areas are involved in the performance of a given cognitive task, such as reading comprehension (Logothetis, Pauls, Augath, Trinath & Oeltermann, 1996). Very recently, another technique, the near-infrared spectroscopy (NIRS) has been introduced to the study of language comprehension, being considered a promising tool for it allows subjects' movement while performing the task under examination (Scherer, 2007). Different from PET and fMRI, NRIS and ERPs are able to register the minor variations in brain activity and can provide clear information on the sequence of events involved in cognitive tasks.

Different functional imaging studies have been carried out in the past decade to investigate different cognitive processes, such as: attention, memory, mental imagery and language. In the specific case of language, there is a considerable number of studies that have been developed at the level of words (Illes et al., 1999; Rosen, Ojemann, Ollinger & Petersen, 2000, Tan et al., 2003, among others); sentences (Just, Carpenter, Keller, Eddy & Thulborn, 1996; Federmeyer & Kutas, 1999; Coulson & van Petten, 2002; Coulson & Lovett, 2004, Buschweitz, 2006, among others) and at the discourse level (Mazoyer et al., 1993; Nichelli, Grafman, Pietrini, Clarck, Lee & Miletich, 1995; Dehaene et al., 1997; St George et al., 1999; Tomitch, Just & Newman, 2004, Scherer, 2007).

Due to the interest of this research in discourse comprehension processing, emphasis will be given to the last group of studies which were carried out at the discourse level.

In one of the first studies to use brain imaging to investigate language processing at the level of discourse, Mazoyer and collaborators (1993) examined the existence of specialized brain areas for the processing of acoustic signal, of phonological sequence, of lexical items and of prosodic, syntactic and conceptual structures. Subjects were PET scanned while listening attentively to (a) stories in French or in Tamil; (b) stories or lists of words in French and (c) stories that were distorted in terms of the substitution of each content word for either a pseudoword or a semantically unrelated word. The authors reported that the LH showed a superior activation for speech processing which was even more significant as linguistic complexity increased. Nevertheless, a “striking result”, in the authors’ words, was the bilateral activation of the temporal lobes when continuous speech was presented (either in French or Tamil), a fact that was explained by the assumption that the RH temporal lobe could be reflecting the encoding and storage of the stories (p. 476).

In another PET study, Nichelli and collaborators (1995) asked volunteers to read Aesop’s fables displayed in the center of a computer screen using RSVP[12], addressing one of the questions posed by the experimenter at the beginning of the task considering the presence or absence of: (a) font modification; (b) grammatical errors; (c) a semantic feature associated with a fable character and

[12] RSVP: rapid serial visual presentation.

(d) the moral of the fable. Analysis of the results demonstrate that grammatical and semantic decisions and appreciating the moral of a story activated consistently but selectively right and left prefrontal cortices. Convergent with other findings that demonstrate that integrative processes are needed to achieve global meaning, i.e., to appreciate the moral of a fable (Kaplan et al. 1990; Hough, 1990; Molloy et al., 1990; Stemmer & Joanette, 1998; Federmeier & Kutas, 1999) is the focus activation of the right inferior frontal gyrus and the right midtemporal gyrus (Broadman's areas 47 and 21, respectively – see the gyri location as well as Broadman's areas in Figures 4, 5 and 6 below). As stated by the authors, thematic interpretations of a text can only be achieved across individual story events and such interpretation is accomplished across distributed brain regions in the RH (p. 2313).

Figure 4 – Lateral surface of left cerebral hemisphere, viewed from the side. Image obtained online at: http://e.wikipedia.org/wiki/Image:Gray726-Broadman.png#file, retrieved on Oct 1, 2006.

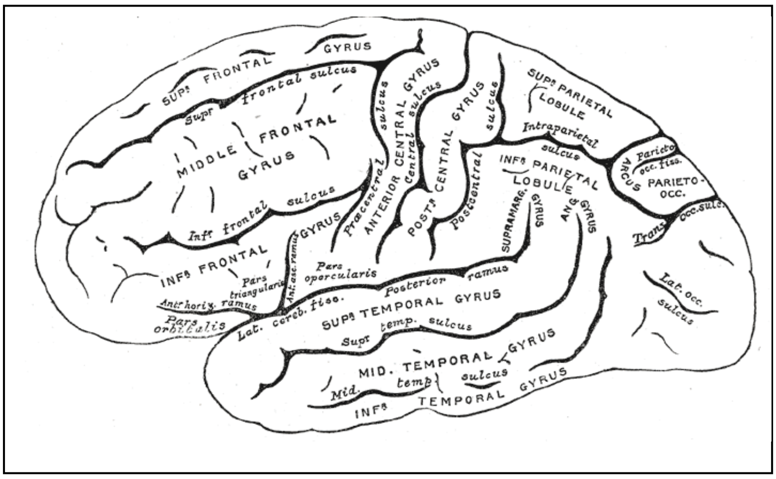


Figure 5 - Medial surface of left cerebral hemisphere. Image obtained online at: http://e.wikipedia.org/wiki/Image:Gray727-Broadman.png#file, retrieved on Oct 1, 2006.

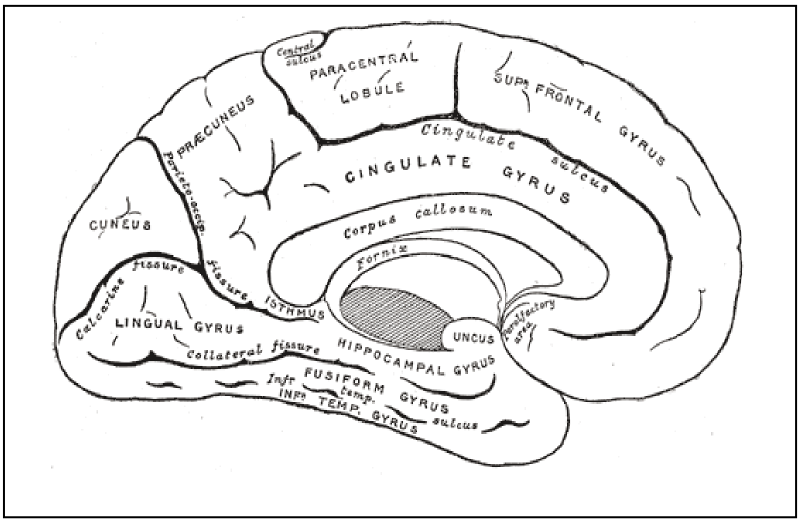
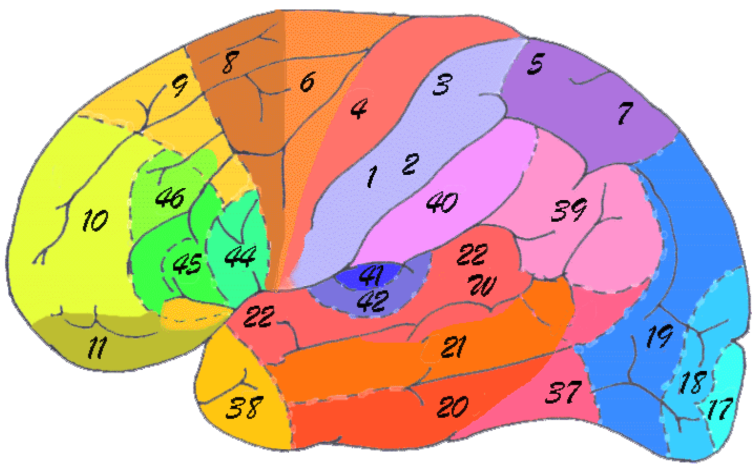


Figure 6 – Broadman's areas. Image obtained online at: http://spot.colorado.edu/~dubin/talks/brodmann/brodmann.html , retrieved on Nov.16, 2007.



Dehaene et al. (1997) also investigated the cortical representation of language comprehension through listening tasks. These authors however, extended previous research in submitting subjects to fMRI scanning while they were listening to stories in their L1 (French) and in their L2 (English). Listening to L1 activated consistently the left temporal lobe all along the left superior temporal sulcus. Listening to L2 activated a variable network of bilateral frontal and temporal areas, sometimes being focused on the RH only. These findings are consonant to the hypothesis that L1 relies on the LH “while late second language acquisition is not necessarily associated with a reproducible biological substrate” (p. 3815), a fact that seems to be subjected to individual differences.

In agreement with Nichelli and collaborators’ findings presented above, is the research developed by St. George and collaborators (1999). In a study with ten individuals reading paragraphs with(out) a title for comprehension, St. George and her colleagues are recognized as being the pioneers to demonstrate, through the use of fMRI, RH brain activation while processing discourse. The authors observed an increased activation in both hemispheres while subjects were reading the paragraphs and a greater activation was noticed in the right inferior temporal sulcus and right middle temporal sulcus in the absence of a title condition. In this way, one can conclude that the RH is involved in other aspects of language processing rather than only figurative language, as proposed by former investigations (e.g., Molloy et al., 1990).

A recent fMRI study carried out by Tomitch, Newman, Carpenter and Just (2008) brings some new evidence regarding text integration. Graduate students read twelve three-sentence expository paragraphs: half the paragraphs introduced the theme in the first sentence, which was followed by arguments and details related to the main idea, such as:

(theme) *First, late in the evening, chain your dog to his doghouse, build a small bonfire and let it burn overnight.*
(argument) *They are insatiably attracted to heat, become enamored of the fire, leave your dog, jump into the flames and die.*
(details) *This is a totally guaranteed method to completely eliminate a flea infestation on your dog or around his doghouse.* (Tomitch et al., 2008).

The other half of the paragraphs presented the supporting argument and details in the first two sentences, leaving the main idea of the paragraph for the last sentence. Similarly to Nichelli et al.'s and St George et al.'s studies, the hemispheres were bilaterally activated when processing the experimental texts. Nonetheless, differently from the other two studies, Tomitch et al. observed greater activation in the LH - temporal cortex, i.e., Wernicke's area and inferior frontal gyrus, i.e. Broca's area – when the topic sentence was in the final but not in the initial position. The temporal region of the RH showed increased activation only by sentence type, revealing an increase of blood flow to topic sentences, regardless of their order of occurrence within the text. As the authors state, these findings were somewhat surprising, since the placement of the topic-sentence affects how coherence is achieved. As the literature demonstrates, the RH plays an especially important role in integrating information in order to attain global coherence during discourse processing (Hough, 1990; Stemmer & Joanette, 1998; Federmeier & Kutas, 1999; Newman, Just & Mason, 2004, among others), a fact that was not observed in this study.

Another recent study carried out by Scherer (2007) with NIRS shows that intermediate-proficient bilinguals' and elderly native individuals' brains work similarly when processing discourse at the micro-, macro-structural and situational levels. The patterns of hemodynamic changes revealed that the RH involvement was more significant in native speakers processing of information at the macro-propositional level of discourse whereas the LH was more involved (mainly the frontal inferior region) in the micro-propositional level for both elderly natives and non-proficient bilinguals. As the author states, this study adds evidence to a recent trend in research that contends that the hemispheres tend to work conjointly, especially when one is faced with a demanding task.

As could be noticed in the studies reviewed in this section, the use of technological tools has certainly added to a large body of evidence that both hemispheres have discriminate roles when someone is performing a language task, be it listening or reading. On the one hand, much of the assumptions raised through the observation of brain damaged patients are being corroborated by functional imaging data that have shown not only that different areas of the brain are in fact involved in different tasks, but also that the level of involvement is variable. On the other hand, unexpected findings, such as the bilateral activation with superior activation in the LH found in Mazoyer et al. (1993) and Tomitch et al. (2008) are more feasible to be detected, once the neuronal activity that was once only inferable through some sort of behavior, can now be observed at the moment of its occurrence.

It seems that, at the same time that technology has come to help and to improve the level and depth of data collection involving the brain, it also came to show once more that understanding the human brain and the multifaceted network of functions underlying its work is certainly a complex task. Much is yet to be explored and learned about the brain and the intricate relationship between this organ and the comprehension of discourse. The next section of this review of literature will present four studies that have been carried out to investigate the process of inference generation through the use of EEG and fMRI to map out the cortical network associated with such process.

2.3.2 Inference making and the brain

The language processing studies involving technological tools to measure cognitive processing that have been conducted in the past decade certainly have contributed to the understanding of human discourse processing. In particular, there are a few studies that investigated the process of inference making with the use of electrophysiological evidence (EEG) and fMRI to explore the network of cortical areas involved in such process, namely, St. George (1995, published later with colleagues: St. George, Mannes and Hoffmann, 1997), Mason and Just (2004), Schmalhofer, Friese, Pietruska, Raabe and Rutschmann (2005) and Virtue, Haberman, Clancy, Parrish and Beeman (2006).

One of the first studies to consider the use of a technological tool to examine the process of inference generation was conducted by St. George (1995).

This experiment provides an example of how ERPs (event-related potentials) can be used to measure on-line cognitive processes at the discourse level through the examination of bridging and elaborative inferences in the comprehension of four-sentence passages, read by high and low working memory span subjects. Results demonstrated that high working memory capacity readers were more prone to generate both types of inferences, counter to low spans, who made only the bridging - obligatory - type of inference. As explained by St. George, it is probable that low span readers were less able to generate elaborative inferences because their working memory was taxed with function words, as demonstrated by the greater N400[13] responses that possibly indicate these readers' difficulty in integrating these words into a coherent textbase. High working memory capacity readers, on the other hand, tended to expand their resources on the text, elaborating on its subsequent parts, as proposed by the *Capacity Constrained Comprehension* theory (Just & Carpenter, 1992), as discussed in a previous section of this review of literature. Despite the fact that the study by St. George et al. did not consider potential differences in left/right hemispheric activation, it brings important contributions to the understanding of inference generation by validating the use of ERPs to assess the generation of an inference, providing researchers with a fairly direct measure that is not dependent on the overt verbalization of the reader through think-aloud protocols (Mason and Just, forthcoming). In fact, in a pilot study conducted by Baretta and Lucena (2005) with intermediate EFL readers, it was observed that low span readers tended to

[13] Recall that the N400 is characterized as a negative deflection in brain waves occurring approximately 400 ms after stimulus presentation. The amplitude of the N400 grows as stimuli get harder to integrate semantically.

verbalize less of their thoughts as a function of working memory capacity, not implying however, that inferences had not been drawn. In fact, results from the free recall protocols showed that even though lower spans reproduced a smaller number of idea units than higher spans, this difference was not substantial in terms of overall means.

Mason and Just (2004) applied the fMRI technique to observe participants' processing of two-sentence narratives varying in the degree of causal relatedness: high, moderate and distant conditions. The objective of their research was to investigate the large-scale cortical networks involved in three aspects of discourse comprehension: *generation* and *integration* of inferences[14] and *basic sentence* processing, i.e., lexical access, parsing. As hypothesized by the authors, the left and the right hemispheric language areas (inferior frontal gyrus, inferior, superior and middle temporal gyri, and inferior parietal area), and the dorsolateral prefrontal cortex demonstrated different levels of activation across the three degrees of causal relatedness. The right hemispheric (RH) language areas showed greater activation in the moderate condition, revealing an inverted-U-shaped function (p. 4); activation in the left hemispheric language areas did not differ significantly across the three conditions, being the activation in the moderate condition quite similar to that observed in the RH; activation in the dorsolateral prefrontal cortex – the site of working memory - increased as the sentences became more distantly related and no differences across the hemispheres was registered. These data suggest that there is a distinction between the two

[14] According to the Construction-Integration model proposed by Kintsch (1988, as cited in Mason & Just, 2004) the reader first *generates* various possible inferences and then selects the one that fits into the representation of the text, a process that is called *integration* (p. 01).

components of inferencing (generation and integration) and that different brain areas are involved in each one of these. Thus, as Mason and Just observe, it can be assumed that the RH "may be involved in the *integration* of inferences once those inferences have been *generated* with the DLPFC [dorsolateral prefrontal cortex] involvement" (p. 6, emphasis added).

Schmalhofer, Friese, Pietruska, Raabe and Rutschmann (2005) reported an fMRI study conducted to explore the brain processes involved in the coherence relations between a sentence and a subsequent test statement. Subjects were required to evaluate as true or false test statements that had to be related to a previously read situation that ranged from an explicit and a paraphrasic to an implicit and a control condition, such as in:

"While the flight attendant served the passenger a full glass of wine, turbulence occurred which was very severe."

Test statement*: wine spilled - True or false?* (p.1950)

Overall, results demonstrated that the left and right superior and middle frontal gyri and inferior frontal gyrus had a significant role on the process of inference making. Furthermore, Schmalhofer et al. observe that posterior and prefrontal brain regions, i.e., posterior cingulate, superior temporal gyrus, left and right inferior frontal gyrus and medial frontal gyrus, form a network that is consistently activated to suffice the demands imposed by the task of establishing coherence relations. This is interpreted in the light of two distinguished but interactive brain processes involved in sentence coherence relations: memory resonance (a basic and involuntary memory reactivation process) and situational constructions (goal-directed process in search of meaning), both of them fundamental to the process of inference making.

Virtue, Haberman, Clancy, Parrish and Jung-Beeman (2006) examined the neural mechanisms involved in the listening comprehension of short stories by higher spans at two critical points: when the verb implies an inference and at a coherence break. The superior temporal gyrus and the inferior frontal gyrus were found to be active when subjects had to draw inferences, corroborating the studies of Mason and Just (2004) and Schmalhofer et al. (2005) that found similar results. Furthermore, the right superior temporal gyrus showed earlier activity during the comprehension of inference events, while the left homologue demonstrated greater activation at the coherence break. According to the authors, the fMRI data provided in this study lend support to previous work demonstrating that the RH recruits information for inference generation earlier than the LH (this finding is also mentioned in the study of Schmalhofer et al., 2005). Finally, despite the fact that Virtue and collaborators focused their analysis on higher spans for having greater tendency to generate inferences, the authors could observe that lower spans demonstrated lower levels of activation in the inferior frontal gyrus than their counterparts in the implied events condition. This inferior frontal gyrus activation found for high working memory capacity comprehenders, suggests that they were selecting the appropriate inference when they faced a coherence break, contrary to low spans who did it less frequently.

The results presented by the studies reviewed above corroborate behavioral data that has suggested that inference making is a process of cooperative and effortful computation. In addition, as already pointed out by (some) discourse comprehension models (e.g., Gernsbacher, 1990, 1997; van den Broek et al., 1999) and the insightful proposals to explain the different factors involved in inference generation presented above, the fMRI data signals that inference making is based on at least two distinct processes. The first occurs earlier after the presentation of the critical information and works as a memory resonance process, so that the reader can generate a possible inference. The second process probably takes place later in relation to the onset of the critical information since it is a more effortful, task dependent process of situation construction that integrates the previously generated inference to the internal representation of the text.

