Right Hemisphere and Language:

O Hemisfério Direito e a Língua(gem)

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Abstract

The purpose of this paper is to present a review of literature on the role of the right hemisphere in language processing, more specifically, in reading comprehension. The review is organized in three main sections. First, some context that may explain why the right hemisphere has been neglected until the past decades when one considered language comprehension and production is presented. Secondly, the contributions originated from clinical observations and empirical research with brain-lesioned and normal participants, highlighting and distinguishing the role of the right side of the brain are discussed. Then, in the final part of this paper, the contributions of technological tools to the development and refinement of brain studies are addressed, showing that the right hemisphere works conjointly with its other half, so that reading comprehension is achieved.

Keywords: Right hemisphere. Language. Reading.

Resumo

O objetivo deste artigo é apresentar uma revisão de literatura sobre o papel do hemisfério direito no processamento da língua(gem), mais especificamente, no que tange à compreensão do texto escrito. Este artigo está organizado em três partes. Primeiramente, é apresentado o contexto que explica porque o hemisfério direito tem sido negligenciado, até recentemente, quando se abordavam questões relativas à compreensão e à produção linguística. Na segunda parte, as contribuições oriundas de observações clínicas e pesquisas empíricas com pacientes com e sem lesão cerebral, que destacam e definem o papel do hemisfério direito, são apresentadas. Finalmente, as contribuições de ferramentas tecnológicas que alavancaram o desenvolvimento e refinamento de pesquisas com o cérebro humano são apresentadas, mostrando que o hemisfério direito trabalha conjuntamente com a sua outra metade para que a compreensão em leitura seja alcançada.

Palavras chave: Hemisfério direito. Língua(gem). Leitura

Introdução

The evidence that the right hemisphere (RH) possesses specialized abilities has been known since the early days of the concept of cerebral dominance in the mid-1800s (SPRINGER; DEUTSCH, 1998). Nevertheless, it is not until the 1950's when more evidence started to emerge, that scientists began to take a closer look and reconsider the functions of the RH in our everyday activities.

For almost a century - after Broca's and Wernicke's findings - the right side of the brain was neglected. Although some isolated evidence continued to suggest that the RH does have contributions in language related activities, that

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is, left hemisphere brain damaged (LHD) patients with complete loss of speech were yet able to sing, scientists were not much concerned with the RH for several reasons.

The literature suggests several justifications for this. Among them, is the fact that lesions in the RH are generally not accompanied by drastic changes in behavior, such as speech loss or meaningless language production, as LHD aphasic patients reveal. Moreover, the impairments caused by the right side were not easy to analyze and diagnose and to fit into the traditional ideas about brain function, once RH lesions tend to disrupt patients' behavior in fairly subtle ways (BOGEN, 1997; SPRINGER; DEUTSCH, 1998; St. GEORGE; KUTAS; MARTINEZ; SERENO, 1999; LUNDY-EKMAN, 2004).

For the last decades, important contributions have been made from clinical observations and empirical research, highlighting and distinguishing the role of the RH in language. In this paper, some theoretical, behavioral and (neuro)cognitive studies will be addressed in order to elicit the role and the contributions of the right side of the brain in language processing. In the first section, the early days of the RH in neuropsychological research is presented. Secondly, contributions from clinical observations and empirical research with brain-lesioned and normal participants, recognizing and distinguishing the role of the right side of the brain are presented. Finally, the contributions of technological tools to the development and refinement of brain studies are discussed, and three studies using Positron Emission Tomography (PET scan) and functional Magnetic Resonance Imaging (fMRI) technologies to investigate the process of reading comprehension are presented.

The early days of the RH

Although lateralized lesion evidence for the RH role in non-language functions already existed early, before and during the 1900's (BOGEN, 1997), it was during the mid-1950's that testing of neurologic patients with lateralized lesions brought new evidence to the RH specific functions in the brain. Of particular importance, are the studies carried out by the 1981 Nobel Prize neuroscientist Roger Sperry with split brain patients in the late 1960's and early 1970's (WALDIE, 2004). These experiments have contributed to demonstrate the functional locality for RH specific language tasks.

Using a tachistoscope that requires the participant to focus on a determined spot in the center of the visual field while the stimulus (a word, an image) is projected to either the right or left hemisphere, Sperry showed that both hemispheres are involved in language tasks. In a normal brain, the hemispheres are interconnected by the corpus callosum, but in split brain patients, who suffer surgery to cut the corpus callosum to control severe epilepsy, preventing the seizure from spreading to other areas, the left and right hemispheres can no longer communicate with each other.