Nevertheless, although there seems to be agreement regarding the two stages involved in the process of inference making, i.e., generation and integration for Mason and Just (2004) and resonance and situational construction for Schmalhofer et al. (2005), it is not very clear what brain areas are specifically recruited in each of these two component processes – notice that the studies of St. George (1995) and Virtue et al. (2006) have not discriminated the two processes involved in inference making. For Mason and Just, bilateral dorsolateral prefrontal cortex (BA 9 and 46) is involved in the generation of an inference which is further integrated into the reader's internal representation of the text by the RH-language areas, i.e., inferior frontal gyrus (BA 11 and 47), temporal gyri (BA 20, 21 and

22) and inferior parietal areas (BA 40) (p. 6). For Shmalhofer and collaborators, on the other hand, the memory resonance process – the activation of relevant information to generate an inference – shows the involvement of the right posterior cingulate gyrus (BA 31) and the situational construction – the integration of an inference – seems to be dependent on the left and right superior (BA 6, 8 and 9) and middle frontal gyri (BA 46), and the inferior frontal gyrus (BA 44, 45 and 47).

The data reviewed in this last part, can be better interpreted in the light of the framework of multiple bilateral semantic processes proposed by Jung-Beeman (2005). As established by this researcher, the construction of meaning from natural language is a process of cooperative computation that is basically organized around two principles. The first, establishes that among all the processes and subprocesses involved in language comprehension, there are at least three distinct but highly interactive components of semantic processing[15] supported by different brain areas: semantic *activation*, semantic *integration* and semantic *selection* that are paramount to natural language comprehension. The second principle determines that although each type of semantic processing occurs bilaterally, each hemisphere processes information differently: the RH processes relatively coarser semantic coding while in the LH this computation is relatively fine-grained, although not localist (p. 513).

Therefore, according to this framework, depending on the type of semantic processing under investigation, that is, generation and/or integration of inferences

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[15] As explained by Jung-Beeman, the term *semantics* is used in a broader sense than that adopted in linguistics, denoting "any function pertaining to the extraction and elaboration of meaning from language input" (p. 513).

in the specific case of the studies just mentioned, different brain areas in both hemispheres (posterior middle temporal gyrus for *activation*; anterior temporal lobes for *integration* and inferior frontal gyrus for semantic *selection*) will be recruited, as also suggested in the study of Mason and Just (2004). In addition, the findings of Virtue et al. (2006) that the RH is more involved in earlier stages of comprehension of inference events is consonant with the assumptions of this framework that proposes that “rapid integration and tight links [occur] in the LH, and maintenance of broader meaning activation and recognition of distant relations [occur] in the RH” (Jung-Beeman, 2005, p. 517).

As one can see, much is yet to be investigated in what concerns the process of inference making before further conclusions can be drawn. Little is known for instance, about the effects that different types of texts may exert on the process of inference making, for there are few behavioral studies and no brain imaging study - to my knowledge - that have compared this process across different types of texts. The present study is expected to contribute to the identification of the different brain areas involved in the large-scale cortical networks underlying the component processes of inference making by investigating the generation of bridging inferences while subjects read narrative and expository texts.

The following chapter presents the methods adopted to carry out the present study.

CHAPTER 3

METHOD

In order to investigate the hypotheses raised in this study, an experiment was conducted at the Center for Cognitive Neuroscience at The University of Auckland in New Zealand. The experiment was conducted individually and involved two main parts: the assessment of subjects' working memory capacity, and the recording of electroencephalogram (EEG) while subjects read four-sentence long texts and judged the suitability of the final sentence of each paragraph, according to previous information. The present chapter presents the method adopted for data collection and for analyzing data. It describes the subjects, the materials and procedures for data collection and analysis.

3.1 SUBJECTS

Sixteen male, right-handed paid subjects participated in this study. The reason for working with male subjects, only, was due to the fact that men tend to be more language lateralized than women (Davidson, Schuwartz, Pugash & Bromfiled, 1976; Shaywitz et al. 1995) and also, because recently, researchers have discovered that women’s hormonal cycle affects the transfer of information in the female brain (Hausmann, Becker, Gather & Güntürkün, 2002). Therefore, given the number of subjects of this study, it was decided that the variable of gender would be disregarded so that results would not be confounded.

All subjects were native speakers of English and students at the University of Auckland at the moment of data collection. Their average age was 22 years (range 18-31). The subjects had normal visual acuity with no known language impairment or any neurological or psychiatric disorders. Each subject read and signed a consent form approved by the University of Auckland Human Participants Ethics Committee (ref. 2007/104).

Two of the subjects were eliminated from the analysis. One, due to technical problems in segmenting his data, and the other, because of his highly discrepant scores in the behavioral part of the experiment, which led us to consider him an outlier. Therefore all the analysis was carried out with fourteen subjects.

3.2 MATERIALS

The materials used in this research consist of 120 four-sentence long paragraphs, a reading span test and a written questionnaire which will be described as follows.

3.2.1 Stimuli

The stimuli consisted of 30 narrative paragraphs that were based on a previous study conducted by St. George (1995) and 30 original expository paragraphs that were extracted from naturally occurring texts in English and adapted to satisfy the requirements of the experiment.

One of the reasons for choosing these two types of texts was the limited number of studies investigating inference making in expository texts (Linderholm & van den Broek, 2002) or that compared inference making across narrative and expository texts (Winne, Graham & Prock, 1993; Narvaez, van den Broek & Ruiz, 1999; Horiba, 2000). Another reason was the technological tool involved in data collection. Given the fact that the design of this experiment was based on the study conducted by St. George (1995) with narrative episodes, this researcher understood that it would be important to compare the data generated by the expository paragraphs with the data originated by the narrative paragraphs, validated in a previous study.

All the paragraphs were four-sentences long and the length of the sentences ranged from 4 to 14 words for the narratives (means= 8.4 words) and from 5 to 14 words for the expository paragraphs (means= 8.7 words). Each paragraph talked about different situations or facts and addressed information related to general knowledge, i.e., education, health, technology, hobbies, leisure, work life, everyday routine and so on.

The original expository paragraphs were written and adapted so that they represented a complete and unified piece of writing in terms of structure and texture (Halliday & Hasan, 1990). The paragraphs were organized on the basis of a logical sequence relation of facts (Winter, 1994), so that the information presented in each sentence was interrelated so as to lead to a plausible conclusion, i.e., a deductive or causal sequence for each paragraph.

Similar to St. George's narrative paragraphs, the thirty expository paragraphs had a *bridging* and a *control* condition version (30 x 2 = 60 expository paragraphs). The *bridging* condition refers to the paragraphs whose first three sentences suggested/lead to the inference stated in the fourth sentence. The *control* condition illustrates the paragraphs that although may sound coherent in the first three sentences, do not lead to the inference stated in the fourth sentence, causing surprise in the reader when reading the final sentence (see Table 2 below). The first and the last sentence was the same for both conditions of a particular paragraph. The first sentence presented a fact that contextualizes the paragraph, (e.g., "Alcohol and antibiotics is not a good combination.") and the fourth sentence explicitly stated the conclusion/inference, (e.g., "Alcohol should be avoided when on antibiotics."). In the *bridging* condition, the second sentence presented information that, connected to the previous sentence, suggested an inference, (e.g., "Apparently, alcohol lessens the effects of the medicine."). The third sentence presented supporting evidence or added information to the generation of an inference (e.g., "People take longer to recover when they drink during treatment."). In the *control* condition, the second and the third sentences were designed to maintain coherence (in the first three sentences) but to keep the reader from making an inference, (e.g., "Doctors recommend eating heaps of yoghurt while on antibiotics. Some antibiotics destroy the flora in our gut.").

Table 2 - Sample paragraphs

Expository paragraphs	Narrative paragraphs
Bridging condition	Bridging condition
Alcohol and antibiotics is not a good combination. (situation)	His parents wanted to surprise him with something special for Christmas. (setting the scene)
Apparently, alcohol lessens the effects of the medicine. (eliciting a conclusion)	He had never had a pet before. (eliciting an outcome)
People take longer to recover when they drink during treatment. (supporting information)	On Christmas morning he awoke to the sound of barking from the living room. (supporting information)
Alcohol should be avoided when on antibiotics. (stated inference)	His parents had gotten him a puppy. (stated inference)
Control condition	Control condition
Alcohol and antibiotics is not a good combination. (situation)	His parents wanted to surprise him with something special for Christmas. (setting the scene)
Doctors recommend eating heaps of yoghurt while on antibiotics. (distracting information)	He had never had a bike before. (details of the scenario)
Some antibiotics destroy the flora in our gut. (distracting information)	All his friends had them. (details of the scenario)
Alcohol should be avoided when on antibiotics. (stated inference)	His parents had gotten him a puppy. (stated inference)

Sixty prospective expository paragraphs were given to at least 50 people (30 EFL proficient readers and 20 native speakers of English) who were asked to judge whether the last sentence of each paragraph was a suitable conclusion for that paragraph. The 30 paragraphs with the highest percentage of agreement among subjects (higher than 85% among a group of at least 20 readers) were selected as the experimental expository paragraphs used in this study. After the two versions of the paragraphs were written (bridging and control conditions), three independent raters were asked to read both the bridging and the control conditions of a group of ten paragraphs and were asked to verify the organization of the paragraphs. The raters were invited to suggest adjustments in terms of vocabulary and/or restructuring. Disagreements were resolved between the researcher and the raters.

After editing the paragraphs, five native speakers - other than the ones involved in the actual experiment - were asked to read the 30 expository paragraphs in the same way the experiment was carried out. That is to say, excepting for EEG recording, speakers read the thirty paragraphs presented word by word in the center of a computer screen and after each paragraph, they had to judge whether the final sentence was (in)adequate to the previous read information. After finishing reading all the paragraphs, participants were asked if they had any problems in performing the task, and none of them reported any difficulty.

The 30 paragraphs selected from St. George’s study to represent the textual type of narration in this experiment described a different scenario. As mentioned previously in the explanation about the expository paragraphs, the first and the last sentences of both *bridging* and *control* conditions were the same for a particular scenario. The first sentence set the scene of the paragraph (e.g., “His parents wanted to surprise him with something special for Christmas.”) and the fourth sentence stated the inference (e.g., His parents had gotten him a puppy.”). In the *bridging* condition, the second sentence contained information that suggested a particular outcome for the scene described (e.g., He had never had a pet before.”), and the third sentence presented supporting information to the making of an inference (e.g., “On Christmas morning he awoke to the sound of barking from the living room.”). In the *control* condition, the second and the third sentences presented information that discouraged the generation of the particular inference (e.g., “He had never had a bike before. All his friends had them.”).

Each subject read a set of 60 paragraphs: 30 narrative and 30 expository texts. For each type of text, there were 15 paragraphs for the *bridging* condition and 15 paragraphs for the *control* condition. Two sets of 60 paragraphs (15 paragraphs x 2 types of inference x 2 types of text) were organized so that both types of texts were represented equally across the bridging and the control conditions.

Each subject saw only one of the two versions of each paragraph. After reading each paragraph, subjects had to answer by typing “1” or “2” whether they agreed (1) or disagreed (2) that the last sentence of that paragraph was a suitable conclusion of it. For the visualization of the 120 paragraphs, see Appendix A.

3.2.2 Reading span test

The reading span test (RST) adopted in this study was originally developed by Daneman and Carpenter in 1980 and slightly modified in 1983. The version adopted in this investigation is the 1983 version. This psychometric test consisted in presenting the subjects with five sets of two, three, four, and five sentences and three sets of six unrelated sentences that ended in a different word. Differently from the original and modified versions, the sentences were presented in a computer monitor using the Power-Point program. Each sentence was typed in black letters on a single line across the center of a white screen. Subjects were presented one sentence at a time and asked to read them aloud while they memorized the last word of the sentence.

Increasing sets of sentences were presented to each subject, that is, five sets of two sentences, three sentences, four sentences, and so on, until they reached the end of the last set of six sentences. At the end of each set, the subjects faced a blank screen when they had to say out loud the last word of each sentence in that set, preferably in the order that they appeared. For example, after reading the sentences:

Due to his gross inadequacies, his position as director was terminated abruptly.

It is possible, of course, that life did not arise on the earth at all.

from the first set of two sentences, subjects had to recall “abruptly” and “all”. If subjects could not remember the exact order, they were instructed to say as many of the last words as they could without saying the last word first. The presentation of the sentences was controlled by the researcher: as soon as the subject finished reading the last word of a sentence, the researcher pressed “enter” so that the next sentence appeared on the screen and the subject had to start reading it aloud.

3.2.3 Retrospective questionnaire

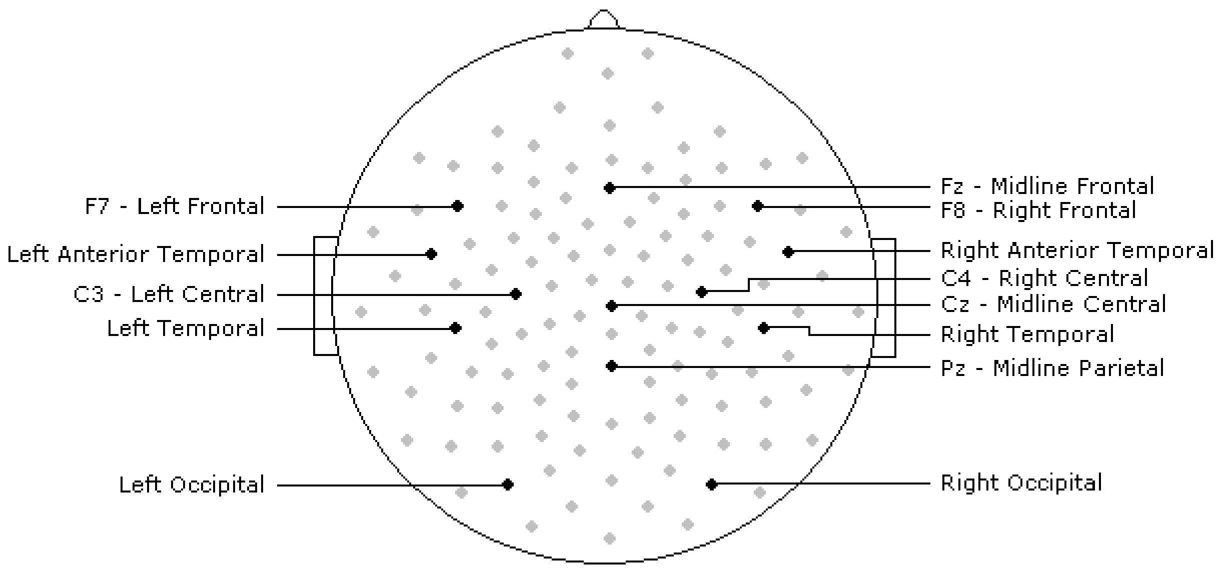
After the EEG recording, subjects were given a written questionnaire to evaluate and briefly explain their performance in the experiment, mainly the reading of the paragraphs (see Appendix B). The objective of this last task was to try to elucidate how the subjects approached the reading task and whether they had any difficulty in performing it.

3.3 ELECTROENCEPHALOGRAM (EEG) RECORDING PARAMETERS

The EEG was recorded continuously on an Electrical Geodesics Inc. (EGI) 128-channel Ag/AgCl electrode net (Electrical Geodesics Inc., Eugene, OR, USA). Midline frontal (Fz), central (Cz) and parietal (Pz) recording sites were used, along with lateral pairs of electrodes over frontal (F7 and F8) and central (C3 and C4) scalp as defined by the 10-20 system (Jasper, 1958). Three lateral pairs were also used: (1) an anterior temporal pair placed midway between F7- T3 and F8 - T4 (approximately over Broca’s area and its right hemisphere homologue); (2) a temporal pair placed 33% lateral to Cz and (3) an occipital pair placed midway between T5 - O1 and T6 – O2 (see Figure 7 below).

All the electrodes were referred to a common vertex (Cz) on line and later re-referenced to an average of the left and right mastoid sites. Recordings that were contaminated by excessive eye blinks were rejected (rejection criterion of 70 μV in eye channels). Automatic eye-movement correction was conducted, according to the methods used by Jervis et al. (1985). EEG was recorded continuously with a sampling rate of 1000 Hz. Impedance of electrodes was kept below 40kΩ. All data was stored on hard disk for later analysis.

Figure 7 - Headmap with the electrodes considered in this study



3.4 PROCEDURES

Subjects were run individually in one experimental session lasting approximately 90 minutes. Data collection was divided into three parts.

In the first part, subjects received explanation about the steps involved in the whole experiment, read and signed their informed consents and performed the reading span test, after receiving training on the procedure involved in this test. As already explained above, subjects read aloud increasing sets of sentences displayed on a computer monitor, that is, five sets of two sentences, three sentences, and so on, until they got to the last set of six sentences. Every time subjects faced a blank screen which signaled the end of a set, they had to say out loud the last word of each sentence in that set. If subjects could not remember the exact order of the words, they were instructed to say as many of the last words as they could without saying the last word first. The presentation of the sentences was controlled by the researcher: as soon as subjects read the last word of a sentence, the researcher pressed “enter” so that the next sentence appeared on the screen and subjects had to start reading it aloud. All sets of sentences were completed by every subject.

In the second part of the experiment, after the set-up of the EEG net (approximately 20 minutes), subjects were tested in an electrically shielded chamber. They were seated in a comfortable chair, approximately 57 cm in front of a VGA monitor and were instructed to read 60 four-sentence long paragraphs for comprehension and judge whether the last sentence of each paragraph was a suitable conclusion for that paragraph, by pressing “1” or “2” after the prompt “Agree =1 / Disagree =2” appeared on the screen. Subjects were told that they could control the initiation of each paragraph by pressing any key in the keyboard. They were instructed not to blink excessively or move their heads during words presentation; they were free to rest their eyes or move their head during the breaks between paragraphs. The paragraphs were presented word by word in black lowercase Arial letters (the first letter of each sentence was presented in capital letter) against a white background, in the center of the computer screen. The words were displayed for a duration of 300msec/word with a 300/msec interword interval plus 8/msec for screen refresh (stimulus onset asynchrony = 608msec). Subjects received practice before the actual experiment and the trials were presented in two blocks with 30 paragraphs each, with a break of 3 to 5 minutes between the trials.

In the last part of the experiment, subjects were given the retrospective written questionnaire to answer. When the subjects handed in the questionnaires, the researcher quickly read their answers and asked for clarification whenever necessary. Furthermore, any comment made during the experiment in relation to data collection and which was not reported in the questionnaire, was written down by the researcher in the subject’s respective questionnaire.

3.5 DATA ANALYSIS

3.5.1 Scoring reading span

The span measure adopted in this study was the level at which the subject was correct on three out of five of the sets, composed of two, three, four, five and six sentences. That is to say if the subject correctly recalled three final words out of the five *three*-sentence sets, he was given a score of 3. If he was able to recall three final words out of the five *four*-sentence sets, he was given a score of 4 and so on. If the subject was correct on only two of the three-sentence set, for example, he was given a score of 0.5. In this way, the subject would obtain a span of 2.5 (two for the previous set composed of two sentences and point five, meaning half point).

3.5.2 EEG data

Recordings for each participant were segmented off-line into epochs with a pre-stimulus baseline of 100 msec and a post-stimulus of 600 msec. The recordings were averaged across all trials per condition, generating averaged waveforms of the words presented in each paragraph type, for each electrode site, for each subject. The data from the paragraphs were sorted as Text Type (narrative, expository text), Paragraph Type (bridging inference, no-inference) and Word Type (content, function) for both the third and fourth sentences separately.

In this study, content (or major and also, open) words classification consists of nouns, verbs, most adjectives and the -ly adverbs. Function (or minor and also, closed) words include auxiliary verbs (was), articles, complementizers (which), conjunctions, sentence connectors, interrogatives, verb particles, prepositions, pronouns and some adjectives and adverbs.

All the data were bandpass filtered using a bi-directional 3 pole Butterworth filter (Alarcon, Guy, & Binnie, 2000) between 0.1 and 30 Hz. Repeated-measures ANOVAS used the most negative peak values computed for each subject in the typical N400 window of 300 to 500 msec, for both third and fourth sentences. For the N1 component, this study considered the most negative value between 85 to 135 msec, also for both third and fourth sentences.

3.5.2.1 Behavioural responses

The behavioral data, which was recorded simultaneously to EEG acquisitions, with the aid of EPrime program, was scored according to the subjects' responses in relation to their judgment of the paragraphs (suitable conclusion/agree or not suitable conclusion/disagree) and sorted according to each type of paragraph, i.e., exposition bridging, exposition no-inference, narrative bridging, narrative no-inference.

3.5.3 Retrospective written questionnaires

Answers of the subjects in relation to their overall performance in the experiment were transcribed verbatim and can be visualized in Appendix C. The subjects' comments made during any part of the experiment and which were not included in their written answers were added by the researcher and registered between brackets, in a smaller font in bold.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents and discusses the results obtained from the instruments used in this study: the Reading Span Test (RST), the retrospective questionnaires as well as behavioral and EEG data. The chapter is organized in the following way.

In the first part, the results concerning the RST and the retrospective questionnaires are reported; in the second part, behavioral data generated from the experimental paragraphs is presented then, in the third part, the EEG data is presented according to two time windows of interest (85-135 msec for the N1 component and 300-500 msec for the N400 component). The N400 and N1 data referring to the fourth sentence will be presented first, followed by the data for the third sentence.

In the fourth part, the discussion of the data will be presented in the light of the review of the literature discussed in Chapter 2. Finally, the hypotheses investigated in the study will be discussed according to the findings reported in the present chapter.

4.1 READING SPAN TEST

As mentioned previously in Chapter 3 – Methods, the span measure adopted in this study was the level at which a subject was correct on three out of five of the sets. Subjects were classified as higher or lower span readers according to their scores on the reading span test on a scale of 0.5 to 6.0. As Tomitch (2003) explains, there is not much agreement in the literature to what constitutes high and low spans readers. Therefore, in the present study, subjects who scored 2.0 and 2.5 were classified as lower spans (n= 4) and those who scored from 3.0 to 4.0 were classified as higher spans (n= 10) as can be seen in Table 3 below.

Although many studies on working memory capacity have considered extreme-groups designs, that is, only the upper and lower quartile of a distribution of working memory scores are considered as higher and lower spans (Conway et al., 2005), the present study could not adopt such design because of the small number of subjects involved in the sample.

Table 3 – Subjects' scores on the RST

Subject	RST score
1	2,5
2	2,5
3	2,5
4	2,0
5	3,0
6	3,0
7	3,0
8	3,0
9	3,0
10	3,0
11	3,5
12	4,0
13	3,5
14	3,0

4.2 RETROSPECTIVE QUESTIONNAIRES

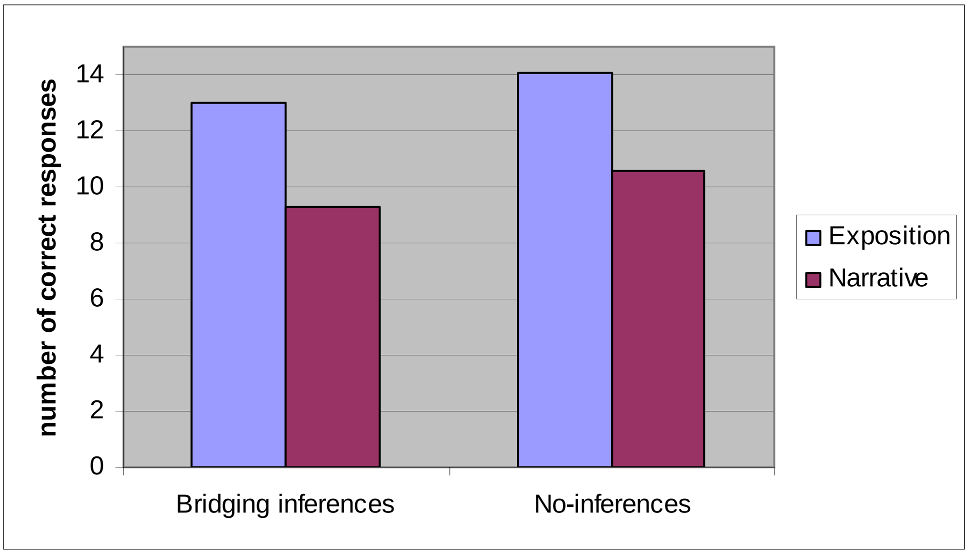
Data obtained from the retrospective questionnaires (see Appendix C) shows that half of the subjects considered the reading task as “very good”; the other half of the subjects classified their performance as excellent (n= 02); good (n= 03) and average (n=2). The question about possible difficulties in reading the paragraphs presented word by word on a computer screen while wearing the EEG cap, reveals that subjects 09 and 11 had physical difficulties and problems in maintaining concentration; subjects 03 and 10 recognized their difficulty in deciding the suitability of the last sentence, and subject 11 stated that sometimes it was hard to remember back to the first sentence. Considering the subjects’ criteria for judging the last sentence of the paragraphs, i.e., whether it was a suitable conclusion for the preceding sentences, one can conclude – based on the subjects’ responses – that they understood the purpose of the task, and that their decisions were mainly based on the bridging inferences drawn during reading. Finally, subjects 02 and 08 recognized their difficulty in the working memory test; subjects 01 and 14 mentioned doubts about vocabulary and subject 13 stated it was difficult to keep focus towards the end of each session of 30 paragraphs.

4.3 BEHAVIORAL DATA

The behavioral data corresponds to the subjects’ judgment in relation to the suitability of the last sentence, i.e., whether it was a plausible conclusion according to the information presented in the three previous sentences, for each of the 60 paragraphs. For each subject the number of correct answers (n= 15) was counted and sorted according to paragraph type (exposition-bridging, exposition-no-inference, narrative-bridging, narrative-no-inference).

Descriptive statistics show that subjects were better at drawing bridging inferences while reading expository paragraphs (means= 13.0) than when reading narrative paragraphs (means= 9.29 - see Figure 8). The same pattern occurs for the no-inference condition: subjects were better at judging the unsuitability of the last sentences of expository paragraphs (means= 14.07) than those presented in the narrative paragraphs (means= 10.57).

Figure 8 - Overall means for behavioral performance in judging the suitability of the last sentence

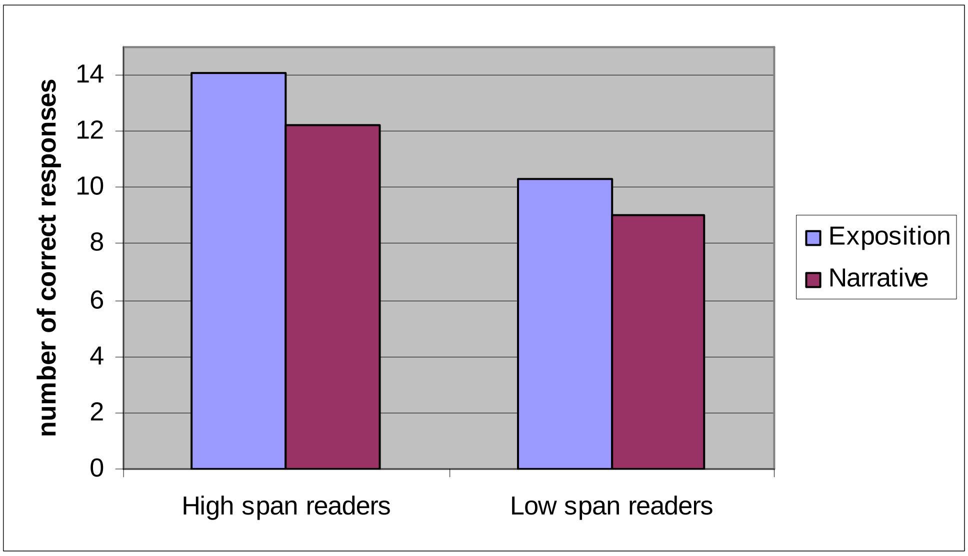


A repeated-measures ANOVA with the factors type of inference (bridging, no-inference) and text type (expository, narrative) revealed a significant main effect of text type (F (1,13) = 21.317, *p*= <.001). The main effect of type of inference approached significance (F (1,13) = 4.613, *p*= .051). The interaction between text type and type of inference did not reach significance. The RST was not considered as a between-subjects variable in this part of the analysis and the following EEG analyses due to the limited number of low span readers (n=4) in this study, which is insufficient to run ANOVAs.

Overall means demonstrate that both high (n=10) and low (n=4) span readers tended to perform better when reading the expository paragraphs (means= 14.05 and 12.25, respectively) than when reading the narrative paragraphs (means= 10.31 and 9.0 respectively – see Figure 9).

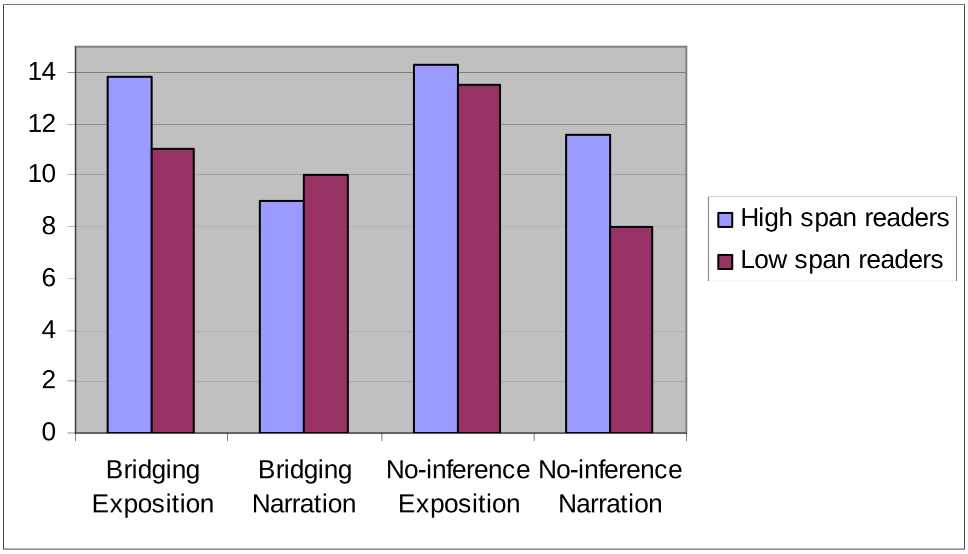
Pearson's correlation coefficient shows there is a significant, positive correlation (r=.748) between scores for the bridging inferences in the expository paragraphs and the Reading Span Test (RST) (*p*= .002). A negative (r= -.474) and

Figure 9 - High and low span readers' performance in judging the suitability of the last sentence



non-significant correlation (*p*= .087) was found between scores for the bridging inferences in the narrative paragraphs and the RST. The correlations between the RST and the control conditions, i.e., no-inferences, for both expository and narrative paragraphs did not reach significance (see Figure 10).

Figure 10 – Higher and lower span readers' performance in judging the suitability of the last sentences per condition



4.4 EEG DATA

As mentioned above, given the insufficient number of low span readers in this study, it was not possible to consider the Reading Span Test as a between-subject variable. Therefore, EEG analyses will consider all the factors investigated in each run of data as within-subjects variables, that is to say, all the variables will be measured and related to a single, homogeneous group.

The N400 component

Before presenting the results related to this component, let us recall that the N400 amplitude indexes the ease or difficulty of semantic integration between the focal and the preceding context. Given the fact that all words elicit an N400 (Kutas & Schmitt, 2003), this is a sensitive measure for meaning access and integration, being therefore, a useful index for analyzing discourse processing (Kutas & Hillyard, 1984; Raney, 1993; van Berkum, Haggort & Brown, 1999; Salmon & Pratt, 2002) and more specifically, the process of inference making (St. George, 1995). Now let us move to the results.

The N400 data generated by the words in the final and third sentences of each of the paragraphs was analyzed according to the 300-500 msec time-window, typical of the N400 component. The data for the fourth sentence will be presented first, followed by the data generated by the third sentence. Results will be presented in the following order. First, differences in amplitude between paragraphs types (exposition bridging, exposition no-inference, narrative bridging, narrative no-inference) across scalp sites (13 levels) will be examined; then amplitude differences regarding type of word (content, function) across text type (exposition, narrative) and scalp areas (midline, RH, LF) will be presented.

N400: sentence four

The values for the N400 component were calculated by locating the maximum negative values in microvolts (μV) between 300 and 500 msec for each of the conditions considered in this study, for each subject. The grand averages for the paragraph types in the final sentence (exposition bridging, exposition no-inference, narrative bridging, narrative no-inference) are displayed in Figures 11 and 12 below. In accord with other studies using visual words (Coulson & Van Petten, 2002) the ERPs in this study are characterized by N100 peaks at frontal and central sites and a P2 component seen at all sites, except the occipital. These components are followed by N400s, identified at most sites.

A two-way repeated-measures ANOVA with paragraph type (exposition bridging, exposition no-inference, narrative bridging, narrative no-inference) and scalp site (13 levels) was conducted to verify possible amplitude differences between paragraph types. The analysis showed that there is a significant main effect of scalp site (F (12,156) = 14.102, p= <.001), with the maximal amplitude measured over the central site (Cz, means = - 3.12 μV) which was significantly different from amplitudes measured at all other sites (p<.05), except the midline Fz and Pz and the right occipital site (p>.05). No other main or interaction effects were found. Even though not statistically significant, it is interesting to mention that, for the bridging inference condition, the focus of this study, all electrodes placed over the RH (right hemisphere) of the scalp yielded marginally larger N400s than their respective pairs, placed over the left hemisphere (LH).

Figure 11 - Headmap showing electrodes of interest. Average waveforms for each site for the Expository Bridging (blue line) and Expository No-inference (pink line) conditions. The electrodes are referred to their location and correspond respectively to electrodes (from left to right, top to bottom): 11, 129, 62, 122, 104, 115, 102, 90, 33, 36, 39, 46, 65. Negativity is plotted up.

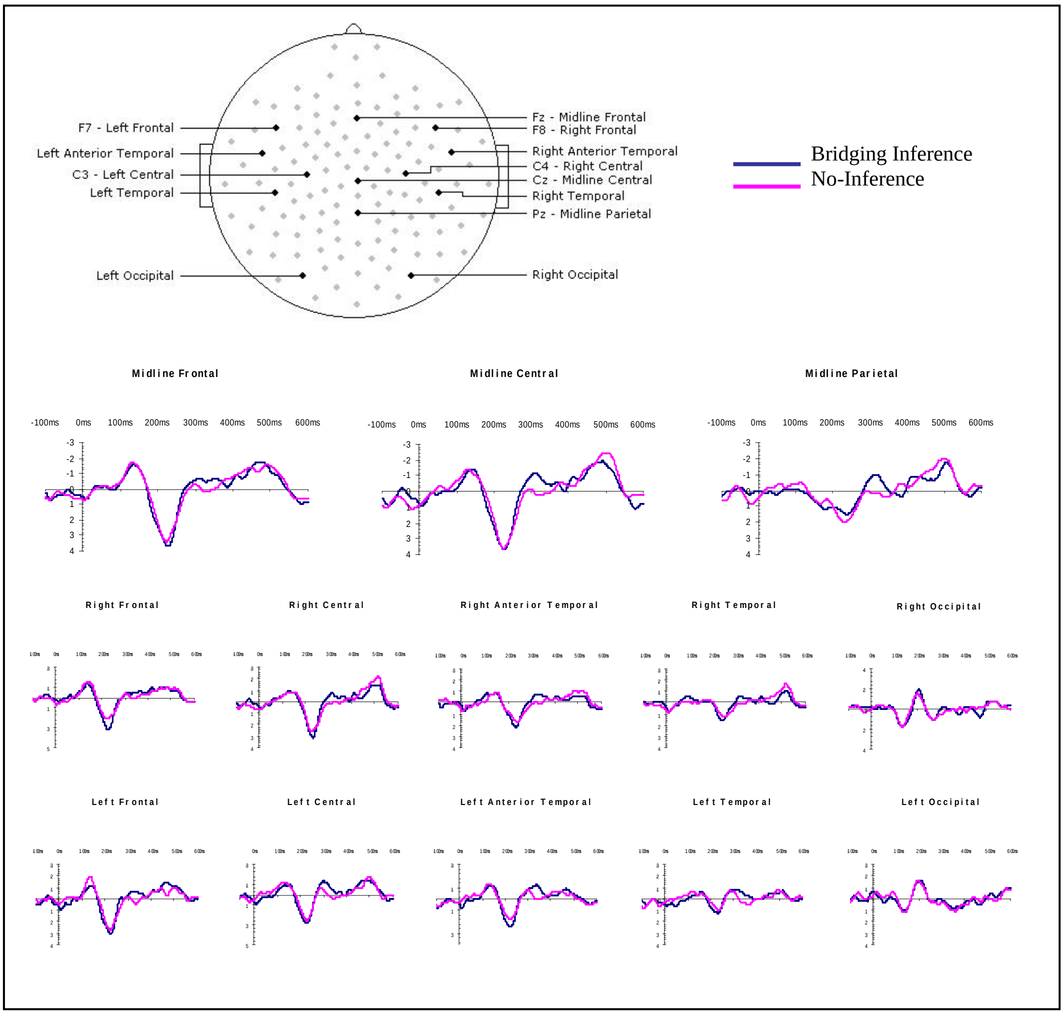
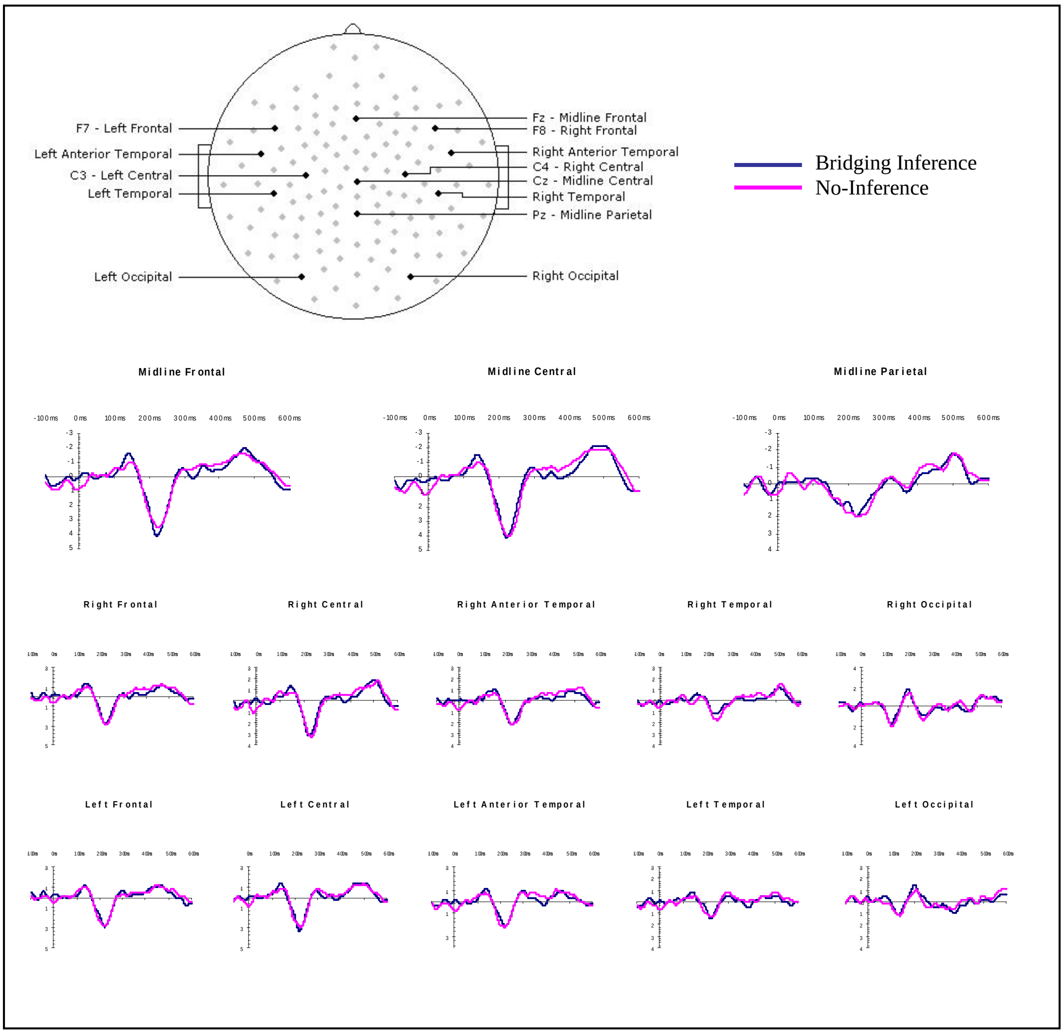