In one of Sperry's innumerous experiments, the word "ring" was projected to the right visual field of split brain patients, going to the so-called talkative left hemisphere (LH). Similarly, the work "key" was projected to the left visual field, going to the mute RH. As expected, the patients only reported reading the word "ring", being unaware of the word "key", while normal informants always reported the word "keyring". Nevertheless, when pushed to think harder about seeing any sort of image, split brain patients reported seeing a flash of light on the left side of the screen, asserting that it was a flash of light and not a word. Interestingly

enough, when asked to reach the object just seen on the screen with their left hands, patients reached the "key", although denying seeing that word moments before. Moreover, when asked to name the object they had touched, split brain patients responded "ring".

These amazing findings not only give further evidence that the corpus callosum is responsible for the communication between the two halves of the brain, but also that the RH plays a role in language. If this is not the case and if the RH is illiterate, as many researchers believed for so long, how can one explain Sperry's patients reaching the object "key"? It is important to remember that "key" was projected to the left visual field as a word and not as a picture, giving evidence that the RH can read. Therefore, even though the RH is not able to 'verbalize' what it saw, it is capable of communicating by other means (BAXTER, 2004). One should observe that the emphasis of this assertion is on seeing rather than on comprehending, deemphasizing, once again, the participation of the RH in this specific language task, and giving full credits for the LH.

As the literature demonstrates, Sperry's insights on hemispheric abilities are just one fraction of the vast amount of research carried out with brain damaged, callosotomized and hemispherectomized patients. These studies have provided the cornerstones of what is known about the human brain nowadays (BOGEN, 1997; SPRINGER; DEUTSCH, 1998; GELLATLY; ZARATE, 1998; MATLIN, 2004; LUNDY-EKMAN, 2004; ROSA, 2010, among others). Throughout the years, brain investigators have used different methodologies from neuropathology and lesion studies to behavioral measures with brain damaged and normal patients to try to identify and understand the role of each hemisphere in language processing (CODE, 1997). Although there is some incompatibility regarding the studies and their results, there are some assumptions related to the role of the RH commonly accepted among researchers, as will be discussed below.

RH involvement in language

Studies concerning brain damaged patients remark that right hemisphere damaged (RHD) people do not typically have the language impairments (phonological, syntactic or semantic problems) observed in aphasics; nevertheless, they frequently have communicative and cognitive deficits, normally addressed in speech therapy (McCAFFREY, 1998-2008). These deficits, as discussed by McCaffrey, can be divided into linguistic, extra linguistic and nonlinguistic.

The linguistic deficits comprise some of the tasks designed to evaluate aphasics, namely: body part naming, auditory comprehension of complex and/or difficult material, word fluency, writing, and oral sentence reading. According to McCaffrey, some RHD patients also demonstrate problems in performing these tasks. In fact, in a study carried by Hough (1990), when RHD patients had to listen to narratives with delayed presentation of a central theme, results demonstrated that they had difficulties and "performed significantly poorer when theme presentation was delayed compared to its normal organization" (p. 261). Nevertheless, in a previous study conducted by Brookshire and Nicholas (1984), when RHD also had to hear short narrative paragraphs, their performance was not significantly different from controls. As the authors state, and it seems to be quite plausible, predictions about RHD or LHD patients' listening comprehension of discourse in daily-life situations have to be based upon samples of their performance in real discourse, and not upon their performance in traditional tests composed

of simple sentences (p. 35). The same comment can be generalized to some other behavioral tests designed to evaluate and categorize patients with brain lesions, without careful analysis.

Regarding the extra linguistic deficits, although RHD are unlikely to display "speech" problems, they do have problems communicating. The most common problem of RHD people is their inability to integrate information from different sources (HOUGH, 1990; KAPLAN et al. 1990; STEMMER; JOANETTE, 1998). This impairment is supported by electrophysiological responses (measured with the Electroencephalogram) (FEDERMEIER; KUTAS, 1999) and fMRI data (St. GEORGE et al., 1999). That is to say, normal subjects reveal greater brain activation in the RH when integrative processes are needed to achieve global meaning. Also, RH patients do not make adequate use of context in their interpretations of messages (KAPLAN et al.1990; HOUGH, 1990; MOLLOY et al., 1990; STEMMER; JOANETTE, 1998), demonstrating difficulty in distinguishing significant from unimportant information. Moreover, further evidence has showed that RHD people may be able to comprehend only the literal meaning of language (KAPLAN et al., 1990; JUST et al., 1996). Another problem related to RHD patients is the fact that they are unable to interpret body language and facial expressions (SPRINGER; DEUTSCH, 1998), and their speech is frequently aprosodic, or lacking variations in pitch and stress (SPRINGER; DEUTSCH, 1998; LUNDY-EKMAN, 2004). 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, although it is not the main issue discussed in this paper, the nonlinguistic deficits will be addressed due to the fact that some of them may be part of the stimuli designed to evaluate language processing. The nonlinguistic deficits comprise: (a) disorientation to time and direction (although person and place orientation is preserved); (b) left side neglect, i.e., failure to eat food on the left side of the plate, begin reading in the middle of sentences, draw only the left side of pictures, being unaware that it is not complete; (c) anosognosia – inability to recognize their hemiplegia or cognitive deficits and this explains why RHD patients are frequently less depressed than those with LHD; (d) visuospatial deficits and (e) prosopagnosia – inability to recognize familiar faces (LUNDY-EKMAN, 2004; McCAFFREY, 1998-2008; SPRINGER; DEUTSCH, 1998).