Figure 12 – Headmap showing electrodes of interest. Average waveforms for each site for the Narrative Bridging (blue line) and Narrative No-inference (pink line) conditions. The electrodes are referred to their location and correspond respectively to electrodes (from left to right, top to bottom): 11, 129, 62, 122, 104, 115, 102, 90, 33, 36, 39, 46, 65. Negativity is plotted up.



Again, although there was not a statistical significant difference between paragraph types (F < 1.0) overall means show that there was a marginally difference in terms of the N400 peak values between exposition bridging (means= - 2.20 µV) and narrative bridging (means= - 2.02 µV). Overall means also show that the N400 peaks were marginally lower in the narrative bridging condition (mean: - 2.02 µV) compared to the narrative no-inference control (means= - 2.21 µV), but an opposite, unexpected pattern is observed for the exposition bridging (means= -2.20 µV) versus exposition no-inference control (means= - 2.11 µV) conditions. These figures will be further examined when analyzing the N1 component data.

A three-way repeated-measures ANOVA with type of word (content, function), text type (exposition, narrative) and scalp area (midline, RH, LH) as factors was conducted to investigate possible amplitude differences between type of word and text type at three scalp areas, mainly RH and LH. The 13 electrodes considered in this study were grouped according to their position on the scalp: midline position (Fz, Cz, Pz); RH: (F8, C4, electrodes 115, 102, 90) and LH (F7, C3, electrodes 39, 46, 65). The analysis revealed a significant main effect of scalp area ($F(2, 26) = 48.864$, $p = <.001$). No other significant main or interaction effects were found.

For the main effect of scalp area, N400 peak values were larger in the midline area (means= - 2.74 µV), followed by the RH (means= - 2.0 µV) and by the LH (means= - 1.82 µV) in third. Pair-wise comparisons revealed there is a significant difference in the N400 amplitudes between midline area and RH ($p < .001$) and midline area and LH ($p < .001$) but not between RH and LH ($p > .05$).

The main effect of type of word was not statistically significant (F < 1.0) but mean averages demonstrate that the N400 peak values for function words were marginally larger (means= - 2.23 μV) than for content words (means= - 2.16 μV). The main effect of text type was not statistically significant either and mean averages show that the N400s in response to the narrative type of text are marginally larger (means= - 2.20 μV) than the N400s for the expository type of text and (- 2.17 μV).

The N1 component

Following the research conducted by St. George (1995), this study also considered the analysis of an early component, known as N100 or simply N1. This component is a negative wave that occurs at approximately 100msec post-stimulus. Although this component is commonly investigated in auditory and visual discrimination paradigms, the N1 was considered in this study to investigate subjects' cognitive load while reading the words presented in both third and fourth sentences.

The rationale for using this component as a valuable measure of attentional capacity is based on previous studies that suggest that the N1 reflects low-level processes, such as word encoding (Raney, 1993; St. George, Mannes & Hoffman, 1994; St. George, 1995). According to these researchers, when subjects are facing difficulty to integrate sentence information into a coherent text, they have fewer resources to allocate for word encoding, which is revealed by low N1 amplitudes. Lower N1s can be interpreted then, as the subjects' greater involvement in the process of making sense of the text, or in the case of this study, the subjects' involvement in making inferences.

The N1 data generated by the words was analyzed according to the 85-135 msec time-window. Results will be presented in the same order of the N400 component, i.e., first, differences in amplitude between paragraphs type across scalp sites (13 levels) and then amplitude differences regarding type of word (content, function) across text type (exposition, narrative) and scalp areas (midline, RH, LF) will be presented.

N1: sentence four

A two-way repeated-measures ANOVA with paragraph type (exposition bridging, exposition no-inference, narrative bridging, narrative no-inference) and scalp site (13 levels) as factors was conducted to verify amplitude differences between paragraph types. The main effect of scalp site was significant (F (12,156) = 6.876, *p*= < .002) (see Figures 10 and 11 above for differences in amplitudes). No other main or interaction effects were found. Although not statistically significant, electrodes placed over central, frontal and temporal sites yielded smaller N1s in the LH for the expository type of text, and in the RH for narration, in the bridging inference condition. The other electrodes placed over anterior temporal and occipital sites yielded smaller N1s for both types of text.

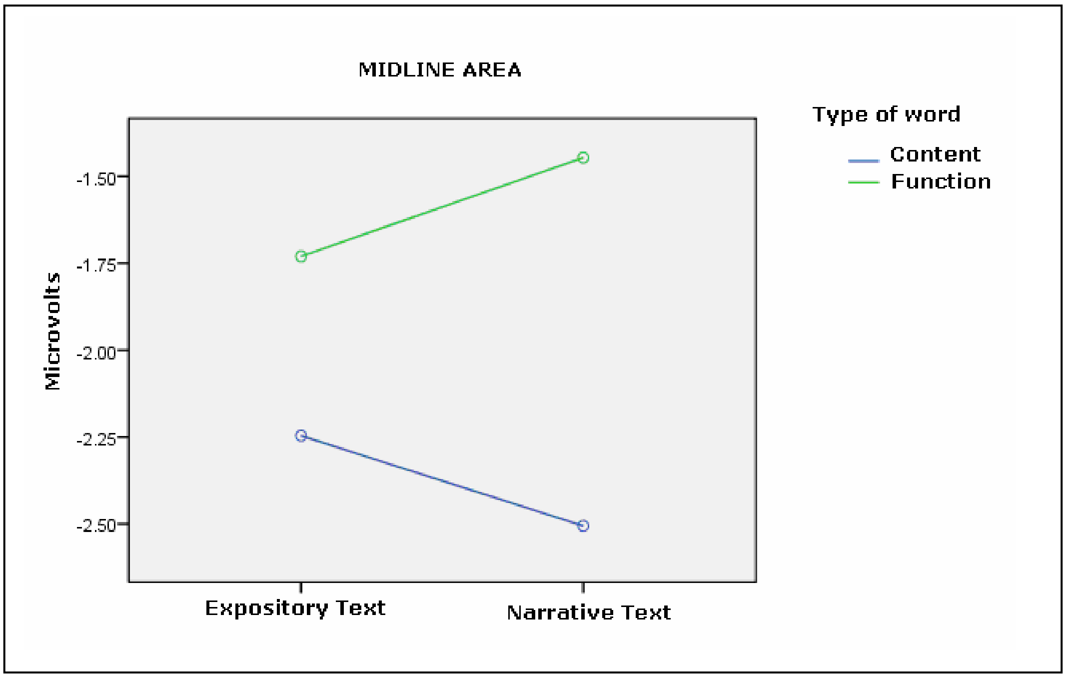
Mean averages show a lower N1 component for the exposition bridging (- 1,26 μV) compared to the exposition no-inference type of paragraph (- 1,59 μV), corroborating the N400 data. Remember that the N400 results presented an unexpected finding in relation to these two types of paragraph, i.e., that the N400 peak in the expository no-inference condition is lower (instead of larger) than the N400 in the expository bridging condition. The N1 values for these two types of paragraph demonstrate that the expository no-inference condition demanded less cognitive capacity of the readers to process the words of the fourth sentence thereby freeing their capacity to concentrate on word encoding, reflected by a large N1. All the other N1 means corroborate the figures of the N400 data.

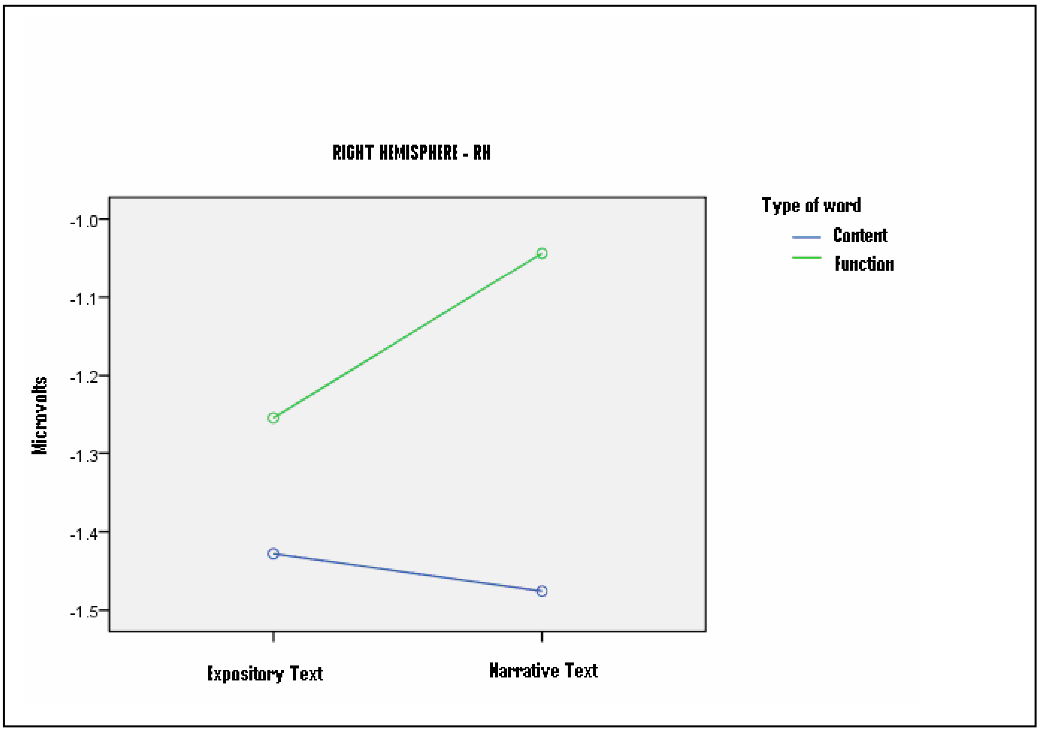
A three-way repeated-measures ANOVA with type of word (content, function), text type (exposition, narrative) and scalp area (midline, RH, LH) as factors was conducted to investigate possible amplitude differences between type of word and text type at three scalp areas. The analysis showed significant main effects of scalp area (F (2,26)= 20.740, *p*= <.001) and type of word (F (1, 13)=19.403, *p*= .001) and significant interactions between scalp area and type of word (F (2, 26)= 7.351, *p*= .004) and text type and word (F (1, 13)= 7.661, *p*= .016). No other significant main or interaction effects were found.

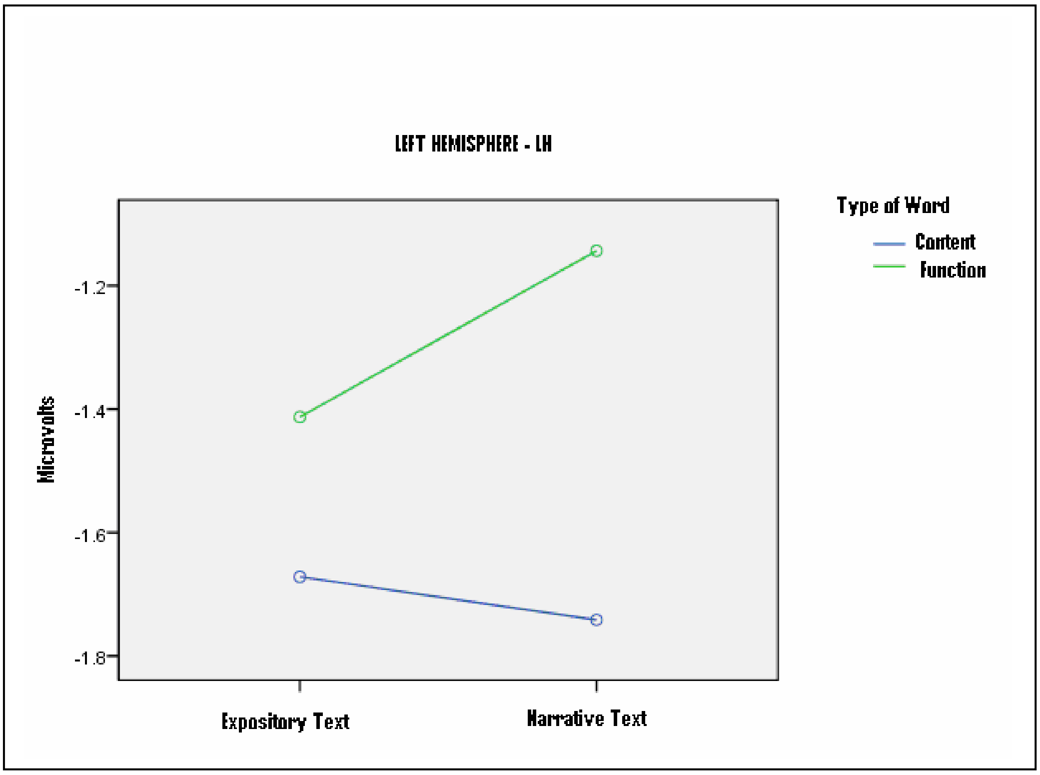
For the main effect of scalp area, mean N1 amplitudes were lower in the RH (means= -1.3 μV), followed by the LH (means= - 1.49 μV) and by the midline area (means= - 1.98 μV). Pair-wise comparisons demonstrate there is a significant difference in the N1 amplitudes between midline area and RH (p<.001) and midline area and LH (p<. 006) but not between RH and LH (p>. 05).

The N1 amplitudes for the main effect of type of word were lower for function words (means= - 1.33 μV) than for content words (means= - 1.84 μV). The interactions between scalp area and type of word and text type and type of word are illustrated in Figure 13 below. Analysis of results revealed that the N1 peaks were larger for content words in the narrative type of text and function words in the expository type of text, in all the three scalp areas, suggesting that subjects approached/read the two types of texts differently. As shown in Figure 13, there are considerable differences in the N1 amplitudes for the type of word across text types. Although the results from the N400 marginally signal that subjects had more difficulty in reading the function words of the paragraphs, the N1 amplitudes indicate that this seems to be the case. As the figures demonstrate, the function words elicited lower N1 amplitudes when compared to the content words in all the selected sites signaling that subjects were devoting more cognitive resources to process those words. When reading the narrative paragraphs, subjects seemed to devote more attention to function words, as revealed by the low N1s, than when reading the expository paragraphs. For this type of text, subjects tended to adopt a balance between content and function words, that is, they seemed to share their cognitive resources to process both types of words in a similar fashion.

Figure 13 – Means for the interaction between scalp area and type of word and text type







N400: sentence three

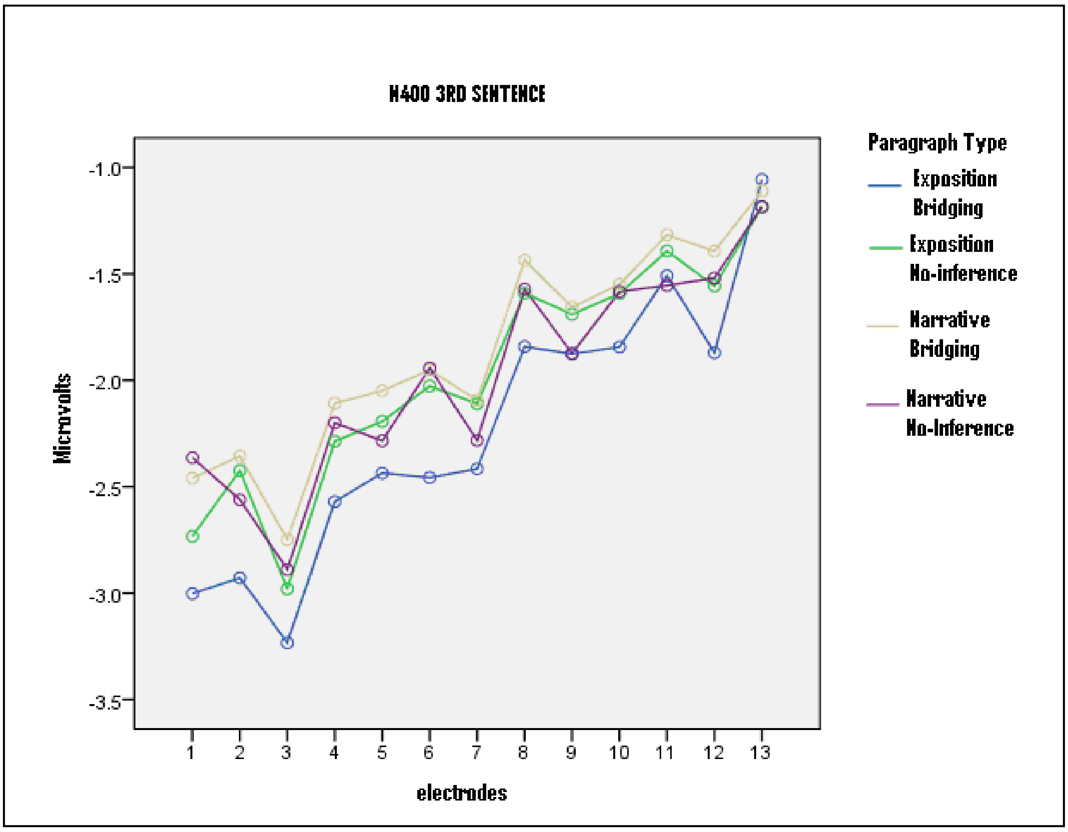
The N400s for the third sentence are examined in this study to investigate possible amplitude differences already in sentence three. The marginally different N400 results for sentence four led us to believe that there may be differences in sentence three. It was hypothesized that since subjects were in the process of making inferences during the second and third sentences, that they could have anticipated the outcome of the paragraphs in a suitable / unsuitable conclusion before the beginning of the fourth sentence. If this was the case, there ought to be differences in amplitudes for sentence three.

A two-way repeated-measures ANOVA with the same factors used for sentence four, i.e., paragraph type (exposition bridging, exposition no-inference, narrative bridging, narrative no-inference) and scalp site (13 levels), was conducted to verify possible amplitude differences between paragraph types in sentence three. The analysis showed significant main effects of scalp site (F (12,156) = 17.591, *p*= <. 001) and paragraph type (F (3, 39) = 4.860, *p*= .008). In relation to the main effect of scalp site, maximal amplitudes were measured over the central site (Cz, mean = - 2,96 μV) and they were significantly different from amplitudes measured at all other sites (*p*< .03), except the midline Fz and Pz (*p*> .05). Even though differences did not reach statistical significance, the bridging condition yielded larger N400 amplitudes for the electrodes placed over the LH at central, temporal and occipital sites; for the anterior temporal site, higher amplitudes were found in the RH, for both types of text.

Pair-wise comparisons for the main effect of paragraph type showed a significant difference between exposition bridging (more negative) and narrative bridging conditions (*p*= .018) (see Figure 14). No other significant comparisons were found.

Although the interaction between scalp site and paragraph type did not reach significance (F < 1.0), it is interesting to note that the expository bridging condition showed larger N400s at all electrodes sites, except at the left central, left anterior temporal and left occipital sites.

Figure 14 – N400s for 3rd sentence



Electrodes: (1) midline frontal (Fz); **(2)** central (Cz); **(3)** parietal (Pz); **(4)** right central; **(5)** left central; **(6)** right frontal; **(7)** left frontal; **(8)** right anterior temporal; **(9)** left anterior temporal; **(10)** right temporal; **(11)** left temporal; **(12)** right occipital) and **(13)** left occipital

A three-way repeated-measures ANOVA with type of word (content, function), text type (exposition, narrative) and scalp area (midline, RH, LH) as factors was conducted to investigate possible amplitude differences between type of word and text type at three scalp areas, already in sentence three. The analysis revealed that the main effect of scalp area was significant (F (2,26)= 26.102, *p*= < .001) and that there is a significant interaction between scalp area, text type and type of word (F (2, 26)= 14.672, *p*= .001). No other significant main or interaction effects were found.

The main effect of scalp area show that the N400 was considerably larger in the midline area (means= - 2.66 μV) than on the RH (means= - 1.98 μV) or LH (means= - 1.79 μV). Pair-wise comparisons demonstrate there is a highly significant difference in the N400 amplitudes between midline and RH ($p < .001$) and midline and LH ($p < .001$) but not between RH and LH ($p > .05$). The interaction between scalp area, text type and type of word show that in the midline area, N400 amplitudes were larger for function words in the expository text only (means= - 2.88 μV). Content words revealed larger N400s in the expository type of text in both the RH (means= - 2.01 μV) and LH (means= - 1.80 μV) and in the narrative type of text in the midline area (means= - 2.69 μV). The same N400 amplitude was registered for both content and function words in the narrative type of text in the RH (means= - 1.97 μV) and LH (means= - 1.79 μV).

N1: sentence three

The N1 data generated by the words in the third sentence will follow the same order adopted to present the data of the N400 component. Therefore, differences in amplitude between paragraphs types across scalp sites (13 levels) will be presented first, followed by amplitude differences regarding type of word (content, function) across text type (exposition, narrative) and scalp areas (midline, RH, LF).

A repeated measures ANOVA with the factors of paragraph type (exposition bridging, exposition no-inference, narrative bridging, narrative no-inference) and scalp site (13 levels) yielded a main effect of scalp site (F (12,156) = 7.867, *p*= < .002). Mean averages of N1 amplitudes were found considerably lower over midline parietal (Pz), right and left temporal and occipital sites (means= - 0.69 µV) than over central and frontal sites (means= - 1.37 µV). No other main or interaction effects were found.

For the bridging condition, even though not statistically significant, lower N1 amplitudes were yielded in the LH for electrodes placed over central, frontal, temporal and occipital sites, for exposition. The anterior temporal site yielded lower N1s in the RH for both types of text.

Another ANOVA with type of word (content, function), text type (exposition, narrative) and scalp area (midline, RH, LH) as factors was conducted to investigate N1 amplitude differences between type of word and text type at three scalp areas. The analysis showed highly significant main effects of scalp area (F (2, 26)= 12.773, *p*= <.001) and type of word (F (1, 13)= 29.232, *p*= <.001) and significant interactions between scalp area and type of word (F (2, 26)= 9.831, *p*= .001) and text type and word (F (1, 13)= 5.602, *p*= .034). No other significant main or interaction effects were found.

The lower amplitudes were measured in the RH (means= -1.31 µV), followed by the LH (means= -1.41 µV) and by the midline area (means= - 1.81 µV). Pair-wise comparisons reveal there is a significant difference in the N1 amplitudes between midline and RH (*p*= .004) and midline and LH (*p*= .009) but not between RH and LH (*p*>.05). The main effect of type of word show that the lower N1s were measured for function words (means= -1.18 µV), which differs significantly from the content words (means= -1.84 µV). The interaction between scalp area and type of word revealed that function word amplitudes were lower than content words in all the scalp areas. The interaction between text type and type of word showed that both expository and narrative types of text yielded lower N1 amplitudes for function words.

The data presented in the previous pages will be discussed below in light of the findings brought by the relevant literature addressed in Chapter 2.

4.5 DISCUSSION OF RESULTS

This section is organized in the following way: first, the results concerning the behavioral data, the Reading Span Test (RST) and the answers to the retrospective questionnaires will be discussed and related to findings of previous studies; then the results concerning the EEG data will be addressed regarding the two ERP components considered in this study: the N1 and the N400. Finally, this section will close with the discussion of the hypotheses that nurtured the present investigation.

In relation to the ***behavioral*** data, results on accuracy performance (i.e., agreement/disagreement for the appropriateness of the last sentence for each paragraph) demonstrated that subjects had a significant better performance when reading exposition, that is to say, they probably generated bridging inferences more easily and were better at judging the unsuitability of the last sentence in the expository rather than in the narrative paragraphs. These findings were somewhat surprising, since the literature has provided substantial evidence that readers generate considerably more inferences when reading narratives (Graesser & Kreuz, 1993; Trabasso & Magliano, 1996). Nevertheless, in the study conducted by Horiba (2000), the author also observed that readers generated backward connecting inferences, i.e., bridging inferences, more frequently for essays than for stories. The author interpreted that the type of expository text used in that study - newspaper essay - was less demanding than the typical expository passages that have been used in former research with exposition. This also seems to be the case in the present study, as will be explained below.

The expository paragraphs designed for the present investigation, as already described in Chapter 3, were extracted from authentic material and adapted so that they represented a complete and unified piece of writing. The paragraphs addressed topics related to general knowledge and were not aimed at presenting information which readers were expected to acquire as knowledge. In fact, most of the studies that have investigated the process of inference making in exposition have worked with quite difficult or unfamiliar science topics, such as chlorine compounds and propellants (Noordman, Vonk & Kempf, 1992), nuclear power and star explosions (Millis & Graesser, 1994), among others.

Therefore, given the fact that the expository paragraphs of this study approached general topics and were organized on the basis of a logical sequence relation of facts, which were interrelated across sentences, it is possible that readers processed the informational structure quite easily, once they were all university students and as such, are often required to read more complex expository texts than the paragraph-like texts they had to read during the experiment. Hence, it is possible that the reading process of expository paragraphs was somewhat similar to the flow of reading normally associated with narratives, which are generally processed easily by readers. In fact, subjects' answers in the retrospective questionnaire suggest that this was exactly the case: only two of the fourteen subjects considered their reading performance as "average"; all the other subjects made a positive evaluation about their reading, that is to say, they considered their performance as good, very good, or excellent. In addition, assuming that the subjects of this study probably have more contact with the expository type of text, again, as required by their readings at the university, it seems reasonable to conclude that it may be the reason for the higher number of correct responses in relation to the appropriateness of the last sentence in this particular type of text. Even though narratives are part of everybody' life since infancy and accordingly, expected to be easier to comprehend and to promote increased inferencing than exposition, it seems that, in this study, this factor has not been so influential, similar to the results found by Horiba, in what concerns bridging inferences.

Regarding the accuracy performance in the two conditions explored in this study, i.e., bridging and no-inference, results showed that subjects detected the inconsistencies in the paragraphs in the no-inference condition somewhat more easily than in the bridging condition, although this difference was not statistically significant. It is worth mentioning that this particular finding is difficult to compare with previous research for two main reasons. First, because most of the studies on inference making have used verbal protocols to assess whether inferences were drawn, and second, because the few studies that have used a similar paradigm of investigation, that is, congruent / incongruent conditions, have either not adopted a behavioral response or used one type of response that was not directly related to the judgment of the conditions. The study by Schmalhofer et al. (2005) is the only study - among the studies reviewed in the present dissertation - that used a similar behavioral measure to detect accuracy performance in terms of inference generation. In that study, the authors report a greater proportion of correct responses for the control (no-inference) condition, similar to the behavioral findings observed in the present study. Thus, the results in this investigation provide evidence that when comprehenders read short texts, they are able to detect incoherence in both narrative and expository types of texts.

A previous study conducted by Tomitch (2005) has demonstrated that poor readers tend to have difficulties to detect distortions while reading expository texts. This was not the case in the present investigation: when the subjects of the this study were divided according to their scores on the RST, results continued to show that both higher and lower spanners demonstrated a tendency to perform better when judging the incoherence of expository paragraphs, as contrasted to the narrative paragraphs. Nevertheless, it is important to mention that Tomitch worked with longer texts, when the impact of working memory capacity is probably stronger. That is to say, readers have more competing information that may tax their capacity, and prevent them from noticing inconsistencies, differently to what may occur when reading short, four-sentence long texts, as was the case in the present study. Furthermore, Tomitch adopted two other measures of reading ability, besides the RST, to categorize her subjects as better and weaker readers. One may argue that this fact may have provided an accurate measure to separate better from weaker readers, and that this may also explain the difference in results between her study and the present research. This investigation has a considerably small number of lower span readers, especially when compared to the great majority of studies on individual differences, which tend to work with much larger groups. Nonetheless, the finding that lower spanners demonstrated a similar performance to their counterparts regarding the judgment of incoherent paragraphs was somewhat surprising, especially if one considers the mode of presentation of the stimulus, as also stated in St George's (1995) study. According to Just and Carpenter's Capacity Constrained Comprehension (1992), a reader's working memory capacity involves both lower-level (matching, recoding, lexical access, parsing…) and higher-level (inferencing, summarization, use of background knowledge and strategies…) processes. When working memory capacity is taxed, some of these processes are known to suffer, especially in circumstances when readers are not allowed to retrieve words or sentences for clarification, as was the case in the present investigation. Therefore, the reason for the high percentage of correct responses to the incoherent expository paragraphs by lower spanners in this study, is an issue that deserves further investigation.

The positive correlation between the scores for the bridging inferences in the expository paragraphs and scores on the **Reading Span Test (RST)** reveals that higher spans were better at drawing bridging inferences while reading exposition. The finding that higher spanners outperformed lower span readers is in agreement with previous studies on individual differences and particularly with those that have investigated the process of inference making (Daneman & Green, 1986; Whitney et al., 1991; Singer et al., 1992; Linderholm & van den Broek, 2002; Cain et al., 2004, among others). On the whole, all these studies observed that lower span readers - as a consequence of their smaller storage capacity - seem to have more difficulties to draw inferences than their counterparts, as also found in this study, in relation to bridging inferences in exposition. As explained by the literature on individual differences, as lower spans have fewer resources available to maintain previous portions of text and/or their background knowledge activated while processing the textual, focal information, their comprehension tends to be faulty.

An opposite pattern was found for bridging inferences in narration, when lower spans marginally outperformed higher span readers. Even though such negative correlation did not reach significance, this is an interesting result that is worth discussing. As already pointed out in the previous paragraph, the literature signals that an individual’s ability to process language is constrained by his/her working memory capacity, with low spans having a weaker performance than higher spans. This was not the case in relation to bridging inferences in the narrative paragraphs, when higher and lower spans had a similar performance in judging the suitability of the last sentence of stories. However, when the means of both higher and lower spans for the bridging inference in both exposition and narration are compared (Figure 10 above), one may notice that lower span readers demonstrated a similar pattern of performance for bridging inferences in both type of texts. Higher span readers, on the other hand, had a considerably better performance than lower spans in drawing inferences in the expository type of text. These results appear to point to the fact that the process of drawing bridging inferences in expository paragraphs was, in fact, more demanding for lower span readers, given their lower scores in this condition, when compared to higher spans. According to the literature, differences in performance between higher and lower spans will be robust when the task under investigation is relatively complex or difficult, so that lower spans will have memory capacity taxed and consequently, their performance will deteriorate, as occurred in the present study.

Finally, even though neither of the no-inference conditions reached a significant correlation with RST, it is interesting to discuss the quite similar performance of higher and lower span readers when reading the expository paragraphs. Again, this was an unexpected result, mainly for the marginal difference between the two groups. As pointed out previously, subjects (as a single group) had a better performance for the expository type of text possibly because of the organizational structure adopted in the paragraphs and also, because the subjects of this study, as university students, are acquainted with well organized examples of this type of text. Having this in mind, one may infer that the high scores for the no-inference exposition are due to the subjects' ease to detect incoherent conclusions in expository texts. Yet, regarding the small difference between higher spans' and lower spans' performance, it seems reasonable to infer that lower span readers may have taken longer to decide whether the last sentence was plausible or not - recall that the subjects could control the initiation of each paragraph by pressing any key in the keyboard. This fact may have favored the lower spans' scores in this condition, since they could control for extra time, if needed, to respond to the prompt. This assumption could be better interpreted if response latencies to the last sentences were included in the design of the experiment carried out in this dissertation, as Schmalhofer et al. (2005), for instance, have done. Lastly, considering the no-inference narrative paragraphs, higher spans outperformed lower spans, a result that is in line with the literature on individual differences, as already addressed above.

In relation to the **retrospective questionnaire,** it was included in this investigation for two main reasons. First, because of the apparatus used for data collection, that is to say, to check any kind of discomfort subjects could have had during data collection and that could have affected the results. As seen in section 4.2, some subjects reported having difficulties, but when questioned by the researcher, just after they handed in their answers, if they thought that such difficulty(ies) interfered in their overall performance in the reading task, all the subjects gave a negative response. The second reason for using a retrospective questionnaire as an instrument of data collection was because this researcher wanted to verify if subjects had any problems in drawing inferences across the four conditions investigated (i.e., exposition bridging, exposition no-inference, narration bridging, narration no-inference). Only two subjects - one lower and one higher span - reported having difficulties in deciding for the suitability of the last sentence. Inspection of these subjects' scores on the four conditions showed that both of the subjects did, in fact, have difficulties in judging the last sentence of the narrative paragraphs. Although the answers provided in the questionnaires might be of little help to interpret the averaged data on the one hand, i.e., the response of two individuals is a small percentage in a sample of fourteen subjects, on the other hand, some other answers have contributed to eliminate wrong interpretations, like for instance, that subjects were not comfortable during EEG recording and that this was reflected in the results.

Now, moving to **EEG data,** the first finding that calls one's attention is the lack of significant difference between bridging (experimental) and no-inference (control) conditions in the fourth sentence, when subjects' reading process should have varied considerably in terms of N400 amplitudes across these two particular conditions. That is to say, the no-inference condition should have elicited larger N400s for its unexpected or incoherent conclusion, i.e., *Gum chewing increases cognitive capacities.*, in a context stating that *repetitive chewing motion stimulates, besides insulin going to the brain, salivary flow and that it is a combination of water-soluble ingredients*. The bridging condition, on the other hand, given that the conclusion of the paragraph is coherent to the previous context, i.e., *Repetitive chewing motion stimulates insulin going to the brain, as well as thinking and memory,* should have elicited a smaller N400 peak. Although it is possible to visualize that there were differences between bridging and no-inference conditions, i.e., that there was a tendency for more negative N400 waves in the no-inference condition at most sites, as depicted in Figures 11 and 12 above, it is intriguing that these differences were not significant - nor partially significant - as were the findings reported in the St. George study (1995). Recall that the narrative paragraphs used in the present study are the same paragraphs used in the research carried out by St. George. In her study, the author investigated whether individual differences influenced the generation of bridging and elaborative inferences in that investigation. Analysis of data revealed that the most significant differences were observed between bridging and no-inference conditions, contrary to the present study, where differences between these two conditions were small and similar across the text types under investigation, i.e., exposition and narration.

It has been thorny to find a possible explanation for this intriguing finding. Apart from the population - St. George's study was conducted with thirty-three Americans and the present study was carried out in New Zealand, with fourteen native speakers of English - and the behavioral measure - St. George asked subjects to recall (at random) 10% of the paragraphs and the present study asked subjects to judge the suitability of the final sentence according to the three previous sentences - both studies were conducted in the same way.