As stated previously, the information about the RH involvement in our everyday life reviewed so far is based on research carried out during the past decades. The findings of studies with brain damaged, calosotomized and hemispherectomized patients contributed to the establishment of functionality between the two halves of the brain and to the enlightening of the subtle linguistic and nonlinguistic problems caused by RH damage. In the last part of this paper, one PET and two fMRI studies related to the engagement of the RH in reading will be discussed.

Cerebral imaging and the RH

The advancement of new technologies to register brain activation while a person is accomplishing a task has certainly contributed to the refinement of studies that investigate the cognitive processing of language. Differently from the studies with brain-lesioned patients, the neuroimaging tools, like PET scan, fMRI, and NIRS provide a new alternative for researchers to study in vivo what occurs in one's brain when different stimuli are presented. During the past decade, a great number of linguistic studies have been developed at the level of words (DEHAENE;

COHEN, 2011; GROSSI; COCH, 2005; ILLES et al., 1999; ROSEN et al., 2000; WALDIE et. al. 2012, just to cite a few), sentence (FEDERMEYER; KUTAS, 1999; KELLER; CARPENTER; JUST, 2001; MEYLER et al., 2007; NEWMAN et al., 2012; YARKONI; SPEER; ZACKS, 2008, among others) and at the discourse level (BARETTA et. al, 2012; DEHAENE et al., 1997; NEWMAN; JUST; MASON, 2004; NICHELLI et al., 1995; SCHERER et al., 2012; St. GEORGE; KUTAS; SERENO, 1999; TOMITCH et al. 2004; 2008, among others). Given the objective of this article, this part of the paper will focus on the discussion of three studies at the discourse level that showed RH involvement in the reading ability: Nichelli, Grafman, Pietrini, Clark, Lee, and Miletich's (1995); St. George, Kutas, and Sereno's (1999), and Tomitch, Newman, Carpenter and Just's (2008) studies. Before discussing the studies per se, the neuroimaging tools mentioned above will be briefly presented.

Among the neuroimaging techniques mostly applied to investigate brain activation, there is Positron Emission Tomography (PET scan) and functional Magnetic Resonance Imaging (fMRI). Both techniques are known for providing high spatial resolution, i.e., they show brain images in terms of millimeters, showing precise images of brain activity. Using radioisotopes to monitor the increase of the blood flow, glucose and oxygenation in brain areas, researchers can assume, therefore, that those areas are involved in the performance of a given cognitive task, such as reading comprehension (LOGOTHETIS et al., 1996; TOMITCH et al., 2004). Since the early 1990's, fMRI has been largely used in brain research given the fact that it does not require participants to be injected with contrast agents or radioisotopes so that blood flow can be measured, as in PET scan (BINDER, 2007). Quite 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 the participants' movement while performing the task under examination (SCHERER, 2007). Different from PET and fMRI, NRIS is able to register minor variations in brain activity and can provide clear information on the sequence of events involved in cognitive tasks. Now, let us discuss the studies.

The PET research conducted by Nichelli and collaborators in 1995, investigated the performance of 09 volunteers who were instructed to read Aesop's fables displayed in the center of a computer screen using RSVP (rapid serial visual presentation), 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 (d) the moral of the fable. Regarding the two last categories, subjects were told which moral or semantic feature to look for before each of the tasks. Analyses of 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; FEDERMEYER; KUTAS, 1999) is the focus activation of the right inferior frontal gyrus and the right midtemporal gyrus (Broadman's areas 47 and 21, respectively. These areas can be visualized at the following sites, accessed on Oct, 15, 2013: http://commons.wikimedia.org/wiki/Brodmann_areas; http://commons.wikimedia.org/wiki/Sulci_(neuroanatomy). According to 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).

In agreement with Nichelli and collaborators' findings is the research developed by St. George and colleagues (1999). In a study with 10 individuals reading paragraphs with(out) a title for comprehension, St. George and collaborators are recognized for being the pioneers to demonstrate through the use of fMRI, RH brain activation while processing discourse. Sixteen paragraphs (half titled, half untitled) were presented visuocentrally, one word at a time to the subjects, who were scanned during their performance. The authors observed an increased activation in both hemispheres while subjects were reading the paragraphs. They also noticed that there was a greater activation of the right inferior temporal sulcus and right middle temporal sulcus in the absence of a title condition. Differently from the study carried out by Nichelli et al. discussed previously, the subjects in this study read "ordinary paragraphs, in some cases much like the instruction manual one might find for assembly of a newly purchased product" (p. 1323), not including figurative language interpretation, i.e., finding the moral of a story, but demanding "literal" interpretation. In this way, one can conclude that the RH is involved in other aspects of language processing rather than only figurative language.