One may speculate that the behavioral task used in the present study might have differently influenced the way subjects read the texts, generating, therefore, different results from St. George's. It is quite probable that the reading instruction of the present investigation - read to decide if the last sentence is suitable to the paragraph - influenced the reading process as the studies of Narvaez, et al. (1999), Linderholm and van den Broek (2002) and Calvo, Castillo and Schmalhofer (2006) demonstrated. Nevertheless, if we take this issue into account, the present study should have elicited even larger N400s for the no-inference condition, since subjects were focused on the semantic plausibility of the fourth sentence, expecting an adequate conclusion when there was not. In the St. George's study, subjects were instructed to read for comprehension and to be prepared to recall some of the paragraphs. In this way, if we compare the reading tasks of both studies, one would assume that the behavioral task of the present study tends to elicit a more focused semantic processing of text than the task adopted in the study conducted by St. George. Again, this should have elicited larger N400s and not the opposite, as found in the current investigation. This is, therefore, another issue that deserves further investigation, with a larger number of subjects, before any assertions can be made.

One of the main objectives of this study was to investigate whether different types of text would influence the process of bridging inferences. Recall that the behavioral results showed that subjects had a significant better performance in generating bridging inferences and in judging the unsuitability of the control condition when reading the expository type of text. Given these preliminary results, it was expected, therefore, that the EEG data would corroborate these findings, but this is not what it was observed. According to the EEG results, the expository type of text was found to be more difficult to process, as revealed by the larger N400s in the fourth and third sentences for this type of text. Although there was not a significant difference in the N400 waveforms amplitudes in the fourth sentence (where subjects read the explicit inference) between exposition and narration, there was a significant difference in the third sentence (where supporting information was given so as to elicit the inference explicitly stated in the next sentence). This finding appears to signal that, since subjects were already in the process of generating inferences while reading sentences two and three, that they may have anticipated the outcome of the paragraphs already in sentence three, being the fourth sentence, a confirmation for the inference just drawn. This would explain the lack of significant difference in the N400s between exposition and narration in sentence four, i.e., as the words presented in this sentence reflected the inferences already drawn, the N400s for both types of texts were quite similar, once they (N400s) were indexing expected information.

Another finding that led us to the interpretation that bridging inferences (and probably the judgment for the no-inference condition) were already being drawn in sentence three and therefore, support the assumption that exposition was more demanding than narration, in terms of N400 amplitudes, is related to the N1 component. This ERP component revealed significantly lower amplitudes for function words in both exposition and narration in that sentence.

According to some previous EEG studies that discriminated words into *content* (nouns, verbs, most adjectives, -ly adverbs) and *function* (auxiliary verbs, articles, conjunctions, connectives, pronouns, prepositions…) classes (St. George et al. 1994; 1997), there are differences in terms of the N400s elicited by these two categories of words. Function words tend to yield smaller N400s (when compared to content words) probably because of their higher frequency and greater predictability in language (van Petten, 1995). Therefore, it is reasonable to assume that lower N1s for this type of words would mean that subjects were allocating significantly more resources on syntactic carrier-words to integrate the focal information into a coherent text representation, as a result of the process of inference making. When the N1 means of the third and fourth sentences were compared, it was possible to notice a considerable increase (although not statistically significant) in the N1 amplitude in the fourth sentence. This was interpreted as a reduction in the amount of attention being allocated to function words when subjects were integrating their inferences into the internal representation of the paragraphs. It seems reasonable to conclude therefore, that since subjects had already computed the necessary syntactic information required to generate inferences while reading sentence three, that they could have allocated their resources differently by focusing more on semantic information, that is, content words, and possibly other levels of discourse while reading sentence four for inference integration.

Let us get back to the fact that the EEG data contradicts the behavioral results concerning the expository type of text. Although unexpected on the one hand, i.e., it should be in line with behavioral data, the EEG finding that exposition was more demanding than narration, was, on the other hand, one of the hypothesized findings. Let me explain. When the behavioral results were discussed in earlier parts of this section, it was mentioned that the fact that subjects tended to have a better performance while reading exposition, was contradictory to what has been shown, and frequently argued in the literature, that is, that narration is easier to comprehend than exposition (Noordman et al., 1992, Graesser & Kreuz, 1993; Trabasso & Magliano, 1996). The fact that behavioral results showed that the expository paragraphs had a higher number of correct responses than narration, led us to infer that the EEG data would be in line with these findings. Nevertheless, when the EEG results showed that exposition was more demanding (as revealed by the N1 and the N400 amplitudes) than narration, this result was said to be expected, because after all, it is in line with the discourse comprehension literature. Having this in mind, one has to remember that the behavioral findings of this study showed a final product, that is, the results of some cognitive effort to decide for an answer. The EEG results, on the other hand, showed what happened in one’s brain while the cognitive task to read to decide for an answer is undertaken. It is possible, therefore, that these results may not be as contradictory as they seem. This issue will be retaken when interaction between type of word and text type is discussed in the following paragraphs.

As mentioned in the previous paragraphs, the overall N1 amplitudes for function words in the fourth sentence demonstrated a considerable increase, and this was interpreted as a reduction in the cognitive resources devoted to this type of words, in detriment of other lower or higher-order processes. It is interesting to mention, however, that the larger N1 amplitudes were yielded mainly at the midline area and in the LH. In the RH, the N1 for function words revealed somewhat similar amplitudes for both the third and fourth sentences across the two types of texts. This finding seems to indicate that, besides the fact that subjects approached the two texts differently, (as measured by the different amplitudes for function words, discussed in section 4.4 above), the RH was differently involved in the process of inference generation, as expected. According to the literature, the RH tends to maintain various interpretations or distant semantic relations of words weakly activated (Beeman, 1993; Beeman et al., 2000; Virtue et al., 2006(b)), a role that has demonstrated to be quite important - if not essential - to the process of inference making (Mason & Just, 2004; Schmalhofer, 2005; Virtue et al., 2006(a); 2006(b)). The LH, on the other hand, is specialized in strong activation of smaller semantic fields, focusing on the concepts directly related to the information being processed. This is what the N1 data appears to demonstrate. While the RH showed a similar pattern of focal attention to content and function words while the third and fourth sentences were being processed, probably when inferences were being generated and integrated into discourse, the LH demonstrated more involvement with function words in the third sentence, only. This probably occurred because it was during sentence three that inferences were being generated and, as so, the syntactic relations had to be correctly interpreted to be incorporated into the ongoing process of inference making. In sentence four, when the inference was being integrated into discourse, the LH demonstrated less involvement with function words, possibly in detriment of decoding, which could receive more attention given the fact that the information being read matched the previously generated inference. The RH, on the other hand, given its coarse semantic coding (Beeman, 2000) tended to maintain a similar pattern of activation for both types of words.

Regarding the interaction between type of word and text type: as already mentioned in section 4.4 above - N1 Sentence four - the results concerning the N1 component in the fourth sentence seem to suggest that subjects tended to approach exposition and narration differently. This interpretation was based on the finding that the N1s for function words in the narrative text were lower than the N1s in the expository text. Having in mind the assumption raised in relation to the N1 component previously, i.e., that lower N1s would indicate more difficulty in processing input, it seems plausible to conclude that the reading of the fourth sentence of narrative paragraphs was somewhat more demanding than the reading of expository paragraphs. At first, this finding seemed to contradict the results related to the third sentence, that is, that the low N1s for the expository paragraphs signaled that this type of text was more demanding than narrative. Nonetheless, when one recalls the behavioral results, i.e., that subjects tended to generate inferences more easily while reading exposition, as measured by the number of correct responses for this type of text, the lower N1s for function words in narration in the fourth sentence seem to make sense. Remember that the behavioral results in the present study concern the judgment of the suitability of the fourth, final sentence of paragraphs. It seems reasonable to conclude, therefore, that the EEG data related to the fourth sentence of these paragraphs is consonant to the behavioral findings, for it demonstrates the subjects' difficulty in integrating the function words of narrative paragraphs into connected discourse, as demonstrated by the lower scores in performance in that type of text.

In relation to the significant interaction between scalp area, type of word and text type, it is possible to notice that there was an overall tendency towards lower N1s for function words in both types of texts, across all scalp areas (midline, RH and LH). The biggest difference - between content and function words - was found at the midline area in both third and fourth sentences. Nevertheless, given that this investigation is particularly interested in the involvement of the RH and LF in the process of inference making, the discussion of results will be focused on the two hemispheres.

In the RH the difference between content and function words (although not statistically significant) was smaller than in the LH, for both types of texts in both sentences, except in sentence three in the expository type of text, where the LH showed a smaller difference between content and function words than the RH did. This finding, although tricky, appears to be in agreement with what Virtue et al. (2006b) have argued in relation to the generation of bridging inferences. According to these authors, since bridging inferences tend to be more constrained by the text, it is possible that the LH shows greater involvement than the RH in the process of semantic information, i.e., content words. Thus, given the structure of the expository type of text and that subjects were in the process of generating an inference in sentence three, as argued above, it seems reasonable to assume that the LH had a stronger participation in the process of inference making in exposition, as demonstrated by the similar N1s for both content and function words (the N400s also showed a small difference in this condition, i.e., between content and function words, in sentence three, in exposition). Even though one may speculate that this pattern should also have occurred in the fourth sentence, mainly because of the constrained structure of exposition, this was not the case.

There is, however, a plausible explanation for this. It is possible that, given the reading purpose of the task, i.e., read to judge the suitability of the last sentence, the RH 'assumed the control' in sentence four, once it was necessary to have a coarse interpretation of the paragraph in order to perform the behavioral task. Therefore, since the RH is specialized in global processing, it seems reasonable to conclude that this hemisphere had to take the lead in sentence four, once subjects had to consider the information presented in the whole paragraph, in order to decide whether the last sentence fit the overall semantics of the just read text. This assumption is in agreement with Mason and Just (2004), who also suggested that the RH may be particularly involved in the *integration* of inferences.

Let us remember the overall finding regarding the involvement of both RH and LF in relation to content and function words, i.e., that the difference between these two classes of words was smaller in the RH than in the LH, excepting the case discussed in the previous paragraph. This overall trend, although not statistically significant, as already mentioned, was interpreted as the RH greater involvement in the process of semantic and syntactic relations of words. That is to say, if lower N1 amplitudes can be interpreted as one's focused attention to make sense of a text, then it seems reasonable to conclude that the smaller the difference between these two classes of words, the greater will be the activation of distantly related concepts. This is what seems to have occurred in the RH. As more concepts were diffusely activated while subjects were reading the two last sentences of the paragraphs, the easily these concepts could have been integrated into discourse, through the generation of successful inferences. It is interesting to remember here, that this investigation found only marginal differences in the N400 amplitudes concerning the fourth sentence, across the conditions investigated (bridging and no-inference). This finding seems to be compatible with what has been described in regards to the RH greater involvement while subjects were processing both the third and the fourth sentences. It appears that, besides all the other interpretations given throughout this section to this surprising result, that is, only marginal differences between bridging and no-inference conditions, the role of the RH in the process of inference making has also to be considered, even though its involvement did not reach statistical significance, as found in previous studies. Finally, in relation to results concerning the N400 in the third sentence, they reinforced the finding that function words were more demanding than content words, particularly in exposition at midline area. All the other figures showed only marginal differences and are in agreement with the N1 results just discussed above.

The discussion presented up to this point has been focused, firstly, on the marginal difference between bridging and no-inference conditions; second, on the different results concerning behavioral and EEG data and third, on the interaction between content and function words with text type and, scalp area. Before closing this discussion of results, there is one more issue that deserves attention, which regards the interaction between text type and scalp sites (right/left central; right/left frontal; right/left anterior temporal; right/left temporal; right/left occipital). Although there was no statistical significance for the comparison between electrodes placed over the RH and LF, it is interesting to mention some of the findings. In terms of the N400s yielded in the fourth sentence, both exposition and narration had larger amplitudes in the RH, at all sites. This finding reinforces the data showed by the N1 component in relation to function and content words - the RH showed a similar pattern of focused attention for these words - as discussed in the previous paragraphs. In the third sentence, the LH showed larger N400 amplitudes at central, temporal, and occipital sites, for both types of text. The RH showed larger amplitudes at the anterior temporal site for both text types. At the frontal site, exposition yielded larger N400s in the LH and narration yielded larger N400s in the RH. These findings are also compatible to the results related to the N1 component, as discussed earlier. That is to say, the LH seemed to devote more attention to function words in the third sentence, so given its specialization in syntactic relations, larger N400s at most sites, for both text types, make sense. On the whole, these findings seem to be in line with recent imaging studies, which have observed that different RH and LH brain areas work conjointly to form a network to suffice the demands imposed by the task of inference making (Mason & Just, 2004; Schmalhofer, 2005; Virtue et al., 2006).

In order to conclude the presentation and discussion of results developed in this chapter, the hypotheses raised in the introduction will be now retaken and analyzed according to the data obtained. The hypotheses will be presented following the same order in which the data and the discussion of results were addressed.

Hypotheses related to behavioral results

Hypothesis 1: Given the evidence provided by the literature that narration is easier to understand than exposition, it is expected that readers will have a higher percentage of accurate responses when judging the suitability / unsuitability of the final sentence of narrative paragraphs.

The hypothesis was not confirmed. The subjects in this study performed significantly better when judging the (un)suitability of the fourth, final sentence of expository paragraphs. Although this finding corroborates the results of a previous study carried out by Horiba (2000), it appears to contradict what is postulated in the literature, i.e., that narration is easier to comprehend than exposition. However, as mentioned previously, one has to consider the topics, the overall organization of the expository paragraphs used, and the subjects involved in the present investigation, before further assertions can be made.

Hypothesis 2: Higher span readers will have a higher percentage of accurate responses when judging the suitability / unsuitability of the final sentence of both expository and narrative paragraphs.

This hypothesis was partially confirmed for basically two reasons. First, because it was not possible to statistically confirm the differences in performance between high and low span readers due to the small number of the latter, which was insufficient to run a powerful statistical test, as mentioned previously, in the presentation of results. Second, because there was only a marginal difference in two of the conditions investigated: higher and lower spanners had a similar performance in detecting the incoherent expository paragraphs and lower span readers outperformed their counterparts in the generation of inferences in narration. These results are in contrast to what has been found in studies on individual differences, in which there is a robust difference between these two groups. Nevertheless, one can observe that there were some visible differences in relation to the generation of bridging inferences in exposition and the perception of inadequate final sentences (no-inference) in narration. These findings, although not statistically analyzed, add evidence to previous research.

Hypotheses related to EEG data

Hypothesis 3: Again, given the evidence presented by the literature, it is expected that readers will generate inferences more easily in the narrative type of text, as revealed by small N400 amplitudes.

This hypothesis was confirmed. The N400s yielded in sentence three (where supporting information was given so as to elicit the inference explicitly stated in the next sentence) were significantly smaller for the narrative type of text, indicating that readers generated inferences more easily than in exposition.

This finding is in line with the evidence presented in the literature but contradicts the findings of behavioral data. As already mentioned in Hypothesis 1 above, subjects demonstrated a significant better performance in terms of accurate responses to the expository type of text. This overall finding - that subjects' performance in the behavioral task was different from what was observed in terms of the cognitive effort applied to comprehend a text - may in fact, be reflecting two distinct processes, as already suggested elsewhere in this discussion.

It is possible that, after reading the third and the fourth sentences, subjects might have taken a few seconds to reason about the congruity of the paragraphs. As this 'extra time' was not recorded in EEG, one may speculate that some additional, effortful process might have been undertaken, especially for the narrative paragraphs, which tend to have a less constrained context. This additional process would, therefore, be reflected in the subjects' scores in the behavioral task.

Hypothesis 4: Higher span readers will generate inferences more easily than lower span readers in the expository type of text, as reveled by small N400 amplitudes.

This hypothesis was not possible to investigate. As explained in earlier portions of this chapter, the number of lower spanners, participants of this investigation, was too small to run ANOVAs. So all the EEG data analysis was carried out considering a within-subjects design, i.e., all the subjects were considered as a single, homogeneous group.

Nonetheless, it is worth mentioning that higher span readers demonstrated an overall better performance than lower spans in the *behavioral task*, when they had to decide if the last sentence of the paragraphs was a congruent conclusion for the information just read. Although Pearson's correlation showed a significant correlation between the RST and the subjects' performance in the bridging inference condition in the expository type of text, only, one may say that his finding is in line with previous studies on individual differences, which have shown that higher and lower spanners tend to differ in complex cognitive tasks.

Hypothesis 5: The RH will be more involved in the process of inference making, as revealed by high N400 and / or lower N1 amplitudes, particularly in the expository type of text.

This hypothesis was not confirmed in terms of statistical analysis. Nevertheless, N1 and N400 amplitudes demonstrated that, on the whole, the RH tended to be more involved than the LH in both types of text, being in line with what has been documented in the literature in relation to the role of RH in tasks that require global processing. Overall, the RH was found to demonstrate a similar pattern of focal attention to content and function words while the third and fourth sentences were being processed, as demonstrated by the N1 component.

Concerning the N400, this component yielded only marginal differences in relation to the RH and LH amplitudes, but they are in line with the data yielded by the N1 component in what regards the discussion of the present hypothesis.

CHAPTER 5

CONCLUSIONS, LIMITATIONS OF THE STUDY, SUGGESTIONS FOR FURTHER RESEARCH, FINAL REMARKS

This chapter presents final conclusions from the discussions presented in this dissertation in relation to the process of inference making in reading comprehension, based on the findings of the present experiment and the related literature. Furthermore, the main limitations of the study, followed by suggestions for further research are presented. Lastly, some final considerations regarding the present study will be made.

5.1 CONCLUSIONS

The aim of the present study was twofold: (1) to investigate the issue of inference making using Electroencephalography (EEG), with native speakers of English, in order to verify the possible differences in terms of brain processing while reading two different types of texts, namely, exposition and narration and (2) to investigate the patterns of behavioral response (accuracy) in relation to the process of bridging inference across these two types of text.

Regarding the first objective, results revealed that the expository type of text was more demanding for subjects, as measured by the N400 component in sentence four (where the inference was explicitly stated), and three (where supporting information was given, so as to elicit the inference stated in the following sentence). This result is consistent with the discourse comprehension literature that has demonstrated and frequently argued that narratives are easier to comprehend than exposition (Noordman et al., 1992; Trabasso e Magliano, 1996, among others). Furthermore, concerning the involvement of different RH and LH brain areas in the process of inference making, there were no significant differences regarding the two hemispheres involvement across the two text types - except at the frontal site in sentence three, where exposition yielded marginally larger N400s in the LH, and narration, in the RH. The overall involvement of both hemispheres in the process of inference making, being the RH a more active participant of the process, especially when subjects read the last sentence, is in line with previous related studies (Mason & Just, 2004; Schmalhofer, 2005; Virtue et al., 2006), and is congruent with the framework of multiple bilateral semantic processes proposed by Jung-Beeman (2005). As proposed by this researcher, different types of semantic processing occur bilaterally, although each hemisphere processes information differently. In the present study, function and content words showed a similar pattern of focused attention (as demonstrated by lower N1s) in the RH, demonstrating a relatively coarser semantic coding. The LH, on the other hand, seemed to prioritize one class of word (content or function) to process, demonstrating a relatively fine-grained computation, in accord with what is proposed by Jung-Beeman.

In relation to the second objective, results revealed that subjects had a significant better performance when reading the expository type of text. That is to say, subjects were more prone to generate bridging inferences and to judge the unsuitability of the last sentence - as demonstrated by their behavioral responses - in the expository rather than in the narrative type of text. This surprising result, besides being dissonant to what is brought by the relevant literature, i.e., that exposition is more complex to understand than narration, also seems to be at odds with the EEG results related to the first objective.

As already highlighted in Chapter 4, although the EEG and the behavioral data appear to be contradictory, one has to consider that they are unveiling two different stages in the process of inference making. The first stage, as measured by the N1 and N400 ERP components, provided us a picture of the online brain activity involved in the process of inference making, recorded for epochs extending 100 msec before stimulus onset to 600 msec after stimulus onset. The second stage, as measured by a behavioral response, showed us the final product of the cognitive activity involved in the previous stage, plus the time necessary by each subject, in each paragraph, to answer the prompt - remember that subjects could control the initiation of each subsequent paragraph. Thus, it is possible that the time between each paragraph - which was not time-controlled or EEG recorded - may have hindered subsequent cognitive processes, which might add information to the EEG data about later occurring processes, providing a clear picture towards the interaction between the two sources of data adopted in the present investigation. Another possible interpretation for the different results concerning the congruence between EEG and behavioral data is in relation to the on-going comprehension of the texts. As the N400 amplitudes showed, exposition was more effortful, i.e., subjects had more difficulty to read than narration. It seems reasonable to assume that, since subjects probably felt more comfortable while reading stories, as argued by the literature, that they may not have paid as much attention as when they were reading exposition (even though it was inferred in the discussion of results, that subjects may have processed expository texts quite similar to narratives, it is interesting to note that N1 amplitudes tended to be lower in exposition, suggesting readers were devoting more attention when reading it). Thus, when having to judge the suitability of the last sentence, subjects may have faced more problems in narration than in exposition, a fact that would explain the lower N1s for function words and the performance when judging the suitability of the last sentence in narrative paragraphs. Yet, another fact that has to be taken into account is the overall characteristic of expository texts: by their very nature, they tend to be more constrained than narratives, especially in terms of inference generation. This particular feature of exposition may explain subjects' better performance when judging the plausibility of the last sentence in expository texts. That is to say, given that narratives elicit more interest, promoting more explanations and predictions (Narvaez et al., 1999), it is possible that subjects may have faced difficulties when having to judge the last sentence of narratives, for they had to decide, among all the competing activated inferences, if the one stated in the last sentence was suitable for the just read paragraph.

Summing up, the results brought by this study, although not statistically significant in several of the factors investigated, raise some interesting issues that deserve further research. One of these issues, besides the contribution of the N1 component for the process of reading comprehension, is the (in)congruence between behavioral and EEG data. Although different, possible explanations have been discussed since the presentation of results in Chapter 4, this issue should be revisited in subsequent studies involving the use of EEG and behavioral responses that involve cognition.

5.2 LIMITATIONS OF THE STUDY

In this section, I will present the limitations and difficulties encountered throughout the development of this study, so that replications (in part or as a whole) may prevent such shortcomings.

a) **Short time spent abroad:** different from the majority of PhD students (who spend from six to twelve months), I spent only four months at the Center for Cognitive Neuroscience (University of Auckland). This period was definitely too tight to cope with all the activities and the different issues I had to learn in order to conduct the experiment reported in this dissertation. During that time, besides piloting the stimulus with native speakers, I had to learn about the complexities involving EEG data collection procedures, as well about the software used to collect and analyze this data. The possible limitations in what regards data analysis is undoubtedly, a consequence of the short time I had to fully learn the software used by the laboratory. Despite all the help I got from the researchers working at the Center for Cognitive Neuroscience - while I was one of them and after I returned to Brazil - there were some complex issues involving data analysis and interpretation that were not possible to cover during the time I spent at the laboratory.

b) **Number of lower span subjects**: this is probably one of the main shortcomings of this study. As mentioned above, given the short period I had available to carry out the experiment, it was not possible to control for the variable related to the Reading Span Test before a subject had actually taken the test. Even though subjects got payment for their participation, I had a hard time to find individuals who met the features adopted in the present research (university student males, right-handed, native speakers, willing to wear an EEG net). Therefore, before worrying about two distinct groups, i.e., higher and lower span readers I had to guarantee that I would have enough subjects.

c) **Type of inferences:** as it probably happens in most of the studies involving a technological tool, the design of the present study had to be reduced to consider only one type of inference, and not two, as originally planned. Due to

EEG time restrictions - an EEG session cannot take longer than fifty minutes - it was decided that the present investigation would disregard the paragraphs eliciting elaborative inferences, and maintain the paragraphs eliciting bridging inferences. For carrying out an experiment comparing bridging and elaborative inferences, plus the control no-inference condition, across two text types, data collection would have to be split into two sessions. According to the experience of the EEG laboratory manager, a considerable number of subjects do not come back for the second session due to EEG set-up, which tends to be time-consuming (usually twenty minutes). Therefore, given the fact that I had a strict time to collect data, and could not afford to lose subjects for not completing the second part of the task, we decided to concentrate on one type of inference, i.e., bridging inference, across two different text types.

d) **Response time for the behavioral task:** a behavioral task (judgment of the suitability of the last sentence of paragraphs) was included in the present investigation with the main purpose of 'forcing' subjects to attentively read the paragraphs. At first, it was not the interest of this study to analyze response latencies between lower/higher span readers; nevertheless, given the findings observed, if recording of response times to the last sentences were included in the design of the experiment, a thorough interpretation of results could have been developed.

5.3 SUGGESTIONS FOR FURTHER RESEARCH

As an advancement of the study reported in this dissertation, the following suggestions may be considered.

a) Number of subjects: even though most of the studies involving a technological tool tend not to work with large populations due to cost restrictions, it would be interesting to enlarge the sample used in this study, mainly to satisfy the minimum required for statistical power to compare the performance of lower and higher span readers. Another interesting comparison would be inclusion of foreign language learners, with different levels of proficiency.

b) Type of inferences: as mentioned in section 5.2 above, this study had originally planned to compare two types of inference (bridging and elaborative), across two text types. Even though EEG set-up may impinge on data collection in two split sessions, this is an issue that should be taken into consideration, especially if one considers the promising results involving the variables under investigation.

c) EEG epoch: in this study, the EEG waves were recorded for epochs extending 100 msec before stimulus onset to 600 msec after stimulus onset. Given the results generated, it would be interesting to consider the analysis of later ERP components (LPC, P550, which are thought to be associated with semantic processing, as found by Salmon & Pratt, 2002) by enlarging the epochs to 920 msec after stimulus onset.

d) Additional software: besides ERP analyses, one may include the use of localization software, such as LORETA (low resolution brain electromagnetic tomography) to estimate the neural sources of inference generation and to allow a more accurate verification of the brain areas recruited in this process, across different types of text.

5.4 FINAL REMARKS

The design of the present investigation was mostly based on a previous study carried out by St. George in 1995. As mentioned in the discussion of results, some adaptations were made, i.e., the inclusion of a different behavioral task to guarantee that subjects would pay attention to the task, so as the objectives proposed for this study could be accomplished. The decision for working with narrative and expository type of texts came from the discourse comprehension literature, which abounds with empirical evidence concerning the cognitive aspects involved in the comprehension of stories, but lacks studies that involve the expository type of text as stimulus. The comparison between narrative and exposition has received an even smaller share, possibly because the conclusion is taken for granted, i.e., that narratives are easier to understand than expository texts.

The present study intended to contribute to a better understanding of the process of inference making across different types of text, by investigating, through the use EEG, how readers achieve meaning while reading a text. Despite the limitations regarding data collection and the lack of significant results concerning some of the variables investigated, the study suggests that the two types of text investigated are indeed, processed differently by the brain. Even though it was not possible to delineate a clear picture in terms of brain processing, given the lack of robust results, this study might be the first of many steps towards a complete understanding of the cognitive processes involved in discourse comprehension.

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APPENDIX A

EXPOSITORY AND NARRATIVE PARAGRAPHS USED IN THIS STUDY

EXPOSITORY TEXTS (1-30)

- First paragraph: bridging condition; second paragraph: control
- The paragraphs total number of words is the first number in parenthesis; the second number is the number of words for the 4th sentence.

1
Overweight children usually spend long hours in front of TV.
When they watch TV, they snack often.
As a result, they have high overall caloric intake.
TV contributes to the gain in weight of children. (35/9)
(Adapted from: The Hamiltor Spectator newspaper, 2006, p. 7)

Overweight children usually spend long hours in front of TV.
Many parents don’t control the quality of programmes their kids watch.
When kids are in front of TV, they watch anything that is on.
TV contributes to the gain in weight of children. (43/9) /

2
The XE Universal Currency Converter is a straightforward web site.
People can make currency conversions in a matter of seconds.
The site includes all the world's currencies.
Currency conversion is made easy with technology. (34 / 7)

The XE Universal Currency Converter is a straightforward web site.
It helps people to find information about the history of money.
The site was developed by a historian.
Currency conversion is made easy with technology. (35/7)
(Adapted from: SpeakUp magazine, year XV, nr. 186, p. 5)

3
Alcohol and antibiotics is not a good combination.
Apparently, alcohol lessens the effects of the medicine.
People take longer to recover when they drink during treatment.
Alcohol should be avoided when on antibiotics. (33 / 7)
(Adapted from: http://www.drweil.com/drw/u/QA/QA326593/, accessed on June 18, 2007)

Alcohol and antibiotics is not a good combination.
Doctors recommend eating heaps of yoghurt while on antibiotics.

Some antibiotics destroy the flora in our gut.
Alcohol should be avoided when on antibiotics. (32/7)

4
Philadelphia, the fattest city in the USA, is on a diet.
The City Council decided to help the city's inhabitants to lose weight.
The Council is sponsoring TV programmes on healthier cooking and aerobics classes. In Philadelphia, fat is not desirable. (41/6)
(Adapted from: SpeakUp magazine, year XIV, nr. 173, p.4)

Philadelphia, the fattest city in the USA, is on a diet.
The mayor decided to help the city's inhabitants.
He wakes up at 5 in the morning to work.
In Philadelphia, fat is not desirable. (35/6)

5
Nearly 97% of the Earth's water is salt water.
Only 1% of the Earth's water is fresh water that we can use.
Another 2% is locked up in the polar ice caps.
Pure water is a precious resource nowadays. (39/7)
(Adapted from: http://www.metrowater.co.nz/waterconservation/keyfacts.aspx, accessed on 13 June, 2007)

Nearly 97% of the Earth's water is salt water.
Approximately 3% of the Earth's water is water that we can use.
We are not facing a shortage for the next few decades.
Pure water is a precious resource nowadays. (39/7)

6
Children growing up bilingually develop different strategies of thinking.
Bilinguals are able to use the same neural processes more efficiently than monolinguals.
Bilinguals understand things better and faster.
Bilinguals have cognitive benefits. (32/4)
(Adapted from: Melbourne University magazine, April edition, 2007, p.16-17)

Children growing up bilingually develop different strategies of thinking.
They generally play games using the foreign language.
When they play games in their native language, they can't think properly.
Bilinguals have cognitive benefits. (33/4)

7
At City Club Hotel pop stars and rock singers are not welcome.
At this hotel privacy, not popularity is top priority.
The hotel is so understated that its lobby is hidden in a corner.

City Club is for private, discriminating people. (41 / 7)
(Adapted from: SpeakUp magazine, year XV, nr. 182, p. 4)

At City Club Hotel pop stars and rock singers are not welcome.
For the owner of this hotel, these people are too arrogant.
They treat the staff and the other guests badly.
City Club is for private, discriminating people. (39/7)

8
Steri-Pen is a device to disinfect your drinking water.
The pocket-size pen disinfects up to 500ml of water in a few minutes.
It purifies water by destroying viruses, bacteria and protozoa.
It is a solution for safe water anywhere. (39 / 8)
(Adapted from: SpeakUp magazine, year XV, nr. 182, p. 5)

Steri-Pen is a device to disinfect your drinking water.
It is warranted for one to three years.
The disadvantage is that it only works when connected to electricity.
It is a solution for safe water anywhere. (36/8)

9
Ciba Vision developed contact lens to check diabetics' glucose level.
These lenses give a glucose reading as reliable as that of the prick test.
The lens detects levels of blood sugar in tears.
Needle pricking may become past for diabetics. (40/7)
(Adapted from: SpeakUp magazine, year XV, nr. 182, p. 5)

Ciba Vision developed contact lens to check diabetics' glucose level.
Many people with diabetes also need glasses.
This is because diabetes often damages our retina.
Needle pricking may become past for diabetics. (32/7)

10
As people upgrade to more advanced mobile devices, the old ones pile up.
As this pile grows, the threat to the environment grows too.
Mobiles contain toxic substances and should not be just thrown away.
People should front up to mobile recycling. (42 / 7)
(Adapted from: http://www.earthshare.org/CollectiveGood.html, accessed on 13 June, 2007)

As people upgrade to more advanced mobile devices, the old ones pile up.
Chips nowadays make mobiles more powerful.
All people have to do is change the chip.
People should front up to mobile recycling. (35/7)

11
Zipcar has proposed that drivers share their cars.
The company has encouraged automotive co-ops in cities with traffic problems.
Co-ops reduce the number of cars in the street.
Co-ops are one solution to avoid traffic jams. (36 / 8)
(Adapted from: SpeakUp, year XVII, nr. 203, p. 4)

Zipcar has proposed that drivers share their cars.
Zipcar is a for-profit, membership-based company.
Membership fees run from $50 a month or $300 a year.
Co-ops are one solution to avoid traffic jams. (33/8)

12
Sociologists are studying the e-mail behaviour of men and women.
The researchers say they are finding opposite patterns.
Women are often voluble and open while men are terse and tight-lipped.
Men and women use e-mail differently. (36/6)
(Adapted from: The New York Times, May 17, 2001)

Sociologists are studying the e-mail behaviour of men and women.
The researchers state they are searching for differences.
A data bank with 2,000 messages is being organized.
Men and women use e-mail differently. (33/6)

13
Repetitive chewing motion increases heart rate and insulin going to the brain.
Thinking and memory are improved by gum chewing motions.
Researchers suggest schools should not ban gum during classes.
Gum chewing increases cognitive capacities. (35 / 5)
(Adapted from SpeakUp, year XV, nr. 185, p.5)

Repetitive chewing motion increases heart rate and insulin going to the brain.
It stimulates the production of saliva and increases salivary flow.
Chewing gum is a combination of water-soluble ingredients.
Gum chewing increases cognitive capacities. (35/5)

14
Club Curves is where over-sized people gather to socialize on the weekend.
At this club, people are not embarrassed about their weight.
People of all shapes and sizes come in droves.
This club is where big is beautiful. (38 / 7)
(Adapted from: SpeakUp, year XV, nr. 185, p.4)

Club Curves is where over-sized people gather to socialize on the weekend.
The club is located in the centre of Culver City.
Club Curves is the spot where people who drink have a great time.
This club is the place where big is beautiful. (44/7)

15
Inchworms are sneaker-like shoes for growing kids.
These shoes can expand two half sizes.
They guarantee a few months of wear.
Kids don't need new shoes when they grow a bit. (31 / 10)
(Adapted from SpeakUp, year XVI, nr.195, p. 4)

Inchworms are sneaker-like shoes for growing kids.
Everyone can buy these shoes from the Internet.
These shoes are perfect for soccer players.
Kids don't need new shoes when they grow a bit. (32/10)

16
Focal infection is a disease that develops in one’s teeth, gums or tonsils.
This common oral infection can be fatal.
This is because the disease is easily overlooked.
People may die from oral infection. (34/6)
(Adapted from http://www.buzzle.com/articles/how-good-oral-hygiene-teeth-care-prolong-life.html, accessed on June 18, 1007)

Focal infection is a disease that develops in one's teeth, gums or tonsils.
The theory of this disease is associated with dentistry.
All dentists are familiar with its symptoms.
People may die from oral infection. (35/6)

17
Modern technologies have changed the way people can get a qualification.
Now people can study from the comfort of their own home.
In today’s environment the Internet is the key tool.
Students don’t need to physically attend classes. (38/7)
(Adapted from SpeakUp, year XVI, nr.195, p. 30-31)

Modern technologies have changed the way people can get a qualification.
Nowadays, students can buy their assignments from the Internet.
Most professors don’t know their students do this.
Students don't need to physically attend classes. (35/7)

18
Handbags are a key fashion accessory for working women.
As designers combine briefcases with handbags, bags became bigger and heavier.

Health experts warn bags are a health concern nowadays.
Women's handbags can cause back problems. (35/6)
(Adapted from Reuters, Jan 18th, 2007)

Handbags are a key fashion accessory for working women.
As designers combine briefcases with handbags, they have become colourful.
They look beautiful when women wear them.
Women's handbags can cause back problems. (32/6)

19
The pain that is common the day after workout can be avoided.
Caffeine ingestion lessens the muscle pain the day after workout.
It blocks the activity of adenosine released during exercising.
Coffee can avoid sore muscles. (36/5)
(Adapted from Reuters, Jan 20th, 2007)

The pain that is common the day after workout can be avoided.
A study revealed that vitamin pills lessen the muscle pain.
They block the activity of adenosine.
Coffee minimizes sore muscles. (32/5)

20
Digital enthusiasts that predicted the CD demise are surprised.
CD sales had hit profits last year.
Nowadays, it constitutes 90% of the industry sales.
The CD is still alive. (29/5)
(Adapted from Independent, Jan 22nd, 2007)

Digital enthusiasts that predicted the CD demise are surprised.
They are proven to be correct.
CD sales had no profits last year.
The CD is still alive. (27/5)

21
Pets nowadays are living in the lap of luxury.
They are given much food and little exercise.
Many pets eat as often as their owners do.
Pets are getting fatter. (30/4)
(Adapted from Life etc – just the things that matter magazine. Nov-Dec. 2005, p. 32.)