Nevertheless, a more recent fMRI study carried out by Tomitch and colleagues (2008) brings some new evidence regarding text integration. 08 graduate students read twelve three-sentence expository paragraphs. Half of the paragraphs introduced the theme in the first sentence, which was followed by arguments and details related to the main idea; the other half presented the supporting arguments and details in the first two sentences, leaving the main idea of the paragraph for the last sentence. After reading each paragraph, presented sentence by sentence, subjects had to answer true or false to a probe representing the main idea of the text. Results demonstrated that, like Nichelli et al.'s and St. George et al's studies, hemispheres were bilaterally activated when processing the text. Nonetheless, differently from the other two studies, Tomitch et al. observed a 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 RH temporal region showed stronger 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 and as the literature and the two studies discussed previously demonstrate, the RH plays an especially important role in integrating information in order to attain global coherence during discourse processing (HOUGH, 1990; KAPLAN et al., 1990; STEMMER; JOANETTE, 1998; FEDERMEYER; KUTAS, 1999; NEWMAN; JUST; MASON, 2004, among others). According to Tomitch and colleagues, the LH involvement when the topic sentence was presented in final position can be interpreted in the light of the Structure Building Framework – SBF (GERNSBACHER, 1997). As proposed by these authors, the LH involvement seems to reveal a "shifting" process, i.e., the reorganization of text representation in memory, in those paragraphs where the topic sentence was presented in the final position, showing the LH is involved in comprehension processes at all times (p. 188-189).

Although the results concerning RH activation in the study of Tomitch et al.'s seem to be in disagreement with former literature and more specifically with the two studies discussed above (Nichelli et al.'s and St. George et al.'s), the

authors provide possible explanations for this fact. First, the fact that in St. George et al.'s study half the paragraphs were untitled originated a non-related correspondence among the sentences (see St. George et al. (1999) or Newman, Just and Mason (2004) for an example). On the other hand, the study of Tomitch et al. deals with sentences referring to the same topic, e.g., fire and dogs; whether the topic sentence appeared in final or initial position, "there is always opportunity to generate a coherent text representation" (p.189). This opportunity is not present in the untitled condition of St. George et al.'s study, making it impossible for participants to generate a coherent representation of the text. Second, Tomitch et al. require participants to answer to a probe question after reading each paragraph, a requirement that is not present in St. George's. Third, the brain regions scanned in the two studies are different, so further comparisons are difficult to make.

Considering the RH activation (temporal and prefrontal cortices) found in Nichelli et al.'s (1995), it is important to remember that the stimuli involved stories and that the participants were asked, among other things, to monitor the fables for the moral of the story. As some empirical evidence with RHD patients suggest, interpretation of figurative language involves RH participation (KAPLAN et al., 1990; MOLLOY et al., 1990), a fact that corroborates the findings in Tomitch et al.'s study and may explain the results of the other two reviewed here. One can speculate that, in addition to being considered as isolated sentences, as explained by Newman, Just and Mason (2004), the untitled paragraphs in St. George et al.'s may have been interpreted as a series of metaphors, which provoke activation in the RH, something not possible in the study by Tomitch et al. with paragraphs topic last condition, which had clear references to a topic that was missing. This possibility may also explain why the RH was more activated in the first two studies discussed here.

Final remarks

The objective of this review of literature was to highlight the role of the RH in language processing in order to cast some light in its contribution to text processing. The studies reviewed in the last part of this paper and the different findings discussed throughout this review demonstrate that there is a long path to go.

The advance of new technologies to register brain activation while a person is accomplishing a task has certainly contributed to the search for understanding how language, among other neuronal activities, is processed in the two halves of the brain. The issue of how and to what extent each half contributes to the integrated performance of processing discourse certainly deserves further and continuous investigation (BEEMAN; CHIARELLO, 1998), as the three studies discussed in this paper demonstrate. Particularly, the systematic activation found in both hemispheres in the study of Tomitch, Newman, Carpenter and Just (2008) implies that the two hemispheres work as a team, each one responsible for one aspect of language but aiming at the global level comprehension of discourse (p.192). The assumption that the RH seems to be most important at the discourse level of language comprehension has to be considered carefully. Further research with different types of texts, lengths and tasks are necessary in order to better evaluate the role of each hemisphere in the comprehension of discourse.

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