Pets nowadays are living in the lap of luxury.
Most pets go to beauty parlours once a week.
Some have diamond collars.
Pets are getting fatter. (26/4)

22
Kitchen sponges contain millions of bacteria.
The common microwave oven can inactivate more than 99% of these bacteria.
Two minutes of microwaving on full power is enough.
The microwave is a powerful tool for sterilization. (35/8)
(Adapted from Reuters, Jan 23rd, 2007)

Kitchen sponges contain millions of bacteria.
Millions of people get sick from food borne microbes.
This happens because people don't clean their microwave properly.
The microwave is a powerful tool for sterilization. (32/8)

23
The tiger snake is very common in Australia.
This snake is highly venomous and quick to bite.
When threatened it raises its head above the ground in a classic stance pre-strike.
This serpent has caused many snakebite accidents. (38/7)
(Adapted from Reptiles magazine.com, Mar, 2007, downloaded from http://www.reptilesmagazine.com/reptiles/printer.aspx?aid=28279&cid=3702, accessed on March 26th, 2007)

The tiger snake is very common in Australia.
It is usually quick to escape when cornered.
This snake is not aggressive.
This serpent has caused many snakebite accidents. (28/7)

24
One in ten adolescents take the time to write a traditional diary.
Most prefer to share their innermost thoughts by blogging online.
Most teenagers think writing a diary is too boring.
Internet blogging has replaced diary-keeping. (36/5)
(Adapted from Reuters, March, 6th 2007, downloaded from http://www.smh.com.au/news/web/blogs-make-diaries-pass/2007/03/05/1172943359044.html, accessed on Mar. 6th, 2007

One in ten adolescents take the time to write a traditional diary.
Nowadays teenagers share their experiences with friends.
Some teenagers prefer talking to their parents.
Internet-blogging has replaced diary-keeping. (30/5)

25
Computer giants Microsoft and Google aim to help readers around the world.
They are attempting to make digital copies of every book ever written.
This means digitizing the world's biggest stores of information: libraries.
Readers will have easier access to books. (41/7)
(Adapted from The Press, January 24th, 2007)

Computer giants Microsoft and Google aim to help readers around the world.
They are proposing insurance for rare and valuable books.
Most of these books belong to libraries that can be ruined by natural disasters.
Readers will have easier access to books. (42/7)

26
Overweight video gamers can now rejoice.
A Nintendo Wii user says he is 4kgs lighter due to playing the console.
He played 30-minute sessions of Wii games daily for 6 weeks.
Nintendo Wii can lead to weight loss. (38/7)
(Adapted from Reuters, January, 23 2007, downloaded from
http://www.stuff.co.nz/3936667a11275.html, accessed on Jan 26th, 2007)

Overweight video gamers can now rejoice.
A Nintendo Wii user says he is happy with the console.
He says he feels challenged with the new version.
Nintendo Wii can lead to weight loss. (33/7)

27
Some schools are using video games in their classes.
Video games help students to learn by doing and experimenting.
Most students improve their learning skills after few months.
Video games can be helpful in learning. (35/7)
(Adapted from Reuters, Jan 13th, 2007, downloaded from
http://www.stuff.co.nz/3926637a11275.html, accessed on Jan, 26th, 2007)

Some schools are using video games in their classes.
Many educators, however, scoff at the idea.
They argue video games alter children's perception of reality.
Video games can be helpful in learning. (32/7)

28
A monitor can make a huge difference to how people use computers.
Old monitors can be bad for the eyes.
They tend to tire the eyes easily over long working periods.
Old monitors should be upgraded. (36/5)
(Adapted from The Dominion Post, Oct, 30th 2006, downloaded from
http://www.stuff.co.nz/3843574a18335.html, accessed on Jan 26th, 2007)

A monitor can make a huge difference to how people use computers.
Liquid crystal display screens are a good option.
But these new screens can have dead pixels.
Old monitors should be upgraded. (33/5)

29
The beliefs that healthier foods are much more expensive are wrong.
Healthy eating options for a family of four cost $7 more per week.
In a month, this is less than $30 dollars.
Eating healthier food is only a bit more expensive. (42/8)
(Adapted from: NZPA, Jan, 26th 2007, downloaded from http://www.stuff.co.nz/3940993a19716.html, accessed on Jan 26th, 2007)

The beliefs that healthier foods are much more expensive are wrong.
A study was based on a couple with two children.
The research, however, excluded fruit and vegetables.
Healthier food is only a bit more expensive. (36/8)

30
Research with Europeans studied the incidence of brain tumours.
A significant occurrence was observed within cell phone users.
The incidence was observed with people using cell phones for 10 or more years.
Cell phone users may develop brain tumours. (39/7)
(Adapted from: http://www.physorg.com/news88967425.html, accessed on Jan 25th, 2007)

Research with Europeans studied the incidence of brain tumours.
A significant occurrence of brain tumours was observed within elderly people.
Many people were brain scanned.
Cell phone use may develop brain tumours. (32/7)

NARRATIVE PARAGRAPHS (31- 60)
From St. George's thesis (1995)

- First paragraph: bridging condition; second paragraph: control
- The paragraphs total number of words is the first number in parenthesis; the second number is the number of words for the 4th sentence.

3 1
Mary took her laundry downstairs to the washing machine.
She noticed the "out of order" sign.
She would not be doing laundry today.
The washing machine was broken. (28 / 5)

Mary took her laundry downstairs to the washing machine.
She noticed the "out of order" sign on the light switch.
She couldn't remember how that stain got on her favourite sweater.
The washing machine was broken. (36/5)

32
Susan was nervous as she got up to hand in her exam.
She suspected that the teacher had seen her.
The teacher put a red F on her exam.
She got caught cheating on her exam. (36/7)

Susan was nervous as she got up to hand in her exam.
She suspected that she might not pass.
There were 75 students in her calculus class.
She got caught cheating on her exam. (34/7)

33
Tom was outside with his dog, Freckles.
Freckles did not feel like playing, and Tom hoped that nothing was wrong.
Tom took the dog for an examination.
Freckles was a bit sick. (32/5)

Tom was outside with his dog, Freckles.
Freckles did not feel like playing.
Freckles was a moody dog.
Freckles was a bit sick. (23/5)

34
John enjoyed cooking, and tonight he wanted to bake fish.
He had bought the fish four days ago, but decided to use it anyway.
After dinner he started to feel sick.
The fish had gone bad. (36/5)

John enjoyed cooking, and tonight he wanted to bake fish.
He decided to use the fish he had already bought at a local market.
He made filet of sole with a creamy dill sauce.
The fish had gone bad. (39/5)

35
Roger studied late into the night for his 8 AM Biology final exam.
He forgot to set his alarm.
Roger was mad that he slept late and his roommate didn't wake him up.
He missed his Biology exam. (38/5)

Roger studied late into the night for his 8 AM Biology final exam.
He set his alarm.
He was glad it was the end of the semester.
He missed his Biology exam. (32/5)

36
Tom went for his morning jog through the neighbourhood.
As he ran his foot slipped off the curb.
He would not be able to run for weeks.
He couldn't believe he had injured his ankle. (35/8)

Tom went for his morning jog through the neighbourhood.
Before he ran, he sat on the curb and slipped on his sneakers.
A few squirrels were playing in the grass.
He couldn't believe he had injured his ankle. (38/8)

37
Josh was riding his bike into the city to his new job.
He rushed into the intersection without checking the light.
When he woke up he was in a hospital room.
He couldn't believe that he got hit by a car. (41/10)

Josh was riding his bike into the city to his new job.
He crossed the intersection after checking the light.
He noticed an old lady crossing the street.
He couldn't believe that he got hit by a car. (38/10)

38
Linda was preparing to take a bath and she turned the bath water on.
She left the room to answer the phone.
She had to mop the bathroom for hours.
The bathtub had overflowed. (34/4)

Linda was preparing to take a bath and she turned the bath water on.
She turned the bath water off.
She poured her favourite bubble bath.
The bathtub had overflowed. (30/4)

39
Joyce loved the flowers in her garden behind the house.
She knew she would be unable to water them while she was on vacation.
When se returned she was disappointed.
All the flowers died. (34/4)

Joyce loved the flowers in her garden behind the house.
She asked her neighbour to water them while she was on vacation.
She could not wait to see her friends again.
All the flowers died. (35/4)

40
His parents wanted to surprise him with something special for Christmas.
He had never had a pet before.
On Christmas morning he awoke to the sound of barking from the living room.
His parents had gotten him a puppy. (39/7)

His parents wanted to surprise him with something special for Christmas.
He had never gotten a bike before.
All his friends had them.
His parents had gotten him a puppy. (30/7)

41
He had waited a long time for this opportunity to go deep sea fishing.
He felt a strong tug at his line.
Once on shore, everyone wanted to take his picture.
He caught a huge fish. (36/5)

He had waited a long time for this opportunity to go deep sea fishing.
He enjoyed a strong wind in his face.
He hoped he would not get wind-burn.
He caught a huge fish. (34/5)

42
Jim was out for a drive to the sports arena in his new car.
He did not notice that the speed limit had been lowered due to construction.
Now he would have to explain the ticket to his father.
He got caught speeding. (43/4)

Jim was out for a drive to the sports arena in his new car.
He did not notice that the road was torn up due to construction.
He tried to avoid a pothole in the road.
He got caught speeding. (40/4)

43
In the midst of the party, Mary walked towards her friend Mike.
Mike noticed that she was much more talkative and affectionate than usual.
She was beginning to stumble into things.
Mary had too many drinks. (36/5)

In the midst of the party, Mary walked towards her friend Mike.
Mike had always known her to be talkative and affectionate.
They talked for a while and he asked her if she was seeing anyone.
Mary had too many drinks. (41/5)

44
Mitch was a new employee at the bakery.
He was often late for work.
His boss was annoyed.
Mitch lost his job. (22/4)

Mitch was a new employee at the bakery.
Often he got home late from work.
Mitch was in charge of baking the breads and cakes.
Mitch lost his job. (29/4)

45
Joan went to a party at a friend's house.
Someone spilled red wine all over her skirt.
She was never able to wear it again.
Her stained skirt could not be cleaned. (32/7)

Joan went to a party at a friend's house.
She had too much red wine and danced for hours.
She was hoping she would meet someone.
Her stained skirt could not be cleaned. (33/7)

46
We went to Jamaica on our last vacation.
The sun was much stronger and hotter than I expected.
The first night I was in a lot of pain.
I got very badly burned. (33/5)

We went to Jamaica on our last vacation.
The water was bright blue and the sun was shining.
We relaxed under the shelter of some palm trees.
I got very badly burned. (32/5)

47
He had been training for months for this marathon.
There was talk that he might finish first this year.
All of his hard work paid off.
He won the race. (30/4)

He had been training for months for this marathon.
There was talk that it might be cancelled first this year.
The officials were not sure.
He won the race. (29/4)

48
We always enjoyed going to the circus and watching the trapeze act.
We sat with excitement and fear as we watched the acrobat reach for the bar.
The crowd gasped with horror.
The acrobat lost his hold and fell. (39/7)

We always enjoyed going to the circus and watching the trapeze act.
We sat with excitement as we watched the acrobat reach for the bar.
Nothing beats the circus for sheer excitement.
The acrobat lost his hold and fell. (41/7)

49
Frank went outside to mow the lawn.
The lawn mower stopped abruptly after ten minutes.
Frank had to drive into town to fill up the can.
The lawn mower had run out of gas. (34/8)

Frank went outside to mow the lawn.
Frank stopped the lawn mower after ten minutes to get a drink.
The fertilizer he used on the lawn this year really worked well.
The lawn mower had run out of gas. (39/8)

50
Stacey was very happy.
She had been buying tickets for years.
She would never have to worry about money again.
She won the lottery. (24/4)

Stacey was very happy.
She had been saving to buy a house for years.
Now she was ready.
She won the lottery. (22/4)

51
Alice was hemming a pair of jeans by hand.
It was hard for her to control the needle; the material was tick.
She felt a pain in her finger.
She pricked herself with the point. (35/6)

Alice was hemming a pair of jeans by hand.
It was easy for her to control the needle; she was used to it.
She was almost finished.
She pricked herself with the point. (33/6)

52
Melissa had a wedding to go to on Saturday night.
She got vague directions to the church from her cousin, Ralph.
Melissa was angry at Ralph when she had to stop and get a map.
Melissa was completely lost. (39/4)

Melissa had a wedding to go to on Saturday night.
She got directions to the church from her cousin who she knew vaguely.
Melissa was bringing her new boyfriend, and everyone was anxious to meet him.
Melissa was completely lost. (40/4)

53
Kate was pregnant and went to the doctor for a check-up.
Although she was watching what she ate, she was getting bigger than expected.
After seeing the doctor, she went to buy two cribs.
She found out she was having twins. (41/7)

Kate was pregnant and went to the doctor for a check-up.
Although she knew the doctor was expensive, the bill was much bigger.
After the appointment, she went grocery shopping.
She found out she was having twins. (37/7)

54
Brian and his friends were boating on an unfamiliar river.
Gradually they began to hear a rushing noise.
They panicked when they came around the bend.
There were rough rapids ahead. (31/5)

Brian and his friends were boating on an unfamiliar river.
Gradually they began to relax.
It was so nice to get away for the day.
There were rough rapids ahead. (30/5)

55
Barbara started the water for the laundry, and grabbed the clothes on the floor.
In her haste, she included one of her wool sweaters.
Now her sweater no longer fits.
The wool sweater shrank. (34/4)

Barbara started the water for the laundry, and grabbed the clothes on the floor.
In her haste, she forgot to include the sweater she wanted to wear later.
The sweater was in her closet.
The wool sweater shrank. (38/4)

56
Nicole called information to get the number for the movie theatre.
Before she could write it down, her friend called.
Nicole had to call information again.
She forgot the number. (30/4)

Nicole called information to get the number for the movie theatre.
She looked for a piece of paper so she could write it down.
She wanted to see the early showing of the movie.
She forgot the number. (38/4)

57
Sue had a long research paper due in class the following morning.
At midnight, her computer was completely down.
She did not arrive for class.
She had not finished the paper. (34/6)

Sue had a long research paper due in class the following morning.
At midnight, she sat down at her computer.
She stayed up until three in the morning.
She had not finished the paper. (34/6)

58
He was getting eggs out of the refrigerator to make breakfast.
He was having trouble holding all the eggs.
He cursed his clumsiness as he cleaned up the floor.
All the eggs broke. (33/4)

He was getting eggs out of the refrigerator to make breakfast.
He was having trouble estimating how many eggs to use.
The sizzling bacon smelled good.
All the eggs broke. (30/4)

59
On the last snow day the kids built a snowman in the yard.
The sun was warm and strong the next day.
All that was left was a puddle.
The snowman melted completely. (33/4)

On the last snow day the kids built a snowman in the yard.
I had warm soup waiting for them when they came inside.
The next day they gave him a pipe and a hat.
The snowman melted completely. (39/4)

60

Paul was taking a plane to California for a much-needed vacation.
At the airport he sat down and read the back cover of a book.
The airport was crowded because of the holidays.
He missed his flight. (37/4)

Paul was taking a plane to California for a much-needed vacation.
At the airport he sat down and became absorbed in a book.
He looked up to see his plane pulling away.
He missed his flight. (36/4)

APPENDIX B

RETROSPECTIVE WRITTEN QUESTIONNAIRE

Dear participant,

Thank you so very much for taking part in my research. Your participation is certainly valuable and will contribute to a better understanding of the reading process. Now, I would like to ask you for some more of your precious time to answer the questions that follow.

Thanks greatly.

Name: ____

Please, think about the following questions. You might give short answers, but please, be honest and try to justify your answers when required.

(a) How would you classify your performance in the reading (EEG) task?

( ) excellent ( ) very good ( ) good ( ) average ( ) bad

(b) Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.

____

____

____

(c) What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?

____

____

____

____

(d) Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.

____

____

____

____

____

Thanks so much for you time.

APPENDIX C

SUBJECTS' ANSWERS IN RETROSPECTIVE QUESTIONNAIRES

Subject 01

a)How would you classify your performance in the reading (EEG) task?

(X) excellent ( ) very good ( ) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.

No.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?

Whether it was a suitable inference, given what was presented in the first sentences, i.e., if something totally novel was presented or if it didn't make sense.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.

Coffee-adenosine.

(Subject explained he didn't understand the relationship between coffee and adenosine mentioned in the text.)

Subject 02

a)How would you classify your performance in the reading (EEG) task?

( ) excellent (X) very good ( ) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.

No.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?

The sentence had to make sense with the previous ones.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.

A bit difficulty in the memory test.

(The reading task was a bit tiresome towards the end.)

Subject 03

a)How would you classify your performance in the reading (EEG) task?

( ) excellent ( ) very good (X) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.

No.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
Same topic, fit with the contents of paragraph, relevance.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
At times it was too pedantic with regards to classification of the answers, but no difficulties, really.

Subject 04
a)How would you classify your performance in the reading (EEG) task?

( ) excellent (X) very good ( ) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
No difficulties.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
If it was a suitable conclusion in relation to the first part.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.

Subject 05
a)How would you classify your performance in the reading (EEG) task?

( ) excellent (X) very good ( ) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
A bit tiresome, but no problems.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
It had to make sense in the paragraph.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
No.

Subject 06
a)How would you classify your performance in the reading (EEG) task?

( ) excellent ( ) very good (X) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
No.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
If it made sense – followed logically from the preceding sentences.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
No.

Subject 07

a)How would you classify your performance in the reading (EEG) task?

( ) excellent (X) very good ( ) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
No.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
If the sentences were connected.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
No.

Subject 08

a)How would you classify your performance in the reading (EEG) task?

( ) excellent ( ) very good ( ) good (X) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
No.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
If it followed directly from the preceding sentences or if it was implied in the preceding sentences.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
I struggled with the WM test, especially in the set sizes of >4.

(Subject mentioned he missed some words of one of the paragraphs.)

Subject 09
a)How would you classify your performance in the reading (EEG) task?

( ) excellent ( ) very good (X) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
Yes, trying to keep my eyes continually focused on one position.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
If it fit the right structure of the paragraph, if it flowed and if it was true or not.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
--

Subject 10
a)How would you classify your performance in the reading (EEG) task?

( ) excellent ( ) very good ( ) good (X) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
No physical difficulties. Some (possibly capacity) were difficult to make a decision because the final sentence was associated + could be correct with making assumption outside of the other sentences.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
As above – a combination of each of previous sentences and assumption using current knowledge assumed as certain.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
No.

Subject 11
a)How would you classify your performance in the reading (EEG) task?

( ) excellent (X) very good ( ) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
Yes, I have a short attention span.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
It sounded right (or not) and whether it fit in.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
Remembering back to the first sentence sometimes was tough.

(Subject mentioned he doesn't like staring at a computer screen for too long.)

Subject 12
a)How would you classify your performance in the reading (EEG) task?

( ) excellent (X) very good ( ) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
No.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
The last sentence should have a logical connection with the previous ones.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
No problems.

Subject 13
a)How would you classify your performance in the reading (EEG) task?

( ) excellent (X) very good ( ) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
Not that I remember.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
I disagreed when the last sentence didn't make sense.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
It was hard to concentrate towards the end of each 30 paragraph session.

Subject 14
a)How would you classify your performance in the reading (EEG) task?

(X) excellent ( ) very good ( ) good ( ) average ( ) bad

b)Did you have any difficulty while reading the texts? If YES, which one(s)? Please try to explain.
No, only the memory test.

c)What was your criteria for judging the conclusion of the paragraph(s), i.e., if the last sentence was a suitable conclusion?
If it fitted with what was already stated.

d)Do you remember having any other difficulty in relation to the tasks? If so, which one(s)? Explain briefly.
I was not sure what cognitive meant.

(Subject explained he was referring to the Ethics consent form, where this concept appeared.)